Algorithmic Art and Visualisation:

Objectivity and Creativity from the Machine

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April 2013

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Abstract

This study seeks to look at the relationship between computer generative art visualisations and scientific visualisations and how the human condition affects them both in how they are perceived and created. Visualisations provide insight into data or to give an impression of the data, for knowledge or aesthetics, the border is not always clearly defined.

How do anthropological biases inform the creation of visualisations? To what extent is the generative artist ignoring the real data and manipulating it to a preconceived form? Is this counterproductive in the creation of scientific visualisations or does it enable us to more intuitively understand data while preserving the truth? How do the techniques used differ between generative artists and scientists?

To answer these questions I will look at the co-evolution of the two fields, where there has been crossover and where they have sought to address their similarities.

Introduction

Since the early 1960s and the pioneering work done in both the fields of visualisation for art and scientific visualisation the two have grown side by side. This dissertation will examine the relationship between these fields, how they share similar techniques to different ends and the questions raised by them.

The first chapter will explore the development of visualisations for art; primarily by tracing the history of algorithmic art through to the incorporation of external data and the present state of the movement. In doing so it will review the current thinking in this field.

Galanter (2003, p.4) defines generative art in the following terms:

> Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art.

This is a broad definition which encompasses any technology that procedurally works through a process with autonomy. A more succinct definition can be taken out of context from Sol LeWitt (1967) on conceptual art: “The idea becomes a machine that makes the art”. (McCormack et al. 2012) In this research the focus in the field of generative art will be primarily on subset of algorithmic art.

Chapter two will examine the use of visualisation, particularly computer based visualisation in science and the interdisciplinary interaction between artists and scientists.

The third chapter will look at some of the the concepts of complexity and the anthropological patterns and tendencies that may either inform or undermine artistic creations, understanding and appreciation of both algorithmic art and computer visualisation. It will ask, and attempt to answer, the question: How can a scientific visualisation be objective if it is influenced by the same forces as algorithmic art?

The field of computer visualisation developed in parallel with computer art, it shares many of the characteristics, methodologies and ideas yet its purpose is entirely different. Art may seek to give us an understanding of the human condition and visualisation gives an understanding of data.

Algorithmic Art

As a starting point this chapter will look at the historical development of algorithmic art and some of the technology, concepts and techniques that the movement is based on. As well as this it will establish a context for comparison with visualisation.

History

Generative art is inexorably tied to the current technology of computing. As computational power increases and new input/output devices are conceived and improved the possibilities open to digital artists increase. The programmable digital computer and its proliferation was the prerequisite for the emergence of algorithmic art in the modern digital sense.

There were many key milestones achieved in the history of computing. An early step was the Jacquard loom which used punch cards as instructions for the machine; however, it performed no calculations with them and the output was entirely predetermined. This was an important development in the history of computing anyway as it acted as a precursor to punch card controlled machines with limited computational abilities and later Turing complete programmable computers.

Conceptually algorithmic art appears to be a subset of the process art movement where the end product is not the main focus but instead the process of creating the artefact is; however both the early algorithmic art movement and the processes art movement - inspired by the methodologies of Jackson Pollock in the 1950s - had been formed and ran in parallel as part of a wider artistic culture of the era. The artist and writer Burgin (2003 p.895) in 1969 comments that some recent art is “evolving entirely through attention both to the conditions under which objects are perceived and to the processes by which aesthetic status is attributed to certain of these, has tended to take its essential form in message rather than in materials.” and goes on to say that “aesthetic systems are designed, capable of generating objects, rather than individual objects themselves.” As a description for process art and the timeframe it suggests algorithmic art is part of the same conceptual structure. Conversely it can be argued that algorithmic art, having originated in computer science, is in fact the product of experimentation and so it happened to originate in a time when the computer was proliferating inspiring new theories of cybernetics. The view of the world in terms of systems would provide a fertile ground for systems or process based ideas.

The history of computer generated algorithmic art as a practice has its roots in the early 1960s when pioneers Georg Nees, Frieder Nake and A. Michael Noll created and later exhibited some of the earliest known computer art with Georg Nees the first to do so in Stuttgart 1965 and the others later the same year. Much of this early work was done at large research labs by engineers and scientists as at the time as they were the only people in a position to use the limited computer resources available. It would not be until the next decade that the personal computer would emerge and allow the field to flourish.

In 1968 the Jasia Reichardt's Cybernetic Serendipity exhibition in the Institute of Contemporary Arts, London was an important milestone in the establishment of digital computer art (Grau 2003 p.166) and led to the formation of the Computer Arts Society. The Computer Arts Society was founded by Alan Sutcliffe, George Mallen and John Lansdown who knew Jasia Reichardt and had been involved with the Cybernetic Serendipity exhibition. The society gradually expanded and branches were formed in Amsterdam in 1970 and the US in 1971. In the accompanying catalogue to Cybernetic Serendipity entitled *Cybernetic Serendipity: the computer and the arts* Reichardt briefly describes contemporary computer art, its origins and its place amongst the wider world of art. Speaking on the resistance of traditionalists within art she says that "even now seen with all the prejudices of tradition and time, one cannot deny that the computer demonstrates a radical extension in art media and techniques." In the intervening 45 years gauging the field's progress in terms of acceptance by the wider art communities is difficult, however it seems to be inevitable as with the acceptance of earlier technologies such as the printing press, loom and other means of automation. Wands (2006, p.14) describes the current transition:

> Emerging artists are now growing up with digital literacy as an integrated part of their lives. They will never know a world without the internet, laptop, mobile

> phones or email, to mention but a few of the technological aids that help shape our daily existence. As such, these artists do not regard making art with digital tools as anything different from using traditional tools. The qualifier ‘digital’ has already begun to disappear, and these artists of the future will be considered contemporary artists.

This is also echoed by Freyer, Noel and Rucki (2008) who speak of a generation “born amid the digital revolution [who] speak the language of the machine like natives and understanding technology intuitively, and these factors are fundamental to understanding the rise of technology-infused works”.

In the same article Reichardt describes computer graphics as “a visual analogue to a sequence of calculations fed into the computer”. Here she attributes no intrinsic artistic quality to it but at this early stage before many of the advances that would later shape it, speaks of the collective term for the methodologies used. Manovich (2001 p.180) posits that since the 1970s “the achievement of photorealism is the main goal of research in the field of computer graphics. The field defines photorealism as the ability to simulate any object in such a way that its computer image is indistinguishable from its photograph.”

The first annual SIGGRAPH (Special Interest Group on GRAPHics and Interactive Techniques) conference was held in 1974. It continues to be run by ACM (Association for Computing Machinery) SIGGRAPH, founded in 1969 by Andy van Dam who had worked with Ted Nelson on the first hypertext system HES (Hypertext Editing System) in 1967. The following year in Germany the exhibitions *Computerkunst - On the Eve of Tomorrow* and *Impulse Computerkunst* were held in the Kunstverein (art society) in Munich. According to Grau (2003 p.166) “This was also the year computer art became an integral part of the Biennale in Venice, which enhanced the international status of the genre.” In 1979 Ars Electronica was founded in in Linz, Austria with the purpose of developing and exhibiting electronic art after hosting its first annual festival. According to Wands (2006 p.25) “the 1970s witnessed not only valuable technological advancements for digital artists, but also the beginnings of formal institutional support for digital art.” With these exhibitions, societies and institutions came greater opportunities for collaboration and the exchange of ideas. This interdisciplinary crosspollination between people from different backgrounds proved fertile ground for new creativity. Reichardt (1968) writes that some “claim that the computer provides the first real possibility of a collaboration between the artist and the scientist which can only be based on each other’s familiarity with both media.”

Algorithmic art is primarily concerned with the role of the algorithm. Jean-Pierre Hébert who, with Roman Verostko co-founded the "Art and Algorithms" panel at SIGGRAPH in 1995 defined an algorist. The definition is in the form of a short snippet of code:

```
if (creation && object of art && algorithm && one's own algorithm) {
    include * an algorist *
} elseif (!creation || !object of art || !algorithm || !one's own algorithm) {
    exclude * not an algorist *
}
```

In this definition the algorithm must be “one’s own algorithm” and therefore not a digital recreation of an existing algorithm or the use of existing software where only a number of input variables are changed to create different pieces and not the algorithm itself.

Creation

Algorithmic art in the digital art sense can be created in any programming language provided it is able to output to a display, printer or plotter. Algorithmic art can also be applied to create the designs for sculpture and architecture. Sculpture such as Robert Michael Smith’s *Ephesiancybergin* (2003) and *Gynefleuroceraptor* (2003), which exhibit organic forms, were created in marble with a CNC milling machine. Dan Collins’s *Twister* also in 2003 is a self-portrait where the data was created in 1995 by the artist standing in a full-body laser scanner on a turntable that was spun around resulting in a distorted and twisted effect. This example is not algorithmic art in the strictest sense but demonstrates the desire to extract tangible physical forms from the virtual space of the computer.

The alternative to subtractive techniques like this for translating model data within a computer into physical objects are additive techniques, commonly referred to as 3D printing. 3D printing allows for much more intricate and complex forms in that internal structures are accessible to the machine as it is building the object layer by layer rather than carving into a material. Some sculptures remain as models in virtual space and are experienced through some means of display.

The artist creates an algorithm and a computer executes it to produce the artwork. As with the process art movement the actual process of creating the piece often has greater importance than with other art forms. It would be possible to write an algorithm and then manually execute it using traditional materials, but the speed that the computer affords the artists allows for much more rapid production and therefore more iterations and variations to be created. Franke (1985 p.1) notes the fundamental change the computer offers the arts, in that “for the first time it has become possible to insert a mechanical aid into the creative phase of artistic production.”

Randomness

Algorithmic art makes extensive use of random numbers in the creation of art, this is mainly so that large structural patterns produced by an algorithm can be broken up and introduce an element of serendipity to the process which is otherwise entirely deterministic.

It seems counter-intuitive however in the field of computing truly random numbers are impossible to generate solely by computational means. This is because computers are deterministic systems and given an identical set of instructions and state, two computers will produce the same sequence of numbers. Many of these pseudo-random number generators make use of a seed value which can be set to allow the recreation of the same seemingly random sequence of numbers. Conversely hardware random number generators measure unpredictable signal noise from often microscopic physical processes and generate numbers from these.

Random numbers alone result in random effects but these are not always what the algorist intends for their work, they may instead require “noise”. Noise is characterised by structures on various scales being generated. A sequence of random numbers mapped to a two dimensional space with the pixel’s brightness being determined by the corresponding random number will appear as analogue television static appears, however a sequence of generated noise will appear almost as a landscape heightmap. Algorithms such as Ken Perlin’s “Simplex noise” and earlier “Perlin noise” allow the computation of noise. Simplex noise is able to produce multidimensional noise relatively cheaply. (Gustavson 2005) In computer graphics and computing in general cheapness or expensiveness are relative terms for describing the efficiency and utilisation of system resources. These elegant solutions and many other algorithms are incorporated into many programming languages. The higher level the programming language the more algorithms are incorporated into the language; to what extent does this violate Jean-Pierre Hébert’s “one’s own algorithm” rule? Hébert’s definition does not attempt to accommodate this but it seems to have implications for authorship in programming as very few programmers today work at the lowest levels of computer code. Pragmatically speaking this is not an issue as without the artist’s algorithm, no matter how reliant on existing algorithms, a piece is not produced. A painter does not need to make the canvas, paint and brush.

Random numbers by their very nature are without meaning in of themselves and so rather than solely using a pseudo-random number generator, real world data can be fed into the algorithms. This change marked the first artistic computer visualisations as now they gave an impression of the data in which both information is conveyed and aesthetic forms are created.

Complexity and Entropy

Information theory measures information in data; the idea that ordered data has low information and that disordered data has less. In natural language there is redundancy because there are underlying patterns to the data. This allows compression because the meaning of the data can be preserved even when removing some words and letters. This idea has several applications that enable significant compression of data such as audio and video with minimal loss of quality. Lossless compression preserves all the information by substituting recurring patterns with a shorter piece of data which is converted back to the original form when accessed. Lossy compression removes data which is not integral to the structure and meaning of the data. A completely random string of letters cannot be compressed without a loss of information and can be said to have high entropy opposed to the low entropy highly ordered string. This presents a paradox in that forms with the most information effectively contain no meaningful information at all. So for data to contain useful information it must be between completely ordered and completely disordered. In this regard information as a metric isn’t always useful for intuitively describing the meaningful content in data.

Galanter (2003 p.11) applies complexity theory as a context for generative art. He argues that “Systems exist on a continuum from the highly ordered to the highly disordered. Both highly ordered and highly disordered systems are simple. Complex systems exhibit a mix of order and disorder.” Galanter adopts Murray Gell-Mann’s “effective complexity” as a more useful measure. This model has been criticised by J. W. McAllister for being dependant on a subjective assertion of what is useful information and what isn’t.

In visualisation complexity is minimised in the pursuit of clarity whereas in algorithmic art complexity is a stylistic choice controlled by the complexity of the algorithm. For a hybrid of the two, generative art based on real data, one might wish to emphasise complexity as an aesthetic in its own right.

Can a machine make art?

Algorithmic art poses a number of interesting questions; chiefly amongst these is 'Can a machine originate art?'. A machine is a tool that is created to use energy to achieve a goal; no matter the complexity it is still running deterministically through the processes engineered within it.

The ability to produce art is considered a human trait although from a reductionist perspective humans and all biology could be considered as extremely complex machines. Following this train of thought leads to the problem of identifying what makes us more than a machine and the greater philosophical question: what is life? which falls outside of the scope of this research.

Computers once programmed to do so can recognise patterns and reproduce them but they are unable to understand the emotional connotations within them and so can only create variations or reconfigurations using data captured from existing art. A true test of artificial intelligence in art is for it to be capable of originality and deep insight. A problem here is that there must be a measurement to identify if this has been achieved, a sort of creative Turing test.

Noll (1966) writes of creating an algorithm to replicate the patterns in Piet Mondrian's *Composition with lines* (1917) and then conducting an experiment to see if people could distinguish the computer generated image from the original. Only 28 of the 100 subjects were able to identify the computer generated picture which has the startling implication that the product of a computer could seem more human than that of a human. Noll notes that the more uniform distribution of the pattern in the original *Composition with lines* may have led some to believe that it was computer generated as it may be assumed that a computer as a machine would produce a more ordered pattern whereas a human would create a more disordered one. Noll remarks that "Undoubtedly, an indistinguishable pair could finally be obtained, but performing experiments similar to those reported in this paper would not be too revealing." This conversion of an abstract artwork into computer code shows that there are discernible and extractable underlying patterns within many artworks which can be replicated.

Burton (1997, p.60-65) looks at the creation of two computer programs, *AARON* by Harold Cohen and *Rose* (Representation Of Spatial Experience) by himself, which are designed to creating images mimicking certain aspects of human drawing. Rose ‘perceives’ a 3D model which it then simplifies into bounding shapes and maps it to a two dimensional plane arbitrarily and vaguely in the form of the object, a ‘pen’ traces out the form during which “Rose receives continuous feedback from the drawing in progress” and is “disturbed to simulate poor motor control”. The resulting output during its development “parallels that of a child between the ages of 18 months and five years”. So to an extent human art can be simulated but software is not capable of invention, only variations. According to McCormack et al. (2012) though:

> [It is] impossible for the programmer to completely understand and predict the outcome of all but the most trivial programs - one reason why software has “bugs”. The second objection arises from the ability of a program to modify and change itself. Computer programs, like people, can be adaptive, they can learn, and so initiate new and potentially creative behaviours.

Considering that the program itself must have been created one can then say that the creator of the program is the artist. Genetic algorithms mimic the iterative evolutionary process of design in an attempt to generate an optimal solution to a problem with given conditions and limitations; yet even with this complex process it is still operating through a sequence confined by the person who gave it those conditions and programmed it. Ascott (2003, p.129) says of the computer and cybernetics in general:

> If the cybernetic spirit continues to be the predominant *attitude* of the modern era, the computer is the supreme *tool* that technology has produced. ... For it is not simply a physical tool in the sense that an aluminium casting plant or CO_2 welding gear are tools - that is, extensions of physical power. It is a tool for the mind, an instrument for the magnification of thought, potentially an “intelligence amplifier”... [A cybernetic vision offered by the computer] can be expected to find expression and enlargement in art as well. It can assist in the evolution of art, serving to increase its variety and vigour.

Ascott views the computer not as a replacement by very much a tool for magnifying thought. So instead of a replacement for the artist, algorithmic art is very much about the artist. Unlike traditional art, a layer of abstraction exists between the artist and the resulting artwork. They do not directly create the piece, they may not even know vaguely what they want it to look like but they set in motion a sequence that does. The computer serves as a useful tool, translating dry logical sequences of code into images of beauty.

This chapter traced the path of algorithmic art since the 1960s. The next chapter will look at the field of visualisation and how algorithmic art has influenced and been influenced by it as well as the common challenges faced by both, computer graphics techniques and the distinctions in purpose and approach that separates them.

Visualisation

The previous chapter tracked algorithmic art and to some extent the history of computer graphics, another field which has changed greatly with advances in computer graphics and the same techniques used by algorists has been the field of computer data visualisation. Here a parallel between the two fields will be drawn exploring to what extent there is a relationship, if at all and how they interact.

Definition, Classification and Purpose

The word visualisation could apply to anything that portrays an idea in visual form but visualisation in this context makes the invisible visible. A visualisation takes abstract data and produces a readable and recognisable image from which you are able to derive meaning. A visualisation may take the form of a graph or diagram in two or more dimensions. Visualisations can be a direct representation of something real on the macro scale in 3D virtual space, a model of something microscopic or vast scale which the exact configuration or appearance cannot be known but the physical properties and relationships are known or theorised.

The primary function of a visualisation is to convert data into an image that intuitively conveys information. But it seems that in aiming for this clarity they become aesthetically pleasing in of themselves as a by-product. In McCandless's introduction to *Information is Beautiful* (2012) he describes how people are inundated with a constant deluge of information and the need for clear visualisations to make sense of it: “Every day, every hour, maybe even every minute, we're seeing and absorbing information via the web. We're steeped in it. Maybe even lost in it.” Tufte (2001) says that “Often the most effective way to describe, explore, and summarize a set of numbers - even a very large set - is to look at pictures of those numbers.”

Visualisation can also be divided between artistic and pragmatic or utilitarian in purpose. To further divide pragmatic visualisation there are the fields of Information Visualisation and Scientific Visualisation, the distinction is not immediately apparent. Shneiderman & Plaisant (2010 p.556) describe the abstract characteristic of data as the distinguishing feature. “Information Visualisation can be defined as the use of interactive visual representations of abstract data to amplify cognition.” Whereas for scientific visualisation “three dimensions are necessary, because typical questions involve continuous variables, volumes, and surfaces.” The division of these two terms, one concerned more with graphs and graphics and the other with 3D space and complex relationships. Ware (2004) and Spence (2007) also support this description. Ware (2004 p.4) describes the value of visualisation in science in five points: “Visualization provides an ability to comprehend huge amounts of data.”, “Visualization allows the perception of emergent properties that were not anticipated.”, “Visualization often enables problems with the data itself to become immediately apparent.”, “Visualization facilitates understanding of both large-scale and small-scale features of the data.” and “Visualization facilitates hypothesis formation.” Visualisation is an essential tool for science. Manovich (2002 p.10) describes this form of data mapping as “anti-sublime”, he elaborates:

> If Romantic artists thought of certain phenomena and effects as un-represantable, as something which goes beyond the limits of human senses and reason, data visualization artists aim at precisely the opposite: to map such phenomena into a representation whose scale is comparable to the scales of human perception and cognition.

To understand why visualisation is so effective at conveying information one must look at the human anatomy. In humans a large proportion of the brain is dedicated to vision and the comprehension of what humans see. According to some studies show that 30% of the cerebral cortex is in some way involved with vision (Grady, 1993). It is no exaggeration to say that vision is very important to humanity, it features prominently in language when people talk of the conception, reception and understanding of ideas: imagining, picturing an idea, envisioning something. This speaks of the intrinsic connection between perception and the manner in which human brains work and develop. As an evolutionary device vision grants animals the ability to perceive threats and opportunities remotely using light, the vast majority of the animal kingdom have some form of vision ranging from collections of photosensitive cells in very simple animals up to the highly complex old world primate eyes capable of tri-colour vision, colour differentiation and depth perception. As a crucial weapon in life’s evolutionary arms race it has been selected for heavily and is very closely linked to the function of the human mind; so closely in fact that the retina is actually an isolated part of the brain.

There are a number of points where the history and development of algorithmic art and computer visualisation are strongly linked, mainly through the common techniques in the field of computer graphics but the ideas behind visualisation are much older than the computer.

Visualisation has its historical roots in cartography, when people first sought to understand the landscapes they lived in. Map making was of strategic importance as it allowed people who had never been to an area to understand its geography and the relative locations of various settlements and natural features. Early maps made use of strange perspectives and vague drawings which echoed contemporary art styles but as cartographic techniques and accuracy improved the top down perspective became standard. Visualisation of abstract data in the form of graphs did not appear till much later during the Enlightenment which was a time of intellectual reformation, founded on reason and scientific thought.

The earliest computer visualisations preceded algorithmic art as they were what early computer graphics technology was originally developed for. As previously detailed in the previous chapter, after the work of pioneers in algorithmic art their history has been closely linked through the development of computer graphics.

Animation, Virtual Space and Real Space

Animated visualisations include the dimension of time which is normally used to show the effect of the passage of time on the data, progress through a stream of data or show the subject of the visualisation in the process of changing states. The first example of a computer animated film was *Two-Gyro Gravity-Gradient Attitude Control System* by Edward Zajak at Bell Labs in 1961 which visualised an attitude (orientation) control system for satellites, previously the positions of the virtual objects in each frame of such an animated diagram would have to be calculated then drawn and animated by hand. This would have been subject to the abilities of the person drawing. By generating the images with the computer it is visualising a 3D virtual environment.

Visualisation in this sense are extremely useful to science, they give scientists the chance to see for themselves the invisible worlds and underlying patterns in nature they are studying. In many fields this insight can be invaluable in gaining greater understanding of data and the articulation of theories. Some examples of important images for science using visualisation techniques have been the progressively more detailed images taken by the COBE, WMAP and Planck satellites of the slight irregularity in the cosmic microwave background radiation left by the big bang approximately 13.8 billion years ago. These images have implications for physics as theories describing the big bang must account for the pattern formed.

Outside of the sciences, visualisation plays an important role in people's everyday lives. An everyday example of a virtual space which people have grown used to is the desktop environment shown on computer screens. Users manipulate virtual objects on the screen with a mouse, track pad or touch. The mouse cursor becomes an extension of user and they no longer think of moving the mouse, but of moving the cursor. These concepts were demonstrated by Douglas Engelbart in what later became known as *The Mother of All Demos* (1968). In the field of Human Computer Interaction or HCI the Graphical User Interface or GUI could be said to be an applied form of visualisation and also accommodate visualisations. According to Manovich (2001 p.95-96):

> This concept of a screen combines two distinct pictorial conventions: the older Western tradition of pictorial illusionism in which a screen functions as a window into a virtual space, something for the viewer to look into but not to act upon; and the more recent convention of graphical human-computer interfaces which, by dividing the computer screen into a set of controls with clearly delineated functions, essentially treats it as a virtual instrument panel.

This also extends to the concept of virtual space or 3D virtual environments appearing within the screen and other immersive technologies such as a Cave Automatic Virtual Environment (CAVE).

Visualisations need not be confined within the virtual environment of the computer and can be physical objects or material which manifest in a form that relates the data. These can take different forms. The first is to continually take real-time data or a stream of data and through the use of actuators, machinery and electronics to create what can be described as a performance by manipulating physical objects or material. This form of visualisation leads of a kind of data driven and often interactive kinetic sculpture such as Greyworld's *The Source* (2004) in the London Stock Exchange.

Simulation and Ambiance

McCormack et al. (2012) speak of the relationship between generative art and simulation:

> Generative computer art often draws on ideas and algorithms from the simulation sciences. A simulation involves the representation of important characteristics and dynamical behaviours of some target system. However, few generative artists would view or conceptualise their works as direct simulations of reality.

Simulation and visualisation often go hand in hand, a portmanteau of the two words "visulation" is sometimes used to describe a scenario in which both are used simultaneously to compute the model and display it respectively. A visualisation can model data collected previously over span of time, model data in real-time or internally generate its own data based on algorithms and visualise it. The latter is not dissimilar to algorithmic art, but here it is often attempting to replicate a real or theoretical process where the representation real objects is less important than the information that can be obtained from viewing their structure and behaviour.

Another form of visualisation, on the other end of the spectrum of complexity, is the ambient visualisation; these are designed to give a general impression of information at a glance, taking minimal time to comprehend.

Crossover and Differences

The original computers used by the first computer artists were built for visualisation. In *Cybernetic Serendipity* (1968, p.71) Reichardt says that “Since the process suggests inhibiting difficulties to someone who is not an electronic engineer, it may be difficult for an artist to imagine how he could possibly make use of a computer. The solution to the problem lies in collaboration.” This alludes to a second wave of people entering the field, this time rather than people with computer science background such as Georg Nees, Frieder Nake and A. Michael Noll venturing into the creation of art but those with an art background adopting the computer as a tool. 40 years on Wands (2006, p.12) speaks of these two types of digital artist and the need for collaborative relationships this creates.

Born out of computer visualisation computer graphics has pushed technology and in turn the technology has pushed computer graphics, expanding people’s ability to create both visualisations and computer art.

Arguably the main purpose of a scientific visualisation is that it must be clear, somewhat accurate and conveys information. Scales or a key provides a means for extracting information and indicates that it is a visualisation. The creator of a visualisation may or may not consider themselves to be an artist. (Tufte, 2001) Algorithmic art based on data may merely give an impression of the data or it may not illuminate anything of the data and instead act as a seed for the computation and composition of the resulting image.

The comparisons made in this chapter lead to the idea of a strong relationship between the two fields linked by the common bridge of computer graphics. Computer graphics emerged as the specialisation of the techniques developed by computer scientists for both the purpose of visualisation and computer art, here scientists and artists met and continue to meet to create new technologies enabling new creative works.

With the parallels drawn between visualisation and algorithmic art, it's clear that both are linked through the field that emerged between them of computer graphics which acts as a mediator and bridge between computer science, digital art and visualisation for general science. Having looked at the methodologies and techniques that have enabled algorithmic art and computer visualisation the next thing to look at are the underlying principles and important fundamental questions that they raise.

Grau (2003, p.326) describes his view on the boundaries between art and science:

> More than ever, it will become imperative for there to be cross-fertilization between science, social sciences, and art. Much has been done to promote interdisciplinarity and to pull down the barriers erected during the course of the Enlightenment and the nineteenth century, but much more still remains to be done. To bring the natural and social sciences, technology and art, closer together is one of the greatest challenges of the new century.

This seems to suggest a compromise and hints at a much larger question: Is science with the aesthetic sensibilities of art still science? The next chapter will look at the nature of science and its compatibility, or lack of compatibility with art.

Objectivity and Creativity

This chapter will attempt to answer the question: Can visualisation be objective if it is influenced by the same aesthetic forces as algorithmic art? using the preceding chapters as a context for this discussion. The chapter will also look at theories that seek to understand the underlying nature of both fields. This chapter will look at more traditional graphs as the same challenges faced by them should also apply to computer generated visualisations, diagrams and animations.

According to Ascott (2003, p.218) “the project of the art of our century has been essentially to make the invisible visible. Art has progressively sought to be in touch with unseen forces fields, systems, relationships, connections, and transformations and to make them visible.” If this is true then it suggests the art of today is also a form of visualisation.

To what extent is the generative artist ignoring the real data and manipulating it to a preconceived form? To answer this, one can look at the way that scientists deal with the same problems.

Biases

Any visualisation, no matter how far removed and abstracted such as with self-modifying and adaptive algorithms is man-made as the original authorship and facilitator is human. As a product of this a visualisation may be adjusted to meet certain aesthetic qualities. This potentially forms a feedback loop where the algorist is observing the output and modifying the code to meet a desirable form. This is constructive if the purpose is to produce art as the iterative process allows the distillation of a finished piece that reflects the human qualities of the artist. This iterative approach has implications artistically for algorithmic artists as it infers that through its changeability the algorithm is not as important as the form of the end product. Perhaps it is only once there is a final artwork is produced that the algorithm takes on its importance.

This problem of has serious implications for science as it can undermine its core principles of rationalism and empiricism by introducing biases to the observations made by the scientist. It is important to understand the different forms of scientific truth. Sober (2008 p.129-130) describes how empiricism, which emphasises “the role of the sense experience” in forming judgements is often contrasted with both rationalism and scientific realism. For an empiricist he writes:

> If a theory is logically consistent, observations are the only source of information about whether the theory is empirically adequate. For a realist, the observations provide information about whether the theory is true, but there are other considerations as well: if one theory is more explanatory, or simpler, or more unified than another, that counts too. Empiricists often dismiss these considerations as merely pragmatic or aesthetic - theories with those virtues are easier to use or more beautiful to behold, and that is all.

Sober also refers to another related option of instrumentalism which is “often interpreted as claiming that theories do not have truth-values and are merely useful tools for making predictions”. The constant critical uncertainty of empiricism underpins the foundations of science, if new repeatable observations are made then the old model of understanding is wrong paving the way for new science. Science is the systematic endeavour to collate knowledge through logical and objective means. Grau’s (2003, p.324-326) idea of scientific compromise would be incompatible with the principles of empiricism as it suggests the incorporation of subjective elements into the formation of understanding.

Confirmation bias is a well-documented phenomenon which is tendency of people to subconsciously selectively favour information that conforms with their pre-existing beliefs or hypotheses and to interpret information in a biased way. (Nickerson, 1998) A visualisation may be speculative to an extent so there is considerable room for confirmation bias to influence it.

Tufte (2001 p.56-77) describes a measure for the distorting effect of a discrepancy between the relative scales in graphics and in the data they represent; he describes this as the “Lie Factor”. It is calculated from the size of the effect shown in the graphic divided by the size of the effect in the data. A “Lie Factor” of one may be accurately depicting the underlying numbers. Mazza (2009 p.13) describes artists without statistical skills as producing “artistic artifacts rather than clear, direct, and unambiguous visual representations of data”. So in this there is an apparent resistance to embellishing information in visualisations for effect and for good reason, a graphic or visualisation could be used to distort information which in turn could affect decision making or general perception particularly in the layman who is less experienced with detecting this.

Assumptions and Practicality

A simple line graph for example, tracking the rise and fall of a value on one axis with time on the other may have a resolution of one sample taken every hour over the course of a day. As this is a changing value it is implied that between one sample and the next there will be a midpoint where the value is halfway between one and the other. Extrapolating this results in a curving line of peaks and troughs which appeals to a sense of aesthetics and natural forms. The problem with this is that an assumption has been made about the way the value changes that may not actually be true but intuitively and aesthetically makes sense. It could be that the value is infact a random number generator frequently changing its value. The graph, because of the relative infrequency of its sample appears to display a much more stable system than is actually the case. In this way even a simple graph can be extraordinarily deceptive. This effect is known as sample error. Tufte (2001 p.169), perhaps un-charitably, says when speaking on apparent bimodal distributions “Several of these utterly random distributions may lead gullible researchers to jump to conclusions about bimodal distributions and in turn, about multiple causes.” A bimodal distribution is a graph that shows two peaks implying that there is a reason why relatively few exist in an intermediate stage and either gravitate towards one peak or simply do not appear in the data.

Also there are practical considerations which lead to the distortion of reality. Visualising sound waves radiating away from a source in a piece making use of the effect of synesthesia for example is impractical to do in real time and at real speeds as the speed of sound at sea level is 340.29m/s, significantly faster than an observer would be able to see on a reasonably sized display so a concession must be made here.

Aesthetics, Culture and Perception

Aesthetics are highly subjective with countless different cultural or individual personal preferences but there are underlying universal preferences that are detectable in most humans. Much artistic and architectural work, particularly of 20th century, incorporates what is known as the golden ratio (approximately 1.618) as it is believed to be aesthetically pleasing. Another basic example of this is the prevalence of symmetry in the art of various cultures.

Colours are not real, they exist only in the mind. In reality what is happening is that photons oscillating at different frequencies are being received by the eye and the brain categorises it as a colour based on the frequency range it falls into. Based on the molecular structure and composition of an object it will absorb and reflect light at different frequencies. Because colour is a product of the mind, a person can never know for what colours look like to other people. Two people will identify the same frequency ranges with the same names, qualities and examples but actual perception cannot be compared. These subjective conscious experiences are known as qualia and the problem comparing them is known as the explanatory gap. There are however have cases where the frequency ranges are disordered, missing or deformed from what is deemed to be normal, with the inability to distinguish frequencies colour blindness can be detected but if the perception of a spectrum was inverted there would be no way to tell. Amongst other cultures such as the Himba people of Namibia their language divides the visible light spectrum into four colours. Regier and Kay (2009) found that language plays an important role in determining how humans perceive colours; people are less able to differentiate things when they do not have separate words for things.

Even as a product of perception, colours are powerful cultural symbols, the colour red in particular has a multitude of meanings in various contexts and cultures. It is used to symbolise danger, this may be because of the relative rarity of red things in a predominantly blue, green and brown world and it is the colour of blood. In sport, teams or participants have been shown to be 5% more likely to win if they wear red both in direct scoring games and judged sports (Hill & Barton, 2005). The idea that red is hot and blue is cold is afforded to people by nature. Significant blue entities in nature such as bodies of water have a tendency to be cold whereas when a material is heated it may glow red and fire itself has a large component of red light. In a visualisation of temperature it would make sense to use these existing, almost synesthetic notions.

Gale (1979, p.216) describes the position of "Aestheticians" within science:

> At first it might seem strange that science and aesthetics would be at least related. However, there has been a close and definite connection between them since the times of the earliest Greek science. This connection is most evident amongst scientists of a mathematical bent, perhaps since mathematics itself pays close attention to the so-called elegance of proofs.

Gale argues that the reason for a view of beauty correlating with truth implies the idea that underlying universal principles are themselves beautiful and elegant.

The Price of Beauty

A visualisation is an abstraction of an idea, process or pattern and so complex and chaotic systems are reduced to simplified cycles and networks. This cybernetic thinking removes anomalies that may betray a deeper and more interesting process at work. It's in anomalies that new discoveries have often been made. The history of science is full of such examples. The transition from Newtonian physics to relativity serves as a good example of this. Sir Isaac Newton's laws of gravitation and motion proved an excellent model for calculating the positions of celestial bodies however with increasingly accurate measurements it became apparent that the planet Mercury was not where it should have been according to the theory. It was not until Albert Einstein that the relativistic effect of the planet's proximity to the sun was understood and accounted for the discrepancy, affirming the new theory. The pursuit of aesthetically pleasing models of understanding as well as ones that conform to people's existing beliefs can lead to the ignoring of anomalies and missed opportunities to make discoveries and advance.

The inevitable outcome of a comparison between visualisation for science and visualisation for art is to begin comparing the fundamental principles that distinguish the vast and seemingly incompatible fields of art and science themselves. Grau (2003, p.325) identifies common ground between art and science in that they are both social constructs, one a machine for determining truth and the other as an umbrella for numerous methodologies and practices:

> Art achieves its power principally by tolerating a range of methods. This playful dimension leads art, in its experimental dealings with new media, to surprising results and insights. Science is, in its mechanisms and methods, in its systems of truth and proof a social construct. Art is, too, and in this sense, they are comparable.

Ultimately the two both seek understanding and truth, it’s just that there is more than one kind.

Conclusion

By looking at the development of algorithmic art and computer visualisation a clear exchange of ideas, techniques and people is apparent. Computer scientists continue to transition from the cold logical indifference of pure computing into the subjective and human world of art bringing with them their abilities with computer technology. Conversely the general population is becoming increasingly adept with this technology through their proximity with it allowing people to immediately move into algorithmic art without a background in either of the original sources of people entering the field. Through their experimentation with computer graphics artists have expanded the possibilities open to visualisation, both artistic and scientific.

Answering the question: How can a scientific visualisation be objective if it is influenced by the same forces as algorithmic art? The effect of the human on data based generative art could be said to be what gives it its strength, it reconnects the piece to the human, it makes it art. At the same time though when an artefact is using data from the real world, it may be that the piece is not reflecting the world, it is instead reflecting the artist's perception of it. But as all people to some extent share these perceptions it creates an almost universal visual language. Broader algorithmic art in general remains a purely artistic expression executed through the medium of code. Aesthetic quality in visualisation appears to be something to strive for in terms of intuitive readability but this must not come at the cost of integrity if the information within is important. This is very much a contextual issue as the intended audience of a visualisation informs to what extent it is embellished or abstracted and the level of rigor applied to its creation.

To conclude, both algorithmic art and visualisation are affected significantly by the human condition because they are both re-orderings of reality to correlate with people's models of perception and deeply ingrained anthropological and cultural meanings. It's these very models and meanings which allow us to comprehend our window into objective reality and identify truth.

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