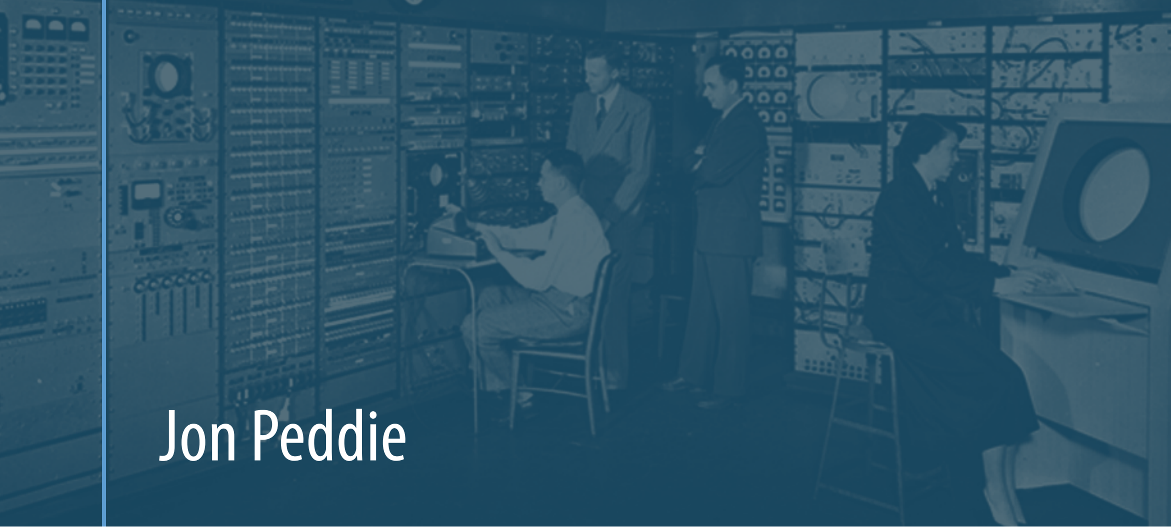

Jon Peddie

The History of Visual Magic in Computers

How Beautiful Images are Made in CAD, 3D, VR and AR

JPR
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Jon Peddie
Jon Peddie Research
Tiburon, CA
USA

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Foreword I

The human visual system enables us to see a world of colour, texture and motion. Using two eyes we have an appreciation of depth in the field of view – thus enabling us to appreciate the three dimensions of the space, or scene, around us. However, the complexities of the operation of our visual system are still far from understood. Are we passive recipients of visual stimuli which we interpret according to our experience of the real world, or are we active processors of visual information over which we are exerting some degree of control? Current research is seeking to find answers to this question.

In general, considerations of 3D computer graphics do not involve the deeper questions of the human visual system. However, it is important to recognise that when graphical information is displayed, it is the human visual system that is interpreting it [1, 5].

This book traces the development of 3D computer graphics in terms of hardware, software, techniques and applications – by a key graphics pioneer who has been involved with the field from the beginning. The key milestones are clearly set out, enabling the reader to understand the significance of the developments that took place.

Computers have been used to draw pictures from the earliest days. Researchers were therefore able to use computer generated output in papers and publications. It gave the impression of authority and authenticity. However, such representations are entirely dependent on the underlying data and the representations that have been chosen. It is well known that either or both of these may not be correct or appropriate (as was already known for statistical data), so visual information has to be treated with caution [7, 13].

Complex ideas can be quickly conveyed using a picture. Painters have used a variety of methods to produce images that are able to convey 3D scene and context, and even motion and emotion. To create an impression of depth in the picture, various foreshortening techniques have been used. Many of these are not necessarily strictly geometric but the eye interprets the picture more or less in the way the painter intended. It is postulated that the great artists had a gift for understanding how their art should be constructed in order to generate the effect they desired it to have on the viewer.

Computers process data, but as Hamming [6] noted – *"The purpose of computing is insight not numbers"*. Pictures are able to represent complex information which would take considerable time to express in words or numbers. In short, a picture can be worth a thousand words (assuming of course that the visual representation is not misleading!).

Outputting pictures using various devices is one thing, but interacting with pictures is quite another, as this implies interacting with the underlying program and data which control the picture. This was not an easy task for the first computers [10].

With the increase in power of workstations and displays it became relatively easy to handle three or more dimensions. Interaction does enable 3D models and objects to be manipulated directly by the user, and enables the user to appreciate the 3D nature of the data, even though the representation on the screen is in 2D (unless stereo is being used, for example).

The rate of general development in computer processing power has been encapsulated in Moore's law [8]. It has been observed that developments in computer hardware result in twice the power for the same price over a period of 1–2 years. This applies to central processing capability, memory and also networking and telecommunications. It also applies to devices where computer-related technology is utilized, such as the number and size of pixels in digital cameras. Thus digital photographs and videos increase in resolution and realism, and are able to consume the ever increasing amounts of storage now available at continually reducing cost!

It is predicted that there must be some limit to the number of components that can be put into an integrated circuit, since ultimately the size of atoms and the speed of light appear to be fundamental barriers. Thus the processes of ever finer photolithography to produce the circuits will reach their limit. However, silicon is just the current technology and it is surmised that other technologies may supercede it when silicon has run its course, such as optical, quantum or DNA computing, which could enable Moore's law to continue into the indefinite future.

Pioneers of computer graphics have noted the "wheel of reincarnation" that has taken place in the architecture of systems that support computer graphics. This began with considering the best way to couple a display to a computer [3, 9]. Building more functionality into the display in order to make it run faster resulted in the display becoming a self-contained computer in its own right, which in turn generated a further cycle which repeated the first.

This book notes that what may be regarded as the centre of gravity of computer processing of information has moved from the main frame to the display device and back again. Supercomputers have been used to generate vast amounts of data for computer simulations, and at the other end of the scale the personal computer has been equipped with more powerful processors and graphics cards to improve its performance with the real-time display of computer games and movies. Now the desk top is moving into the cloud – with the availability of fast network links and massive low-cost servers, which are increasingly zero-cost to the user (at least for normal amounts of storage).

The interfaces to the earliest computers were difficult to use. Punched paper tape and punched cards had to be input, programs compiled, then the data was fed in. Memory and software limitations made input and output a time-consuming process. However, as processor and memory capabilities increased, so did the overall usability. The advent of time sharing enabled users to have a greater degree of direct interaction with the computer and obtain computed results in near real-time. These results could also be displayed graphically either on a terminal or graphics display. Thus the computer moved from being considered solely as a numerical processing machine to a more general form which could process symbols and visual information. Of course, the latter needed appropriate forms of digital representation in order to be processed, but higher-level functions provided this.

Sequences of pictures could also be generated which conveyed the impression of movement when viewed as a movie. Thus computer animation became a discipline in its own right – pushing back the frontiers of algorithms and techniques to generate special effects of the kind seen in today's movies. Such techniques could also be used in simulations of physical processes in order to obtain a greater understanding of the natural world. Simulations can also be used in training procedures which generate artificial situations analogous to those in real-life to enable responses to be practiced in safety. Flight simulators are a good example of this.

It is clear that in some instances developments have been constrained by the available technology. For example, WIMP (windows, icons, point-and-click devices) graphical user interfaces could only become significant when both screens and software had sufficient capability and speed to allow user interaction to take place at reasonable rates. Speed relied in turn upon the underlying hardware and the connectivity between the central processor and the display device. One can also take the view that such developments could have restricted more open thinking about optimum interfaces for the future. WIMP graphical user interfaces that arose in desktop and mouse computing environments only use human vision of what is on the screen and a touch of the mouse or keyboard, and are essentially 2D in nature. Using other human sensory channels is not easy to accommodate, resulting in a user interface that is unnatural as far as normal human-human interaction is concerned. Future work needs to include a better match to the human's ability to process multi-sensory, multi-channel, data and to operate naturally in a 3D environment [12].

In parallel with the developments in computers and computer graphics which could be said to be "in your face", there is also the current trend towards ubiquitous, or seamless, computing. This is computing which is more or less invisible by embedding it into objects and the real-world environment, and even in clothes and people. Smart sensors are programmed to monitor data without human intervention, and produce appropriate responses automatically. Cars are estimated to have somewhere between 50 and 100 microprocessors installed to control the various active and passive monitoring functions of the car's operation. Many of these generate an effect on the 3D environment within the vehicle, or outside it.

3D computer graphics has been an exciting field over the last 50 years or so. Many books, proceedings, and conferences have been devoted to it. This book charts the excitement that the field has generated by the work of hardware designers, software developers, and users alike.

So – what challenges remain?

Sutherland [11] proposed ten unsolved problems in computer graphics. By 1998 there were at least ten more [2], and by 2000 there were at least ten problems left

[4]. In short, as the field expands, more and more problems and challenges remain to be addressed.

This book therefore provides a great opportunity to learn from the past and apply it to the future.

Rae Earnshaw
Computer Graphics Pioneer (elected 1987)
Professor of Creative Industries, Glyndwr University, UK
Emeritus Professor of Electronic Imaging, University of Bradford, UK

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Foreword II

Z

This is a book about the letter "Z". That thing we call the "z-axis", which adds a third dimension. For most of us, we figured out at a young age how to draw squares, triangles, and circles, and we managed to get through geometry, in about the ninth grade – but then along came those pesky cubes, pyramids, and spheres, and our math capabilities skidded to a stop.

When it comes to "Z", we're not even sure how to pronounce the letter – even in English, let alone other languages – where we struggle between "zee" and "zed". And why the Brits use "organise" instead of "organize" confuses further . . . Why we use "measure" instead of "meazure", or conversely, "azure" instead of "asure"; and "freeze/froze/frozen" in the same way we use "chose/chose/chosen" is beyond me . . .

For readers interested in computer graphics and display technologies, we are already accustomed to such confusion. After all, for generations we've blithely accepted as "standard" measures refresh rates of 29.97 frames per second, image heights of 486 lines (or is it 483 lines? Er, maybe it's 480 lines), sampling every other scan line at different times (interlacing), doing matrix arithmetic on nonlinearly encoded color signals . . . Huh?

Centuries ago, we switched from a Greek alphabet starting with alpha and ending with omega – we now use an expanded alphabet that starts with A and ends with Z. Still, now long after we expanded from omega to zed, our use of the letter Z is anything but common. Z is our least used letter of the alphabet, and we use it interchangeably with other sounds, like g, j, si, ts, and x. Somewhat similarly, we are now in the final stages of shifting the world of displays from analog to digital solutions – an enormous change.

This book helps us churn through the history behind such esoteric calculations, enabling us to understand the technology limitations that resulted in the graphics solutions and displays we now use. For many reasons, the history of graphics and displays diverged as the two major industries using the technologies grew – TVs and PCs came up with significantly different solutions, resulting recently in a collision (or should it be "collizion"?) between the two markets.

This collision, (often called convergence), leaves us inevitably to the intriguing notion that our TV display devices will serve as a computer monitor, just as our PC display entertains us with TV output. And then there's "Z" – creating big questions about how stereoscopic technologies will similarly converge across platforms that still offer fundamentally different usage models. Our PCs tend to be single-user, single-view devices; while our TVs tend to be multi-user, multi-view devices – a factor that dramatically transforms the display technology solutions that enable the z-dimension.

Many commentators in the media today are fond of questioning the need for the z-dimension in the market for flat panel displays. Indeed, creating three dimensional images using a 2-dimensional surface is highly problematic. Today's 3D rendering solutions are simply amazing – creating depth cues that are simply amazing – to the point that some suggest that stereoscopic 3D display solutions are simply not necessary.

One of the most common uses of the letter Z is to represent the act of sleeping (zzzz)... Interestingly, it's still a topic of tremendous debate as to whether we dream in 3D or in 2D. Can our mind form the dual views necessary for stereopsis – or do our eyes need to be part of the 3D experience?

The human visual system is based on the placement of our two eyes – and this binocular anatomy defines a stereo world. No matter how good 3D rendering algorithms become, they will always fail to replicate the world we actually see. Accordingly, 3D displays are inevitable, regardless of the skepticism of so many in the media.

This book does an amazing job of identifying the history behind 3D graphics and 3D displays. While the past fascinates, the truly evocative thing about this book is that it identifies that while the technologies are steadily evolving – such that there is no question that 3D visualization techniques and technologies will increasingly become a part of our future.

Austin, TX, USA Mark Fihn

Preface

If you ever looked at a fantastic adventure or science fiction movie, or an amazingly complex and rich computer game, or a TV commercial where cars or gas pumps or biscuits behaved liked people and wondered, "How do they do that" then you've experienced the magic of 3D generated by a computer.[1]

The dedication of this book is to the thousands of people over thousands of years who developed the building blocks and made the discoveries in mathematics, science, and computers that make such 3D magic possible.

Dedications and Acknowledgements

Although mostly linear in its evolution, 3D in computers has come about through multiple disciplines and mutually dependent lines of development. The improvements in processors, memory, displays, input devices, operating systems, drivers and APIs, applications, and software development tools have all moved in parallel and sometimes dependently on each other.

With such a broad scope as the goal of this book you will have to accept that it would be impossible to thoroughly and extensively cover all the richness of all the topics. With that disclaimer let me also apologize to anyone or any organizations I failed to cover in this book. Moreover, anyone who feels I did miss something or someone important please send a note to me about it with that information, this won't be the last book I write, and who knows, we might even have a second edition . . .

A Side Note—Lawyers

Except for their mothers, not many people like lawyers. In the last decade or two a new group of lawyers has cropped up—the intellectual property (IP) harvesters. These are lawyers, who make deals with patent holders, the IP owners, to pursue violators of their IP. Sometimes the deals involve the lawyers buying the IP. It's

[1]"3D" means a geometric model using three dimensions to describe it. It is not the same as a stereovision "3D movie". We refer to stereovision 3D as "S3D" to distinguish it.

a questionable practice and in my opinion one that has been abused. However, it has had an interesting beneficial side effect—it has created historians out of many technologists as they try to trace the origins of IP to defend their inventions and discoveries. These technologists come in three forms, the defendant, the plaintiff, and the expert witness, and all three of them have, and still are, digging through old notebooks, patents, and conducting interviews. In addition, a great deal of that work has thankfully turned up on the web. Therefore, I must give a begrudging note of thanks to the IP lawyers for being the catalyst for a lot of really important research and the rescuing of potentially lost history.

The Inventors, Discoverers, and Architects

As we trace the origins of the developments of 3D on computers, we find that in the very early times an individual was the discoverer of a concept, a law of science, or a novel idea. As we move from the industrial revolution to the computer age, the individual starts to become more difficult to identify, and the credit for a development or discovery goes to the organization. No doubt in the past several people worked on problems but usually only one person got credit for it. Today the teams are so big it's almost impossible to find the person responsible for the original idea.

Compounding the problem is that some of the developments are so large and complex the discoverer can't be the implementer.

This then is a bit of an apology to those creative, imaginative, and certainly hard working individuals that have contributed to the developments I have listed in this book. If your name isn't mentioned it's my fault for not digging deeper or harder. In addition, if you would like to tell me of your contributions and accomplishments, I warmly and strongly encourage you to do so.

No Plotters

Even though I got my official introduction to computer graphics by working on the design of a large lofting flatbed plotter at Litton Industries that we delivered to Ford in 1963, I have not included plotters in this discussion about 3D in computers. It was a difficult decision and the many people who helped develop the plotter industry may criticize me for it—my apologies to them. My rationale is that a plotter produces a non-interactive, flat, static 2D representation of a model or image. Whereas it can be argued that a display also produces a flat 2D representation, the difference (in my mind at least) is that the display can be interactive and can bring the viewer to a state of suspended disbelief.[2]

[2]Suspension of disbelief is a term coined in 1817 by the poet and aesthetic philosopher Samuel Taylor Coleridge, who suggested that if a writer could infuse a "human interest and a semblance of truth" into a fantastic tale, the reader would suspend judgment concerning the implausibility of the narrative. Today we suspend disbelief when we play a game or watch a computer generated movie, but only if the artifacts of the creation are not apparent.

The other argument for including a plotter could be the development of 3D plotters using sintering techniques for rapid prototyping. Whereas this does produce a physically tangible 3D model, it still is just a static representation, and so I have excused myself from discussing it in this book.

Jon Peddie Research Jon Peddie
Tiburon, CA, USA

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