digital light

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Digital and networked media are now very much the established media. They still hold the promise of a new world, but sometimes this new world looks as much like a complex form of neofeudalism as a celebration of a new communality. In such a situation the question of what 'media' or 'communications' are has become strange to us. It demands new ways of thinking about fundamental conceptions and ecologies of practice. This calls for something that traditional media disciplines, even 'new media' disciplines, cannot always provide. The Fibreculture book series explores this contemporary state of things and asks what comes next.

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Edited by Sean Cubitt, Daniel Palmer
and Nathaniel Tkacz

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The cover is a visualization of the book's text. Each column represents a chapter and each paragraph is modeled as a spotlight. The colour reflects an algorithmic assessment of the paragraph's likely textual authorship while the rotation and intensity of the spotlights are based on a paragraph's topic ranking for "digital light". It was made with Python and Blender. © David Ottina 2015 cc-by-sa

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INTRODUCTION

Materiality and Invisibility

Sean Cubitt, Daniel Palmer and Nathaniel Tkacz

There is a story that the very first filter invented for Photoshop was the lens-flare. Usually regarded as a defect by photographers, lens flare is caused by internal reflection or scattering in the complex construction of compound lenses. It has the unfortunate effect of adding a displaced image of the sun or other light source, one that in cinematography especially can travel across the frame, and mask the 'real' subject. It also draws attention to the apparatus of picture-taking, and when used for effect transforms it into picture-making. The lens flare filter is said to have been added by Thomas Knoll, who had begun working on his image manipulation program as a PhD candidate at Stanford University in 1987, at the request of his brother John, a technician (and later senior visual effects supervisor) at Industrial Light and Magic, the George Lucas owned specialist effects house. Its first use would be precisely to emulate the photographic apparatus in shots that had been generated entirely in CGI (computer-generated imaging), where it was intended to give the illusion that a camera had been present, so increasing the apparent realism of the shot. The defect became simulated evidence of a fictional camera: a positive value. But soon enough designers recognised a second quality of the lens flare filter. By creating artificial highlights on isolated elements in an image, lens flare gave the illusion of volume to 2D objects, a trick so widely disseminated in the 1990s that it became almost a hallmark of digital images. In this second use, the once temporal character of flares—as evidence that a camera had ‘really’ been present—became instead a tool for producing spatial effects. That is, they are used not for veracity but for fantasy, evidence not of a past presence of cameras, but of a futurity toward which they can propel their audiences.[1]

The history of lens flares gives us a clue about the transitions between analogue and digital in visual media that lie at the heart of this collection. The movement is by no means one-way. For some years, cinematographic use of flare in films like *Lawrence of Arabia* (David Lean, 1962) had evoked extreme states of consciousness, even of divine light, and with it the long history of light in human affairs. We can only speculate about the meanings of light during the millennia preceding the scriptures of Babylon and Judaea. Somewhere around a half a million years ago human ancestors tamed fire (Diamond 1997: 38). Separating light from dark instigates creation in Genesis. Before the *fiat lux*, the Earth was ‘without form and void’. Formlessness, Augustine’s imaginary interlocutor suggests (*Confessions* XII: 21–2; 1961: 297–300), already existed, and it was from this formlessness that God created the world, as later he would create Adam out of a handful of dust. For Erigena in the eighth century, *omnia quae sunt, lumina sunt*: all things that are, are lights. In the *De luce* of the twelfth century divine Robert Grosseteste:

> …light, which is the first form in first created matter, extended itself at the beginning of time, multiplying itself an infinity of times through itself on every side and stretching out equally in every direction, dispersing with itself matter, which it was not able to desert, to such a great mass as the fabric of the cosmos. (Grosseteste, quoted in MacKenzie 1996: 26)

As the analogue to Divine Light (which, Anselm had lamented, was by definition invisible), light pours form from God into creation. While mystics sought to plunge into the darkness of unknowing in order to find their way back to the creator, Grosseteste attributed to light the making of form (space) as well as the governance of the heavens (time) to provide a model scientific and theological understanding of light’s role in the moment of creation. The word ‘light’ can scarcely be uttered without mystical connotations. Understanding light’s connotations of yearning for something more, something beyond is important because these ancient and theological traditions persist; and because they also provide a persistent counterpoint to the rationalist and instrumental modernisation of light, at once universal and deeply historical, whose transitions from one technical form to another are our subject.

Digital light is, as **Stephen Jones** points out in his contribution, an oxymoron: light is photons, particulate and discrete, and therefore always digital. But photons are also waveforms, subject to manipulation in myriad ways. From Fourier transforms to chip design, colour management to the translation of vector graphics into arithmetic displays, light is constantly disciplined to human purposes. The invention of mechanical media is a critical conjuncture in that history. Photography, chronophotography and cinematography form only one part of this disciplining. Photography began life as a print medium, though today it is probably viewed at least as much on screens. In common with the lithographic printing technique that preceded it by a scant few decades, photography was based on a random scatter of molecules, a scatter which would continue into the sprayed phosphors lining the interior of the first television cathode ray tubes. Mass circulation of photographs required a stronger discipline: the half-tone system, which imposed for the first time a grid structuring the grain of the image. Rapid transmission of images, required by a burgeoning press industry, spurred the development of the drum scanner that in turn supplied the cathode ray tube with its operating principle. But this was not enough to control light. From the Trinitron mask to the sub-pixel construction of LCD and plasma screens, the grid became the essential attribute of a standardised system of imaging that constrains the design and fabrication of chips, the software of image-manipulation software, and the fundamental systems for image transmission. This is the genealogy of the raster screen that dominates visual culture from handheld devices to stadium and city plaza screens. As **Sean Cubitt, Carolyn L Kane** and **Cathryn Vasseleu** investigate in their chapters, the control of light forms the foundation of contemporary vision.

In this collection, we bring together high profile figures in diverse but increasingly convergent fields, from academy award-winner and co-founder of Pixar, **Alvy Ray Smith** to feminist philosopher **Cathryn Vasseleu**. Several of the chapters originated in a symposium in Melbourne in 2011 called 'Digital Light: Technique, Technology, Creation'.[2] At that event, practitioners and theorists discussed the relationships between technologies (such as screens, projectors, cameras, networks, camera mounts, objects set up on rostrum cameras, hardware and software) and techniques (the handling, organisation, networking and interfacing of various kinds of electronics, other physical media, people, weather and natural light, among others). This interest in the creative process has flowed into this book, based on the hunch that artists (and curators and software engineers) proceed by working on and with, but also against the capabilities of the media they inherit or, in certain cases, invent. If our first concern is with the historical shaping of light in contemporary culture, our second is how artists, curators and engineers confront and challenge the constraints of increasingly normalised digital visual media. In this regard, current arguments over the shape of codecs (compression-decompression algorithms governing the transmission and display of electronic images) under the HTML5 revision to the language of the World Wide Web need to extend beyond the legal-technical question of proprietary versus open source standards (Holwerda 2010). These codecs are the culmination of a process (now some fifty years old) of pioneering, innovating, standardising and normative agreement around the more fundamental question of the organisation and management of the image—and by extension, perception.[3]

A unique quality of this edited collection is the blending of renowned artists and practitioners with leading scholars to address a single topic: the gains and losses in the transition from analogue to digital media. Even as we argue that the crude binary opposition between digital and analogue stands in need of redefinition, we also propose that fundamental changes in media are symptoms and causes of changes in how we inhabit and experience the world. The book opens with essays on the history and contemporary practice of photography and video, broadening out to essays on the specificity of digital media. The book constantly moves from an artist or practitioner to a historian or scholar, and then to a curator – in this regard we are delighted to have the participation of leading curators of media art, **Christiane Paul** and **Jon Ippolito**. While various art pieces and other content are considered throughout the collection, the focus is specifically on what such pieces suggest about the intersection between technique and technology.[4] That is, the collection emphasises the centrality of use and experimentation in the shaping of technological platforms. Indeed, a recurring theme is how techniques of previous media become technologies, inscribed in both digital software and hardware (Manovich 2001; 2013). Contributions include considerations of image-oriented software and file formats; screen technologies; projection and urban screen surfaces; histories of computer graphics, 2D and 3D image editing software, photography and cinematic art; and transformations of light-based art resulting from the distributed architectures of the internet and the logic of the database.

If we were to single out a moment of maximum technical innovation, it might well be the mid-nineteenth century. Geoffrey Batchen (2006) considers William Henry Fox Talbot's contact prints of lacework, noting that they were featured at soirées at the house of Charles Babbage, inventor of the Difference Engine and forefather of modern computing. In the same room, Babbage had on display an intricate silk portrait of Joseph Marie Jacquard, whose silk loom was driven by the punch cards that the aptly-named Ada Lovelace would use as the first storage device for Babbage's computer. One of Batchen's points is that in many respects photography *has always been digital*. What we can also learn from his analysis is that innovation seems often to derive from social 'scenes', a thesis which resonates with the chapters by **Alvy Ray Smith** and **Stephen Jones**—who, despite their differences, share an understanding of the vital importance of social as well as technological networks in the making of art.

In his remarkable chapter, **Smith** outlines the development of the pixel, downplaying the importance of output devices such as screens, citing their extreme variability and frequent unreliability, their coarse conversion of vector graphics to bitmaps and their inability to display the full gamut of colours existing in virtual state in the computer. Rather than diminish the importance of screen aesthetics, such statements clarify what is at stake in the practical specificity of different screens. This alone reveals the inadequacy of generalized accounts of digital aesthetics. In fact there is no single, universal and coherent digital aesthetics but a plurality of different approaches, deployments and applications. For if, on the one hand, there is a tendency towards software standardisation, on the other there is radical divergence in technique, and radical innovation in technologies and their assemblage into new apparatuses. These developments must drive us to pay far more detailed attention to the materiality of artworks now than in the recent past, when what a film or television programme was made of scarcely signified, since most works were made of the same things and in the same way as all the others. This characteristic dialectic of standardisation and innovation is integral to building the library of techniques and technologies on which artists and others may draw. One of the most intriguing of these is colour management, which Smith relates in an anecdote about his invention of the HSV (hue-saturation-value) colour space. Smith found that while standard RGB (red-green-blue) system allowed the mixing of the optical primaries, an efficient way of coding colour both for the red, green and blue receptors in the human eye, it is basically a two-dimensional space, based on physical optics, not the psychological optics of human perception. HSV, a three-dimensional colour space, allowed users to make a darker orange or a paler red by changing the value (roughly the brightness) of the defining hue and saturation bringing it closer to the intuitive way we mix colours like brown or pink in the physical world, and the experience of painters and designers.

This insight into creative practice in software engineering opens up a whole new set of relations around the figure of the artist–engineer. The history of video and digital art is full of such characters: if anything, the process is accelerating, even as the norms of dominant software seem to become more and more entrenched. Smith's anecdote also suggested that the critical principle—that nothing is forced to be the way it is—holds good also of engineering, and that familiarity with and faith in a particular solution can become an obstacle to both the fluid use of the tool and the development of new tools. In Smith's case, the older colour model restricted users' ability to generate the effects they wanted, guiding them to the limited palette of colour privileged by the model. Creative software, whether produced in the studio or the lab, provides users with tools only the most sophisticated would have realised, in advance, that they needed. In this instance we also learn that the specific networks of devices and people established to make a particular work, in software or moving image art, are not necessarily stable or harmonious. Instability and ephemerality are near-synonyms of twenty-first century media and media arts, driven as they are by the dialectic between standardisation and innovation.

As Tofts argues of Joel Zika's digital photographs, attuning ourselves to digital perception creates a discomfort, out of which other perceptions and other practices can arise. Similarly, Kane's archaeology of artists at Bell Labs in the formative years of computer arts in the early 1960s demonstrates both the value of artistic creation in blue-skies research and the value of research free from governmental and commercial pressure. It also gives due prominence to Lillian Schwartz, one of many women who, since Ada Lovelace, have played a foundational role in the digital media. Intriguingly, it adds to these concerns the discovery of a perceptual rather than physical production of colour at the very beginnings of digital animation, in experimental artworks that produced optical colour from black and white when handled in subtle and swift succession. The old dialectic between Newtonian optics and Goethe's physiological and psychological approach to colour, though resolved earlier for print and dye media some years earlier, remained in play in the 1960s in experiments which would then become normative in the good-enough colour management systems developed for MPEG and related video transmission standards.

Another dialectic emerges in recent writings of Victor Burgin, whose contribution to the conference from which this book derives has been published elsewhere (Burgin 2014). For Burgin, who has always situated his art practice in relation to the media environment, virtual cameras are a logical extension of the photographic and later video works with which he made his name. Burgin retains a serious and methodical eye not only for the technical detail (for instance, where the panoramic camera's footprint appears in a digital cyclorama) but also a sense of the paradoxes inherent in the concept of the single, whole, and gestalt image which can be taken in, as Michael Fried (1992) once argued, in a single glance. One paradox of Fried's unified image is immediately discernible in panoramas, which surely fall under the concept of 'image', but where the image is not apparent or intelligible without spectatorial movement. In digital panoramas, a mobile viewpoint is always implicit. Today, artists are provided with such a mobile viewpoint in the 'virtual camera' embedded in the workspace of their image processing software. The end user or viewer, especially in the age of computer video games, is surely entitled to expect one too. The dialectic between standardisation and innovation also re-emerges in Burgin's work *bir okuma yeri / a place to read* (2010), a virtual fly-through of a once-iconic Istanbul coffee house, now moved to another site and in disrepair. Burgin's piece reconstructs the building as a 3D graphic, using sprites (photographic surfaces applied to 3D objects) derived from photographs of the surviving parts of the building. Burgin has returned the house to its gardens overlooking the Bosphorus, but the result is an uncanny dialectic between the mobile virtual camera and the unmoving photographed background leaves and waters. Burgin made a point of using off-the-shelf software for this project, suggesting that the dialectic of standardisation and innovation can become the principle of a work of art, not least one concerned with the historical process in which they act out their intertwined destinies.

Such dialectical disjunctures motivate, even necessitate, creative acts taking agency back from automated systems and default values. One example in **Christiane Paul's** chapter is SVEN, the Surveillance Video Entertainment Network (http://deprogramming.us/ai), whose project, according to their website, asks 'If computer vision technology can be used to detect when you look like a terrorist, criminal, or other "undesirable"—why not when you look like a rock star?' Using a variant of recognition software, this closed circuit installation tracks people's movements, and matches them with a library of rock star moves and poses, interpolating the CCTV capture with music video footage, encouraging both a voyeuristic fascination turned playful, and a performative attitude to the ubiquitous surveillance of contemporary society. The goals of such practices are not normative and standardisable but dissenting and in almost every instance productive of alternatives. Such works are political in the sense that they create new conditions of possibility. In this sense virtual art produces the virtual, with its root-word *virtus*, strength, or potential, from its root-word power, *potentia*, the ability to act, that is, to make the virtual actual. As the realm of potential, politics is the power to create possibilities, to unpick the actual in order to create events in which matters change. In changing their own materials, the media arts model the construction of possibility, the construction of the open future. Against such virtual capabilities, efforts to de-materialise the supposedly post-medium media are effectively attempts to stay within the consensual, agentless, eventless horizon of normal culture.

Paul's, Jon Ippolito's, Scott McQuire's and **Daniel Palmer**'s chapters touch on the topic of another specific adaptation of a contemporary medium, that of surveillance, and its new form as the mass surveillance of big data through always-on social media portals. They raised the possibility that a distinguishing feature of digital networks is, in David Lyon's (1994) phrase, the 'electronic panopticon'. It is certainly the case that network media provide governments and even more so advertisers with extremely detailed accounts of human behaviour. As Ippolito points out, the metaphor of light as information and truth is integral to surveillance. This metaphor is, we might add, common to both the surveyors and the surveyed—common to those who seek to use it for government or profit as well as those who want to preserve an imagined privacy, a personal space of truth, safe from the powers of surveillance. In this way the question of the specificity of digital as opposed to analogue light is exposed to a further critique: if analogue photography claims a privileged indexical relation to the real, does that anchor it in regimes of surveillance, as John Tagg (1993) argued decades ago? Does the distributed and dispersed nature of digital light free it from that objectivising and instrumental destiny?

Batchen's (2006) argument, that photography is already digital in its earliest beginnings, is echoed by **Jones's** reference to the switch as the fundamental digital tool. In binary computing, switches ensure that electrical current either flows or does not, providing the physical basis for the logical symbols 0 and 1. Reflecting on the quantum nature of physical light, Jones emphasises the concept that light moves in discrete packets ('quanta') or particles. Yet there remains the doubt expressed by **Palmer** and **McQuire** that in their sheer numbers as well as the material aesthetic of devices, images are becoming data, and subject to the same statistical manipulations and instrumental exploitation as the statistical social sciences that emerged contemporaneously with photography in the nineteenth century.

To reduce the complex interactions of digital and analogue into a simple binary opposition is to grasp at essences where none can be relied on. Both the speed of innovation, and the unstable relation between bitmap and vector graphics and displays suggest that there is no essence of the digital to distinguish it from the analogue, and that instead we should be focussing as creators, curators and scholars on the real specificity of the individual work or process we are observing. However, important recent work in software studies (for example, Fuller 2005) disputes the implication that the speed of innovation implies that computing inhabits a world of perpetual progress, arguing that it is shaped by corporate interests rather than a pure logic of computing, and that it drags along with it redundant engineering principles (a familiar example is the persistence of the 1872 Scholes QWERTY typewriter keyboard into the foreseeable future). **Smith**, however, is more optimistic, arguing the opposite case. In any event, the software studies pioneered during the 2000s are beginning to be matched by studies of hardware. In software studies, the once monolithic concept of code is being broken up into discrete fields: codecs, operating systems, algorithms, human-computer interfaces and many more. Hardware studies likewise point us towards the functioning of both individual elements in digital media—chips, amplifiers, displays and so on—and the often unique and frequently evolving assemblies that constitute the working platform for specific projects. The contributions here, notably **Terry Flaxton's** chapter, provide refreshing evidence that the inventiveness and creativity of artists is integral to technical innovation, and to assessing not just cost and efficiency but such other values as the environmental and social consequences of technological 'progress'. It became clear that, faced with such dedicated craft, at the very least, a critic should pay precise and careful attention to the actual workings of moving image media in the twenty-first century, now that the old stabilities of twentieth century technology and institutions are gone. Only in such attentiveness will we avoid both film studies' prematurely assured belief in the specificity of digital versus analogue media, and art theory's equally assured dismissal of medium specificity. If this book contributes to an awareness of these challenges, while also widening awareness of the richness of contemporary digital media arts, it will have done well.

Of course, many visual technologies have faded into oblivion (Huhtamo and Parikka 2011; Acland 2007) and even in our own era of digital invention, once trumpeted technologies like immersive virtual reality and the CD-ROM have passed on to the gnawing criticism of the mice. Already, in the period of the historical avant-gardes, it had become apparent that every advance was all too readily assimilated into the gaping maw of advertising and commercialism, even as the vanguard of art found itself increasingly severed from its audience by the very difficulty of its innovations (Bürger 1984). The same appears to be true of digital media: every technique is open to exploitation by a ravenous machinery devoted to the churn of novelty. Meanwhile, the old stability of film and television passes into a new instability. In some respects, every film is a prototype, but between the early 1930s and the early 1990s, production techniques, management and technologies remained more or less stable. Today, however, each film assembles a unique concatenation of tools, from cameras to software. We are entering a period of extreme specificity, where the choice of editing software or the development of new plug-ins changes the aesthetic of each film that appears. These cycles of rapid invention, depletion and abandonment make any statement about digital aesthetics moot.

Thus the differences between analogue and digital devices can be overstated. When photons trigger the oxidation of silver salts in traditional photography, a by-product is the release of an electron. When photons trigger the optoelectronic response in chip-based cameras, it is the electrons that are captured, but in many respects the chemistry of the two operations is similar. Both require periods of latency, the one awaiting chemical amplification in the developing process, the other the draining of electrons from the chip prior to the next exposure, a feature that makes clear that there is no difference to be sought in the constant visibility of analogue as opposed to digital images. Meanwhile darkroom technicians have manipulated images with all the subtlety and imagination of Photoshop since the 1870s (Przyblyski 1995). Light itself may well be eternal, and its handling historical, but we should not seek radical change where there is none. The movement of history, especially the history of our sensual appreciation of the world, transforms itself far more rarely and slowly than our politics.

At the same time we should not understate the significance of even small adaptations, as the case of lens-flare should remind us. Just as every film is a prototype, so every print of a film or photo is unique, a point made poignantly in John Berger's (1975) anecdote of the treasured torn photograph of his son carried by an illegal migrant worker. Digital images are no less specific, carrying the scars of their successive compressions and decompressions, the bit rot attendant on copying and the vicissitudes of storage, and the unique colour depth and resolution of the screens and printers we use to access them. Such qualities belong to the particularity of making art with light-based technologies, and with the condition of viewing them. In this they bear highly time-bound and materially grounded witness to the conditions of making, circulation and reception, and thus to the fundamental instability of light itself.

There is no absolute rift between the material practice of managing light and its emblematic function as the symbol of divinity, reason or knowledge. There is, however, a dialectic between symbolic and material functions of light played out in every image, a dialectic that comes to the fore in many works of art made with photomechanical and optoelectronic tools. One of the great terrains of this struggle is realism, that mode of practice that seeks in gathered light the evidence of an extra-human reality. It is striking that the schools of speculative realism and object-oriented philosophy, with their insistent ontology of things, should arise in a moment when digital media have ostensibly driven a wedge between the human sensorium and its surrounding world. Where once the existence of divine providence proved the worth, and indeed the existence, of human beings, since the nineteenth century inventions of technical visual media, it is external reality that proves to us that we exist: as the alienated observers, the subjects, of a reality that appears not only to us but for us. With digital media, and in parallel with the development of chemicals sensitive to other wavelengths, the world no longer necessarily appears in images in the same visual form that it would have to a real human observer at the same place and time. To a certain extent, all images today, analogue and digital, have the characteristics of data visualisations, gathering photons or other electromagnetic waveforms from X-ray to ultraviolet, and indeed energy forms that baffle comprehension (Elkins 2008; Galison 1997). What is at stake in the debates over realism is a quarrel over the status not of reality but of the human.

The light of God, of reason, of science, of truth: light's metaphorical power is undimmed by the material practices in which it is embroiled. Whether invoking the brilliance of creation or an impossibly bright technological future, the practice of light in the hands of engineers, artists and producers generally is a constant struggle between boundless, uncontrolled effulgence and the laser-accurate construction of artefacts that illuminate and move their viewers. This collection undertakes a snapshot of this struggle at a moment of profound uncertainty. The chapters that follow enquire, through practice and thinking, practice as thinking and thinking as practice, into the stakes and the opportunities of this extraordinary moment.

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Notes

1. For J.J. Abrams, here discussing his *Star Trek* film, lens flare belongs to the future:

   They were all done live, they weren't added later. There are something about those flares, especially in a movie that can potentially be very sterile and CG and overly controlled. There is something incredibly unpredictable and gorgeous about them. … Our DP would be off camera with this incredibly powerful flashlight aiming it at the lens. It became an art because different lenses required angles, and different proximity to the lens. Sometimes, when we were outside we'd use mirrors. … We had two cameras, so sometimes we had two different spotlight operators. When there was atmosphere in the room, you had to be really careful because you could see the beams. … [It] feels like the future is that bright. (Woerner 2009)

   Abrams' flares takes us back to the affective level of image capture, and to the artful engineering of analogue flares for the live elements in a CG environment, not for veracity but for fantasy, evidence not of a past presence of cameras, but of a futurity toward which they can propel their audiences. These versions of lens-flares indicate that to some extent all photography depicts not only objects but the apparatus of imaging. Archivists well know that a plate or frame carries the evidence of its making, and indeed of the 'archival life' (Fossati 2009) that it has led since the shutter closed. This materiality is integral to the aesthetics of photography, that diverse family of technologies which use light for mark-making (Maynard 1997: 3).

2. Supported by the Australia Research Council Discovery Project, 'Digital Light: Technique, Technology, Creation' was held at The University of Melbourne over two days, 18–19 March 2011. Our speakers were, in alphabetical order, Geoffrey Batchen, Victor Burgin, Steve Dietz, Jon Ippolito, Stephen Jones, Alex Monteith, Christiane Paul, Jeffrey Shaw, Alvy Ray Smith, Van Sowerwine, and Lynette Wallworth. Another account of the event is given in Cubitt et al (2012).

3. In December 2005, Adobe completed its amalgamation with Macromedia, establishing an effective monopoly of industrial 2D design applications. A little over a month later in January 2006, Autodesk, the market-leader in computer-aided design and manufacture, engineering and architectural visualisation software, acquired Maya, the leading 3D graphics package, adding it to the Discreet workflow and effects manager acquired in 1999 and its internally developed and highly successful 3ds

Max 3D software. In 2008 it acquired Softimage, the 3D company co-founded by pioneer immersive VR artist Char Davies. During the same period, Apple's Final Cut suite of video tools has come to dominate the professional market for moving image post-production. Our case is that the carefully matched workspaces and workflow management of these dominant companies, along with their consequent ubiquity in training courses, produces a normalisation of visual digital culture of a depth and reach, which is unprecedented. We do not make any case here about the business models employed. Rather we are concerned that the experience of using Adobe, Autodesk and Apple frames the vast majority of what we think of as creative practice in the second decade of the twenty-first century; and that the practices which they encourage—as all software does, by making some things easier and others harder to achieve—are becoming the ordinary frame through which our visual culture works. Standards such as codecs are agreed, in the main, between hardware, software and telecommunications corporations (although nominally by governments, and in certain key instances by professional bodies of independent engineers). It would be rash to argue that codec standardisation constitutes a conspiracy to blinker our perceptions. On the other hand, it would be naïve to deny that they inform the way we see and feel space, movement and time, the operations of light and colour (Mackenzie 2008; Cubitt 2008). Codecs establish an aesthetic: they are the frames through which we observe and construct the world and our experience of it. Without necessarily meaning to, and left to its own devices, such normalisation would stifle the innovation and creativity it was designed to encourage. Our attempt at the symposium was to investigate how people both invent new media like these; and how they and others then chip away at the normative tendencies inherent in technical innovation processes to create new uses and applications, which in turn may lead to new technologies, and to new modes of inhabiting the world.

4. Such practices do not simply break up the over-confident binary of analogue versus digital: they also problematize art historian Rosalind Krauss' argument regarding the post-medium condition. Krauss' target is the orthodox modernist aesthetics of Clement Greenberg who argued that each medium (painting, sculpture, music, etc.) has its own internal logic, and that the work of the artist was specific to the logic of the medium. Greenberg believed that the painter should do painterly things with paint, not tell stories, or dramatise events. Krauss proposes instead that Greenberg's media are sets of conventions, 'distinct from the material properties of a merely physical object-like support' (Krauss 2000: 27), and that there is therefore no ontological connection between the physical medium—of paint, for example—and the kinds of activity that can or should be undertaken with it. The talismanic place of flatness in Greenberg's account of painting is thus wholly conventional, and painters should feel free to tell stories or make three-dimensional objects, and use any medium in any way they see fit. By inference, for Krauss there is no ontological characteristic defining digital media; there are no distinguishing features separating digital and analogue, nor verbal and visual or any other media. Against Krauss, however, and against the concept of a post-medium condition, we argue that there are indeed ontological properties and unique aesthetics attached to specific devices of both digital and analogue media. These arise with particular choices such as what analogue film stock or what digital codec to employ, and the design of tools shared by both, such as wide-angle or macro lenses.

CHAPTER 1

A Taxonomy and Genealogy of Digital Light-Based Technologies

Alvy Ray Smith

At a recent SIGGRAPH, in receiving the computer graphics organization's highest award, Rob Cook of Pixar said essentially this: 'It took us almost forty years, but we've done it. Now what do we do?' The accomplishment he referred to was this: we had, over the course of four decades or so, managed to extract competent film and video production from sheer computation. Add to this the more-or-less simultaneous desk-top publishing revolution and later the video game explosion and you have it: the creation of pictures—including moving pictures and interactive ones—from mere bits, the replacement of all earlier picturing media by just one, that of computation. I suggest this accomplishment is what the editors of this book call 'digital light'. We tended to call the process, especially late in the game, the 'digital convergence'. As a participant and observer throughout those forty years, I hope to assist in the project of understanding and criticizing digital light-based technologies and techniques. I use my own experiences as a backbone and timeline from which I hang the genealogy of the concepts involved.

An additional anecdote serves as a teaser for a topic I address later in the paper. At another awards ceremony, that of the technical Academy awards in 1998, Richard Dreyfus, the great actor, was presiding. (Aside: The digital Academy awards are just like the artistic Academy awards shown on the television every year—the same glamour, the same actors, the same gowns and tuxedos and jewels and limos, also in Hollywood. They are just considered not very interesting to the American public, so are not broadcast. The actors contribute their precious time to this event in homage to the technologies they know underlie their field. It was Richard Dreyfus who had the honours that year.) He paid the usual lip service to the joining together of the artistically creative and the technically creative to produce the cinema, but then added: 'We will march together into the next century.' Then looking directly at our table, he said, 'Note that I said *together* you people from Pixar, who made *Toy Story*.' A nervous titter spread through the audience, especially the actors, the fear so expressed being the one that computers would take over the job of actors any day now. Although Rob Cook said we had done it, perhaps the holy grail is still out there: simulation of live action, in particular of human actors. I return to this problem later: Have we yet simulated human actors? Is live action about to be encompassed? Has it already?

Another topic I emphasize is the dangers of 'lock in'. In the early exciting days of new software, with the urge for primacy at our backs, we were prone to make quick decisions about fundamental issues that might later haunt us. The easy idea that looked so good at first blush got locked in by so much code written atop it, and then could not be removed. One of these I discuss is the rectilinear image. It is so wired into the software systems of the world that it is hard to think otherwise. The notion of non-rectilinear images, or sprites, is there to be exploited but it might be too late. A consequence of this lock-in is that there exists two completely distinct interfaces for dealing with discrete pictures vs. continuous pictures. Another lock-in that occurred, despite our last-minute efforts to dislodge the error, is interlaced video in the national high-definition television standard, HDTV.

And another set of ideas are the self-criticisms: How many of the technological developments were mistakes or dead-ends? Or were they? What did we think we were doing at any one time?

A final theme I emphasize is the lack of artists breaking the bonds of the models we early technologists defined for digital light and what we might do to inspire them to break those bonds.

Computation and Moore's Law

Let me first pay tribute to the 'fluid', so to speak, that makes this discussion possible. The notion of computation is a new one really, dating essentially from about 1936. There is the quibble about Babbage and Lady Lovelace, but I'll ignore that pip, much as historians of America skip over Leif Erickson's arrival in North America about 1000 AD in favour of Columbus in 1492. There is no continuous intellectual thread that descends from the earlier events. In 1936 the notion of universal computation, effective procedure, or recursive function, etc. was derived by the likes of Church, Turing, Post, Kleene and others. Beginning particularly with 'Saint' Turing, there has been an explosive growth of the notion of computability into actual machines that realize the universal computation controlled by software to designate which of the infinity of computations is to be universally simulated. Digital light is a subset of this world, and appeared early in the history of computation (at least as early as 1947 that I have been able to ascertain). The background to this discussion is explosive, exponential growth.

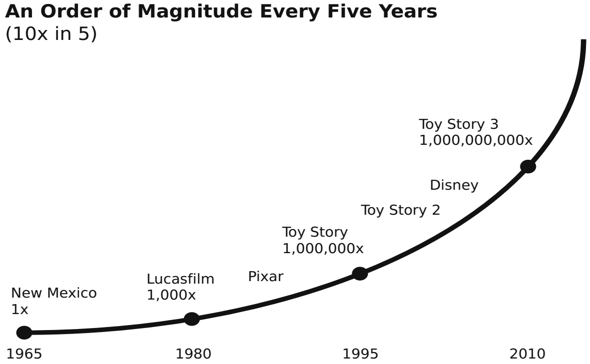

Figure 1. Moore's Law in meaningful form. Courtesy of Alvy Ray Smith.

The fact that the growth from 1936 has been not just firm and steady, but explosive and revolutionary, is captured by Moore's so-called Law. By reworking the math just a little, one gets a useful and intuitive statement of Moore's Law: *Anything good about computation gets better by an order of magnitude every five years*. Or '10x in 5'. So, taking 1965 as about the time when computers began being realized with integrated circuits (to which Moore is restricted), we have been riding Moore's Law for 45 years. 45 years divides by 5 years into 9 units—9 cranks of the Moore's Law handle—so Moore's Law predicts a 10^9 improvement in computers between 1965 and 2010. That's an improvement by a factor of a billion (1,000 millions, see fig. 1). So a kilobyte of memory in 1965 would be $10^3*10^9 = 10^{12}$ bytes today, or 1 petabyte. Pixar measures its memory in petabytes today. I tracked the development of computations devoted to computer graphics for many years and it did follow Moore's Law almost exactly. I'll give examples later. Ed Catmull and I used the 'Law' for years to make business decisions—it was that regular. Importantly for our discussion here, the digital revolution has been revolutionary—and is still fully underway. This is the force field underlying everything about which I speak.

I like to say: *The computer is the most malleable tool ever invented*. It is our goal—and my constant challenge to artists, the explorers at the edges of our culture—to understand what the medium of computation really is, as opposed to what we technologists (mostly) pulled out of the technology in our mad rush to the digital convergence and the first computer-generated major motion picture.

The *amuse-bouche* for this section is: 'There are no 0s and 1s in a computer'. Some people find this surprising, thinking that computers are somehow based on numbers. They are not, anymore than DNA is based on words from the alphabet A, C, G and T. Sir Charles Sherrington's famous 1942 quote about the human cortex could as well describe a computer's changing patterns of energy: 'an enchanted loom where millions of flashing shuttles weave a dissolving pattern.' Back in the early days about all we could interpret from the crude computational power was numbers. In these marvellous times, digital light is an exciting interpretation.

Taxonomy

I have found the following three distinctions—stated as tenets—of high usefulness in understanding picturing, or digital light, and problem-solving in that domain.

1. *The continuous is fundamentally distinct from the discrete.*
2. *Creative space is fundamentally distinct from display space.*
3. *The interactive is fundamentally distinct from the passive.*

These distinctions are orthogonal to one another and dictate a 3D space in which technologies of digital light conveniently fall. I will give several examples after discussing the tenets and their meaning.

1. Continuous vs. Discrete

This distinction may seem obvious, but my experience is that most people, even my colleagues, often have not appreciated its full impact.

There are two branches of digital light corresponding to the distinction. The first is geometry-based and the other is sampling-based. I will assume that everyone knows geometry and its heroes, such as Pythagoras and Descartes. I suspect far fewer know the all-powerful Sampling Theorem—the basis of sampling-based digital light technology—and its heroes, such as Shannon (see fig. 2).

The Sampling Theorem underlies all digital light technologies. I could devote this entire paper to its wonders. But it has to suffice here that you understand that it exists, is well-understood, and is the glue that holds the two worlds, discrete and continuous together. Let me limn the Sampling Theorem in its most basic form: A continuous space of an infinity of points can be accurately represented by a discrete space of countable points IF the points (pixels) are chosen correctly. And, furthermore, one can get from the discrete points back to the continuity they represent accurately IF the reconstruction is done correctly, and the Sampling Theorem tells how this is done. In other words, IF ONE IS CAREFUL, a discrete set of point samples is equivalent to a continuous infinity of points. Otherwise none of our digital displays would work. We think we are looking at a continuum when we watch digital light. To a large degree the history of computer graphics is the learning of how to cross back and forth across the discrete/continuous border defined by the Sampling Theorem. It is so fundamentally important that I think it should be taught in every school to every child. It defines the modern world.

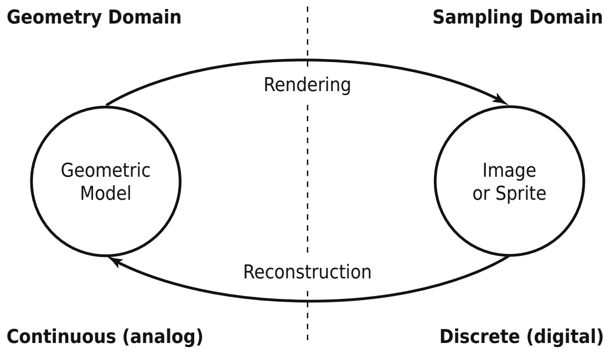

Figure 2. Geometry vs. sampling. Courtesy of Alvy Ray Smith.

The computer animation of Pixar is geometry-based. The sets and characters are defined with geometrical elements, assumed to move continuously through time. But consider digital photography. There is no geometry at all involved. The ‘real world’ is sampled with an array of sensors on a rectilinear grid.

The two worlds have different terminologies and different software applications. An early pair of apps makes the point: Apple’s MacDraw was geometry-based; its MacPaint was sampling-based. Today Adobe has Illustrator for 2D geometry and Photoshop for 2D sampling. The interfaces of the two worlds are completely different. You can’t know how to operate Photoshop by learning how to operate Illustrator. (I think this is a ‘locked-in’ error, by the way, and is not necessary.)

In the early days the two branches held side-by-side conferences. As a new assistant professor at NYU straight out of graduate school, my first chairman was Herb Freeman. He had established the first learned journal in the field, called *Journal of Computer Graphics and Image Processing*.

The history of ‘computer graphics’ often fails to acknowledge the simultaneous development of the sampling side. For example, I’ve often heard that Ivan Sutherland was the father of computer graphics, but I can’t see how that could be true. He came along a decade or more after the earliest computer picturings that I know of—on a Williams tube (32 x 32 memory array of dots on a CRT type tube)—which is sampled, not geometric, and appeared in the late 1940s and early 1950s. Ivan did important early work in the 1960s in interactive geometry-based digital light, but there was simultaneous work going on in sampled imaging, such as the Tiros and Nimbus weather satellite imagery.

That people often confuse the two spaces is usually evident around the notion of a pixel. Many, many think that a pixel is a little geometric square, *but it is not!* It is a sample at a discrete point. It has no geometry (unless one wants to think of the point where the sample is located as its geometry, or alternatively that the reconstruction filter required by the Sampling Theorem supplies the geometry).

The two worlds are often mixed, and deliberately so. For example, classic film cinema has a 2D spatial continuum (the film frame) and a sampled (24 frames per second) temporal dimension. Another way the worlds are mixed is via rendering techniques such as texture mapping, where a sampled image is mapped to a geometric surface.

Why is there such a confusion? Because the geometric world cannot be seen. It is abstract. The only way to see geometry is to render it into a sampled image that can be displayed. So both approaches lead to pixels. Which brings me to the second major distinction.

2. Creative Space vs. Display Space

One might think that this is just a variation on the Continuous vs. Discrete distinction, but the case is more subtle than that. I will start by explaining where the distinction comes from and then extend it to digital light in general.

Classic 3D computer animation is done as follows: A 3D stage set is modelled in abstract geometry, with cones, spheres, cylinders, lines, points, splines, patches, etc. Articulated models serving as the characters are similarly modelled. Animation is provided by controlling the continuous paths along which parts of the models move. As already mentioned, such a scene cannot be seen, so an abstract camera is modelled too. It is positioned in the 3D space and aimed at the portion of the scene which one wishes to see. Then what the camera sees is rendered into a frame. This means exactly that the geometric scene is sampled, according to the Sampling Theorem, into a rectilinear grid of samples, called pixels. In summary, the creation is done in creative space, which is continuous and abstract, but viewing is done in display space, which is sampled and discrete, dictated by the display technology being used.

What is interesting is that there is no reason that once we have distinguished creative space from display space in 3D computer graphics, we don't apply the distinction more generally to all digital light technologies. I think this is profound. It goes against what we've always thought to be the case: That creative space and display space are the same thing. In the old days it was true. Consider a painter and his canvas: creative space IS display space. Consider sculpting a block of marble: creative space is display space. Consider Photoshop: Creative space is display space (and one of the reasons I think the wrong idea has been locked into this pervasive program). Why not have 2D imaging apps that have a camera viewing an infinite discrete creative space? Why not indeed!

Many of the problems I've encountered in digital light boil down to confusion about which space one is in, continuous vs. sampled, or creative vs. display. Once the distinctions are called, then the problems usually resolve themselves. There is a well-known theory, by the way, that instructs us how to convert from continuous space to the discrete space and back. It is a direct consequence of the Sampling Theorem, but this is not the place to go into it.

A case in point is the Visible Human Project at the National Library of Medicine. I was a member of the board of the Library when the Visible Human was proposed. The board was stumped on how to approach the problem of digitizing a human body completely in 3D (with 3D samples that is) and extracting models from the data with which to train surgeons. I was able to convince them that the two problems were in different spaces. The digitization problem was a sampling problem. Solve it first, then use sampling theory to derive geometric models from the samples as a second step. This is exactly what we proceeded to do and surgeons are now training on simulators derived from the sampled human male and female.

A case where we failed was the national high-definition TV specification. The problem here was that we computer people came late to the game. The power and the money—always the controlling forces in Washington—had conspired to define HDTV as a digitized form of the old-fashioned analogue TV standard of the 1950s. In a last-minute battle, we managed to include progressive scanning in the standard but were unsuccessful in ridding it of the old interlaced scanning format of the 1950s. Progressive scanning is what every computer monitor uses, one line after another is painted down the screen in quick succession. The old interlaced idea—one that no longer made any sense in the digital world—was to paint all the even lines first then return to the top and paint all the odd lines. The ugly interlaced standard was locked into the standard, and has cost the consumer dearly.

3. Interactive vs. Passive

Here is the gist of the third tenet. It is obvious that interactivity is distinct from passivity, but as opposed to the other two distinctions I've drawn—continuous vs.

discrete, and creative vs. display spaces—the interactivity vs. passivity dimension is really an axis, not a hard distinction. That is, there are varieties of interaction, from none at all (passivity) to full ‘thumb candy’ exercised by adolescent—and probably not so adolescent—boys with their point-of-view killer video games. The purpose of this tenet is to include under the tent of ‘digital light’ such things as aircraft simulators (games for big boys), video games (for little boys), caves (fully immersive environments), paint programs, even windows-based UI’s on ordinary computers. And even a PowerPoint slide show creation—which is highly interactive—and its quite dumb display. The sequence of clicks in a PowerPoint display is interactive, not passive. Furthermore, it is discrete. So continuous vs. discrete applies to interactivity as well. Despite the different levels of interactivity that are possible in digital light technologies, I am going to use the simple distinction interactive vs. passive as the basis of a taxonomy in this paper.

4. Examples

The three tenets define three orthogonal axes which divide up a taxonomical space into eight regions. It is simple to drop all forms of digital (or analogue) light experiences into the appropriate region, as shown by these examples. Note that I actually catalogue via each dimension of each technology, and distinguish spatial from temporal dimensions by using the + convention—for example, (2+1)D means 2 spatial and 1 temporal dimensions.

Display space examples

Film photo	2D	2 continuous	passive
Digital photo	2D	2 discrete	passive
Device interface	2D	2 discrete	interactive
Classic movie	(2+1)D	2 continuous + 1 discrete	passive
Digital movie	(2+1)D	3 discrete	passive
Video game	(2+1)D	3 discrete	interactive
Volumetric image	3D	3 discrete	passive
Volumetric movie	(3+1)D	4 discrete	passive

Creative space examples

Oil painting	2D	2 continuous	interactive
Paint program	2D	2 discrete	interactive
Drawing program	2D	2 continuous	interactive
Illustrator file	2D	2 continuous	passive
3D modelling program	3D	3 continuous	interactive
Marble sculpting	3D	3 continuous	interactive
Volumetric sculpting	3D	3 discrete	interactive
Animation program	(3+1)D	4 continuous	interactive

5. What About Displays?

I do not use display device differences as part of the taxonomy. For example, whether display is via transmission or via reflection is not used, or whether the display uses additive colour or subtractive colour. Why is that?

We certainly spent years mastering different display devices, but in retrospect that was part of the old, pre-convergence era. We had to master film, video and ink on paper as truly different display media. We had calligraphic displays and raster displays. We mastered the technical details of each display, its colorimetry, its standards, its nonlinearities, etc. For example, I spent years mastering the art of reading and writing bits with colour lasers to and from trilayer Kodak colour movie film. But the digital convergence to digital light has made all those distinctions irrelevant—or at least of greatly diminished importance—in a way that I will now try to explain.

Part of the idea of convergence to a single medium, namely the computational medium, was the relegation of display device quirkiness to the edges of our world. The creative world is linear, whether it be discrete or continuous. We could so define this because it was abstract. We always knew that once the 'rubber met the road'—the actual display in the real world of our creations—the nastiness of the actual devices would have to be taken into account. Real display devices are never linear, and they are seldom nonlinear in the same way. As usual we did not originally know that we were dividing the world this way—originally we often confused the details of display with details of the underlying creation.

So here is the trick: the actual details of a particular display device technology is relegated in the computer-mediated pipeline to the last possible position in the pipeline, in what's typically called a 'device driver'. Device drivers are difficult to write and there is a different one for every monitor on every phone, on every game, on every computer, and a different one for every projector, and for every plotter and printer, whether to ink on paper or film or photographic paper. It is the device driver that handles the transformation (nonlinear in general) from the inner linear creative world to the actual hardware device. Here is where the notion of subtractive vs. additive, aspect ratio, gamma correction, etc. is handled. This is where the gamut of the colours of the inner world is transformed into the gamut of the display device. Here is where each manufacturer's technical choices are accounted for.

The same thing happens on input (or should): the nonlinearities of the input scanner, for example, are straightened out before the bits are passed to the main pipeline.

Note that display *devices* are not to be confused with display *space*. Each display space can map to an infinity of display devices (of course, there isn't an infinity, but the number and variety is always increasing). It is an important trick that we sever the creation of images, which should work universally, from the nasty details of display devices, which are specific, local, and vary with manufacturing advances. (An aside: An underappreciated accomplishment of Microsoft, who does not make hardware (games excepted), is that its software works on thousands of different devices made by hundreds of different manufacturers.)

It is a mistake, in this view, that nonlinearity, such as gamma correction, be included in creative space, whether discrete or continuous. But, unfortunately, the notion is locked in as an artefact in some modern very popular applications.

There is a problem in the world of display devices that should bother us more than it has so far. It has to do with the misrepresentation of the colours of one world by the colours of the displays we choose to use. I have in mind the real world and the human colour gamut therein—all the colours that most humans can see in the world. No display device can replicate this gamut, so whenever the real world is represented with digital light, its gamut has been reduced. Another example: Google has announced a project of putting famous art galleries online. This sounds great, but I am amazed that the colour issue is never raised. The colours of the oils and acrylics and watercolours, etc. in the galleries are not correctly reproduced by the digital light devices. The surprise is that we humans are so tolerant of the colour loss inherent in digital light as realized so far.

Genealogy

I am a scholarly genealogist, in the human family history meaning of that term. In its strictest interpretation it is the tracking of the path the genes take. I shall use it here to mean the tracking of the germ of an idea.

The 'families' I shall track are those defined by the taxonomy. Plus hardware and devices. This is not the way it happened, of course. The taxonomy is my current understanding of what we did, mapped back onto our actual activities.

I have organized this paper along a timeline defined by my career through several centres of graphics development. This naturally cannot encompass the entire history of development of digital light, but the centres I mention (in this order)—Xerox PARC (Palo Alto Research Center), University of Utah, NYIT (New York Institute of Technology), Lucasfilm and Pixar—happen to be the places that did much of the development themselves, and are hence representative of the whole field.

Because there were so many developments I shall skim over many of them, perhaps simply listing them, and concentrate on the profound turning points. There were many dead-ends pursued during the time period I concentrate on (1965–95). We spun our wheels in many areas (2D geometric inbetweening). We devoted too much time to specific displays (analogue video). We devoted too much time to speeding-up programs when a simple wait for Moore's Law to crank would have done the job (tint fill optimization). We often didn't really understand what we were doing, but in the context of knowing exactly what we were headed for (the first completely computer-generated feature film). We worked under models inspired by 'reality', but not bound by it. Our theoretical understanding of what we were doing was often fuzzy and only now being understood (for example, premultiplied alpha). We've already allowed several bad ideas to be locked in (rectilinear images, interlaced TV, two conflicting UI models for pictures). Many of the things we started were never finished and just begging to be done (what ever happened to computer painting?). There are still some very tough problems to solve (live action with human actors). I will attempt to revisit some of these along the way.

1. New Mexico, Our Outback (Moore's Law 1X, 1965)

I start the Moore's Law 'clock' at about 1965 for two reasons: (1) Gordon Moore himself came up with the 'Law' for semiconductor chips which first began to be used about then. (2) I made my first computer graphic in Las Cruces, New Mexico, then (actually 1964), a plot of a 2D equiangular spiral for a Nimbus weather satellite antenna (2D, continuous, passive).

There were other early computer graphics happening about this time other places: Ivan Sutherland's Sketchpad (2D, continuous, interactive, with discrete display!) in 1962–63; DAC-1 (2D/3D, continuous, interactive) in 1959–64 at General Motors; and Bezier patches (3D, continuous, passive). On the image processing front (2D, discrete, passive), there were systems for processing early weather satellite imagery. For example, that from the TIROS, the first weather satellite in 1960.

In relation to New Mexico: there was the development of the Bresenham algorithm in 1965, considered the earliest 'rendering' algorithm. It converted straight geometric lines to point samples (pixels) on a grid (2D, continuous, passive; rendered into 2D, discrete, passive). The surprise to me was to learn, years later, that Bresenham and I came from the same hometown, Clovis, New Mexico. Our moms knew each other.

The display devices were varied at this time: I used a line plotter for the antenna, Bresenham a point plotter, Sketchpad a raster display (which surprised me to learn) but calligraphic output (line plotter), DAC-1 a scanning raster display (it would scan a pencil drawing and represent it internally as a set of cubic polynomials—i.e., a spline); commands could push the design into 3D, output to a milling machine or plotter. Bezier patches were defined mathematically and may have been used to drive a Renault automobile surface milling machine, which would have been therefore the 'display'.

One of the earliest computer graphics animation that I've heard of was a wine bottle pouring wine into a wine glass, on the spots of a Williams tube. I was told about this animation by an old IBM engineer who had witnessed it in 1952. The Williams tube was the 32 x 32 memory device developed originally for the early Manchester computer in the late 1940s. So the graphics was quite crude. And it was discrete! I have still pictures from the Manchester Williams tube from 1947, the earliest graphics that I know.

Pinscreen animation (Alexandre Alexeieff and wife Claire Parker, and Norman McLaren) at the National Film Board of Canada in 1960s and 1970s was discrete. (Their first was in 1933!). Orson Welles' *The Trial* in 1962 featured a pinscreen title sequence (not animated). But *Hunger,* by Peter Foldes (1974), also at the NFB, was geometric and continuous. (It was nominated for an Academy Award.)

Edward Zajec and Michael Noll made early computer films (early 60s). Chuck Csuri made early computer art (MOMA purchased one for its permanent collection, in 1968). Ken Knowlton also contributed in the 1960s. The book *Cybernetic Serendipity* brought a lot of early computer art into focus for me, in about 1968.

Spacewars, perhaps the first widespread 'video' game, was invented at MIT in 1961.

Herb Freeman, who was to become my chairman at NYU in 1969–74, had started in computer graphics in 1961, and had students working on quadric surfaces, for example, when I was an assistant professor working for him. One of his students (Loutrel, 1966) solved the hidden-line problem, which was big at the time, and has simply disappeared as a problem now. He and Azriel Rosenfeld started, in 1970, the *Journal of Computer Graphics and Image Processing*, later the *Journal of Computer Vision, Graphics, and Image Processing.* The point is that this division of the digital light world existed early on.

Lee Harrison's Scanimate, an attempt at video animation, came to my careful attention early on; he and Dick Shoup (see PARC, below) were friends. As did Ron Baecker's Genesys animation system (which I saw in the late 1960s at NYU; later Ron and I would briefly share a house in Redwood City, California).

2. Xerox PARC (10X, 1970–75)

It is well-known that the personal computer, as we now understand it, was being invented at PARC during this time. For digital light in particular, the following ideas were being pursued:

Colour paint program (SuperPaint, by Dick Shoup), 2D, discrete, interactive, creative space was display space. The colourmap made 8 bits capable of producing 16 mega colours (but only 256 at a time).

Colour transforms (RGB to HSV, by me). This was really a cheap trick. I spent years explaining that, despite its names, such as 'hue', it had nothing truly to do with human colour perception, other than a chance resemblance. The exercise did excite a long scholarly interest in me for colour science.

Window-based UI, 2D, discrete, monochrome, interactive, creative space different from display space (the underlying creative metaphor being the desktop covered with papers).

Antialiased geometry (Dick Shoup and Bob Flegal), both passive and interactive, 2D, monochrome, creative space was geometric, so continuous, display space was discrete.

In 2D geometry space: a text and graphics description language (i.e., a 2D modelling language) was in development with John Warnock and Chuck Geschke, eventually leading to PostScript and then to Adobe.

Interestingly, William Newman, who with Bob Sproull wrote the first computer graphics text, was there. I say interesting because we colour guys essentially lost out to the black-and-white guys in Xerox's infamous decision to not pursue the personal computer and to pursue black-and-white rather than colour. Even more interesting, William Newman was son of Max Newman who with Turing programmed the first computer in Manchester in the 1940s.

I do not include in my essay analogue computer art. For example, John Whitney (Sr.) used bombsight 'computers' to drive a flying spot scanner onto film to make early interesting films in the 1960s. I am strict about observing the 'digital' attribute.

3. University of Utah (1X–10X, 1965–75)

Although I never worked at the University of Utah or at the Evans & Sutherland Corporation, I feel justified in including them as if I did. This is because I made an early pilgrimage to Salt Lake City that figured into my future, and that future included many people who came from the University of Utah hotbed and much equipment (and some people too) from the Evans & Sutherland Corporation. Most important of these, of course, was Ed Catmull, who cofounded Pixar with me. Here is the list of people:

Christine Barton, Malcolm Blanchard, Jim Blinn, Ed Catmull, Jim Clark, Elaine Cohen, Ephraim Cohen, Steve Coons, Frank Crow, *Gary Demos,* Dave Evans, Henry Fuchs, Henri Gouraud, *Jim Kajiya, Alan Kay, Martin Newell,* Fred Parke, Bui-Tuong Phong, Rich Riesenfeld, Garland Stern, Tom Stockham, Ivan Sutherland, *John Warnock*, Lance Williams. (The names in small caps were with me at NYIT. The names in italics directly affected my career in other ways: Alan Kay helped me get hired at PARC; Martin Newell helped me get hired at NYIT (it is his famous teapot that became the icon of computer graphics); John Warnock tried several times to either buy my technology or hire me at Adobe; Gary Demos was my archrival (with John Whitney Jr. at Information International Inc. and then Digital Productions) and then later an admired collaborator with me in the HDTV battles in Washington, D.C.; Jim Kajiya and Jim Blinn worked with me at Microsoft, Jim being the only other Graphics Fellow there; and I roomed with Jim Blinn during my short stay at the Jet Propulsion Lab of Cal Tech between NYIT and Lucasfilm, while working on the Carl Sagan *Cosmos* television series.)

Utah was an early powerhouse of 3D geometry-based computer graphics. Amazingly they at first did not have a real-time output device. They would generate files of pixels from their rendering algorithms and submit these to a person whose job was to convert each file into a photograph, done using a flying spot monitor and a camera devoted to it. So these people worked in creative space entirely (except for the final files, rendered to display space).

Among the many accomplishments of this group are these (where I use ‘shaping’ and ‘shading’ to describe two aspects of modelling in creative space, one defining geometry, the other appearance):

In shaping: patches, B-splines, patch subdivision. In shading: Gouraud shading, Phong shading, texture mapping. In rendering (that is, the conversion from continuous creative geometry to discrete display samples): hidden surface elimination algorithms in continuous space, Z buffer hidden surface elimination in discrete space. In 3D geometry-based (continuous) animation: Ed Catmull digitized his own hand, covered the mesh so created with simply shaded polygons, and flew a virtual camera up the fingers which moved. This short test eventually made it into the movie *Future World*. And Fred Parke animated a face and lip-synced the dialog.

Antialiasing: Tom Stockham, in the digital audio world (he got famous for analyzing the 18-minute gap in Richard Nixon’s Watergate tapes), taught antialiasing to Utah students. Frank Crow wrote a thesis on it applied to computer graphics, but all the students imbibed the theory and brought it with them to NYIT. (It is worth noting that digital audio was part of our world at NYIT and Lucasfilm. The problems it was solving were the same as the ones we were solving visually.)

Hardware: Jim Kajiya helped design the first RAM-based framebuffer for the Evans & Sutherland (E&S) Corporation. NYIT was to be the first customer of this crucial device (now known as a graphics card). Gary Demos was a logic designer for E&S hardware (I first noticed him because only his logic diagram was projected from a 3D model!).

4. New York Tech (100X, 1975–80)

The number of things pursued at NYIT was vast and varied. I list here some of them which seem most pertinent to the genealogy of digital light, emphasizing those I believe were most profound and lasting. But first let me mention the context for these developments.

The NYIT campus was heavenly, located on grand estates on the fabulous North Shore of Long Island, the location of F. Scott Fitzgerald's *The Great Gatsby* (1925). It was owned by our first patron, Dr. Alexander Schure, or Uncle Alex as we called him. There was a full animation studio on site, of the classic 2D cel animation variety, with some of the early animators, like 'Johnny Gent', who animated for Max Fleischer. Alex intended for us to make him money by (he thought) getting rid of the labour in the animation process. For our purposes, we were funded better than anybody else in the world, and thereby got access to RGB before anybody else (the first RGB framebuffer cost Uncle Alex the equivalent of today's $1,000,000, for a (merely) video resolution picture memory of 24 bits per pixel). NYIT became a Mecca for those interested in computer graphics. We got a master's lesson in how animation was actually done, an education in logistics as much as the craft itself. Everything we did was aimed at animation, broadly interpreted (so including TV commercials, spots and video animation). New York City was 8 miles away, so I became immersed in the nascent video art world there. Artist Ed Emshwiller lived on Long Island and eventually found us, becoming my mentor; we created *Sunstone* together, my proudest artistic achievement (and now included in MOMA's permanent collection).

The hardware and software context cannot be ignored although strictly speaking it had nothing to do with the genealogy of ideas. We had the first VAX minicomputer. We had the first RGB framebuffers. We had a full video editing facility in a nearby mansion. We had some of the earliest access to Unix and its programming language C. We usually got what we asked for. We also had a digital audio team.

Back to the genealogy:

2D display space: RGB everything, paint3 (for background art in 2D animations), tint till (for opaquing in 2D simulation of cel animation), scan'n'paint (the 2D simulation of cel animation), real-time video frame-grabbing (part of the scan'n'paint system). And the most profound of all: the alpha channel, and matting. (I contend that the profundity of alpha is still not appreciated.) A frame language, utilizing the Unix shell, was designed for creating arbitrary combinations of 2D functions, used mostly for complex matting sequences, but also for repositioning, shadowing, sharpening, reversal, colourmapping, etc. 100s of art pieces created by various members of the team. Ed and I developed the '2-pass' scanline-oriented transformation process (which actually required reconstruction of pixels into continuous space, transformation, then resampling into display space).

2D continuous space: tilings, splines, Tween (Ed's attempt to do cel animation geometrically, which essentially failed after major effort; 3D geometric animation is easier than 2D!).

(2+1)D discrete space (all 3 dimensions discrete): *Measure for Measure*, done almost completely with scan'n'paint. Dissolves, wipes, and fades (dozens of them). A video recording language was developed to drive frame-by-frame editing (i.e., the first frame-accurate digital video editor) of such pieces as *Measure for Measure*, and many art pieces and demo pieces generated by the team. Some of the earliest TV commercials, spots, logos, and rock videos were created this way. *Sunstone* was mostly generated this way.

(2+1)D space, 2 continuous (space), 1 discrete (time): We generated continuous, analogue video masters from the dissolves, wipes, and fades mentioned above, which were then used to control real-time analogue videotape dissolves, wipes, and fades. David DiFrancesco mastered film recording from digital images.

3D continuous space: 3D 'soids' (ellipsoids), patches, modelling language (e.g., I was able to model skeleton hands, skinned by Ed's Utah hand for a Siggraph cover). Ed solved the hidden surface problem of geometric entities at the pixel level—that is, if the world was divided

> into little squares, each of which would map to a single pixel at rendering time, his algorithm solved the hidden surface problem in each such little square (it was working with him on this when we came up with the alpha channel concept).
>
> (3+1)D continuous space: I created Texas (Texture Applying System) which modelled rectangular geometric flats in arbitrary relative position in 3-space, with virtual cameras for display, and with animation controls. Each flat had an image mapped to it—that is, was texture-mapped.
>
> Rendering: Lance developed shadow maps. Texas used the 2-pass algorithm to render transformed, animated flats from the texture given for each. Jim Blinn visited for several months, and did bump mapping while he was there.
>
> Display devices mastered: digital film recorder, NTSC television, PAL television, video tape recorders, RGB broadcast-quality monitors, rhodium coated videodisc recorder, single-shot camera from monitor, and all the gamma nonlinearities and colour gamuts involved. Also, text monitors, E&S Picture System calligraphic displays, Tektronix green-on-green text and line-drawing displays.

Also, many tablets devices were tested, including pressure-sensitive ones (which all failed). The mouse was not interesting to us.

5. Lucasfilm (1000X, 1980–85)

The context at Lucasfilm was of course the movie business, and for us the special effects house, Industrial Light & Magic. George Lucas had hired us principally (only, it turned out) to build three instruments for him: a digital optical printer (which we realized with the Pixar Image Computer and laser film reader/writer), a digital video editor (which we realized as EditDroid), and a digital audio synthesizer (which we realized as SoundDroid). It came as a surprise to us that George did not seem to want us in his movies, but not until I had assembled a world-class team to do just that. We had our first go at the big screen in *Star Trek II: The Wrath of Khan* (via Paramount, not Lucasfilm). THEN George put us in *The Return of the Jedi*. And then Steven Spielberg, George's friend put us in *The Young Sherlock Holmes*.

One of the biggest events for our group (that would become Pixar) was the hiring of John Lasseter as our animator, and my directing him in his first piece, *The*

Adventures of André & Wally B. A surprise was to discover that George did not believe we could do animation. Another big event for the Graphics Group was the deal made with Disney to digitize their cel animation process. We, of course, had done the first steps already, at NYIT with scan'n'paint. The result was CAPS (Computer Animation Production System), a very successful project that bonded us with Disney, finally.

Then George and Marcia Lucas divorced, leaving him without enough money for us. At that point Ed and I decided to spinout our group as a separate company, Pixar. We spent a lot of time finding funding for the new venture.

At the very beginning of the Lucasfilm era, we emphasized that no code was to be written that did not correctly antialias. I created 'No Jaggies' T-shirts to make this requirement known, internally and externally.

Now back to the genealogy:

> 2D display space: RGBA everything, paint4, premultiplied alpha and matte algebra, advanced 2-pass algorithms.
>
> 2D continuous space: tapered splines (which was actually a rendering technique from continuous into discrete space).
>
> (2+1)D discrete space (all 3 dimensions discrete): digital video editing project (not aimed at broadcast video, but at cinema), CAPS.
>
> 3D and (3+1)D continuous space: modelling language, articulated variables, fractals, graftals, particle systems, matrix package (for splines, for scene transformations, for transformations at joints of articulated models), view package (for virtual camera control of perspective and other view parameters), motion blur control.
>
> Rendering: motion blur realization, materials properties, universal solution for antialiasing, Reyes = Renders Everything You Ever Saw, micropolygons.
>
> Display device mastered: Laser to trilayer film printer (built by David DiFrancesco). Also a laser reader of film.

It should also be mentioned that Ed Catmull was asked by George to start a games group, which he did. Although this was not our main interest, it was definitely a strong move in the interactive world.

6. Pixar (10,000X, 1985–90)

The context at Pixar was, at first, hardware and keeping our company alive until Moore's Law cranked another turn or two. The Pixar Image Computer was the world's fastest discrete 2D machine for a short time. We did image processing on it. Textured terrains. Hydrodynamic flows. Material stress analysis. Medical imaging. The animation group continued to produce better and better shorts, as Moore's Law gave us power and more features were packed into the software. CAPS was successful (*Rescuers Down Under* in 1990 was arguably the first completely computer-generated movie, except the artwork wasn't done digitally). Then in 1991 Disney came to us and proposed that they produce a computer-animated film and that we produce it. That was, of course, *Toy Story* (1995). The story of Pixar since then has been one of movie after movie, all successful. Many techniques for handling ever more complex productions were created. Growing pains for a company, from 200 to 1200 persons. Building rendering farms of very increasing computational power and memory size. I departed in 1992 in a spinoff, Altamira, which I then sold to Microsoft. I departed when I knew that John Lasseter would be comfortable in working with Disney (who had fired him) and that *Toy Story* was a go. Altamira was devoted to 2D and (2+1)D discrete space, an image composition application featuring sprites—i.e., non-rectilinear images.

Toy Story 2 was released in 1999. I performed tests with my friends at Pixar that compared frames from *Toy Story* to frames from *Toy Story 2*, but both executed on the same hardware. During this crank of Moore's Law (almost) the number of polygons doubled approximately (from 3–17 megapolys to 4–39 megapolys per frame), but total rendering time increased by approximately Moore's Law's prediction. So as Moore's Law 'gave us' an order of magnitude more computation power, the complexity of each frame increased accordingly. The same goes on now.

Back to the genealogy:

> 2D display space: All software for the Pixar Image Computer, sprites, IceMan language.
>
> (2+1)D discrete space (all 3 dimensions discrete): CAPS development.
>
> 3D discrete space (all three spatial): volumetric imaging (I become trustee at the National Library of Medicine and help create the Visible Human).

3D and (3+1)D continuous space: modelling and animation improvements, much of it to adapt to the needs of the animators, lighting control, ever increasing lighting model detail, fur, hair, cloth, skin, etc.

Rendering: the Renderman shading language (perhaps the most profound development at Pixar after solution of universal antialiasing).

7. Now and the Future (1,000,000,000X, 2010–20)

Context: *Toy Story 3* was released in 2010, when Moore's Law hit 1 million X. There was enough horsepower to generate it in '3D' (which, of course, is not 3D creative space, but 3D display space). This means the movie was computed twice, once for each eye. Importantly, in 2009 *The Strange Case of Benjamin Button* was released, featuring the first convincingly rendered human actor, 'driven' by Brad Pitt.

We are not proposing that the computer do the acting. We haven't a clue how to do that. But we are proposing that the computer will convincingly render the avatar of the actor. That was proved by *Benjamin Button*. I looked at it eagle-eyed and just could not tell what parts were computer generated.

Actors and animators are the same kind of talent. Pixar hires animators by how well they act. The difference is that actors animate their own bodies, convincing us that those bodies belong to someone completely different than the actor, and to someone different for each role. An animator convinces us that a stack of geometric polygons is alive, and conscious, and feeling and thinking. The difference so far has been the quality of the avatar. Pixar has elected to keep the avatar cartoonish. Other producers have made it monstrous, and others have made them animals. These are all tricks for avoiding the very difficult task of creating a convincing human.

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SIGGRAPH’*nn* represents the (year) 19*nn* or 20*nn* SIGGRAPH annual conference, that of the special interest group on computer graphics of the Association for Computing Machinery (ACM).

Most of Alvy Ray Smith’s papers and memos are available on <alvyray.com>.

CHAPTER 2

Coherent Light from Projectors to Fibre Optics

Sean Cubitt

Recent influential accounts of technology recount the history of technical development as a tale of components assembled and reassembled in increasingly complex orders, overdetermined by larger systems of energy production, manufacture and transport that shape them, to the point of autonomy from human invention (for example, see Stiegler 1998: 76–78). This kind of account is less true of modern visual technologies, at least until these underwent a major change in the nineteenth century. The archaeological record shows that the light of flames was the only source of nocturnal illumination up to and including the invention of the gas mantle in the 1790s; and that hardly any major changes marked the history of lighting by oil lamps (in warmer) and tallow or wax candles and rushlights (in colder climates) over a period of millennia. It was only with the invention of the light bulb, and even more importantly Edison's central electrical power generation system, that the modern system of visual technologies began to form the kind of system envisaged by Stiegler. In fact, electric light was not the only visual technology system to come into existence in the late nineteenth century: cinema, redeploying older entertainment systems and optical devices together with new road and rail transportation, would produce a complex new method for the distribution and display of visual arts. More recently, television must be seen technically as the offspring of the pre-existing systems of wire telegraphy and radio transmission. Yet, later still, laser and fibre optics would bring a third major new system into existence.

Flame produces soot as a by-product, and, in the large quantities used for public entertainments, combustion lighting tends to produce a lot of heat that uses up the available oxygen and encourages swooning. Heat is an entropic quality in electrical as in mechanical systems: waste energy, with no usable formal properties, radiates and dissipates. This is also a typical quality of light itself in the form of flame: as the heat vaporises molecules of the fuel, and by-products of combustion fall away, free radicals are excited sufficiently to shed excess energy in the form of photons. The colour of flame is a function of the kinds of material vaporised, a chemistry which remained ill-understood until very recent times, even after the notably late invention of photometry and colorimetry (Johnston 2001), part of the rush of invention in the nineteenth century (O'Dea 1958; Schivelbusch 1988; Bowers 1998). The latter seems to have been led by the rise of mass spectacle, as much as by the requirements of extending the working day in manufacturing, the former seen especially in the new department stores which also hastened the development of plate glass, and advertising, especially in the extremely popular World's Fairs (Benedict 1983; Geppert 2010). At the time, the expenditure of waste energy must have seemed at the time an integral part of the spectacle of modernity. In the twentieth century, however, the increasingly integrated systems of electrical power and electric light gradually brought this waste under the managerial ideology of efficiency. In this process other visual technologies took a lead, starting with the cinema.

While it is important to understand the originality of these changes, it is also important to understand their continuities with older technologies. This chapter develops an argument that certain technologies, especially glass and mirrors, have been and remain key to both analogue and digital management of artificial light, while also arguing that visual media have played a central role in the evolutions of related technologies such as glass and mirrors. At the same time, however, the surprisingly short history of electrical light allows us a privileged view of how a new invention rapidly installs itself as a new system, with all that implies for standardisation and bias towards innovation—improved efficiencies and applications—rather than invention—the more startling emergence of wholly new techniques.

Projectionists

Although its roots lie in far older visual displays, such as the magic lantern, it is only with the Lumière Brothers' first public display at the Salon Indien in 1896, that cinema emerges as the first real employer of light as a projection medium. Not long afterwards, projected and reflected light was largely overtaken as a general display medium for public space. The Moore tubes of 1902 and the first neon tubes from about 1910 followed the use of arrays of bulbs as the medium of choice for display. Yet, projection did retain some place in public space in the form of arc-lamp based searchlights. These were displayed at World’s Fairs from the 1880s, but their extensive use in military applications would only start with the development of aerial warfare in the 1930s and during World War II. Cinema projection provided the test bed for these new forms of organised light. The heart of the projection system is the lamp. For a considerable period, well into the 1960s and in some cinemas for far longer, tending the lamp was a full time occupation, since the illumination source forcing light through the tiny 35mm aperture onto theatrical screens metres across was a carbon arc, which burns away in use and has to be adjusted constantly to keep the spark brilliant and steady. The xenon arc lamps which came in from the late 1950s were far easier to manage, but the change-over system of projection—where two projectors alternate, with reels of between ten and twenty minutes following one another—and the use of rectifiers to increase the voltage sufficiently to power the big lamps, meant that projection was a concentrated and technical profession. The introduction of ‘cakestands’, holding a whole program (features, trailers, ads, music, even cues to open and close curtains and adjust tabs) and of clockwork and later digital towers (allowing one or several films to be programmed across multiple screens from a single control point) changed much of the old craft, but the principle of controlling light carefully and of forcing it through a small area onto the screen with the minimum flicker and shudder remains a constant of cinematic projection.

Piercingly bright for the operator, arc and xenon lamps have to be observed—when checking for flicker or wear—through the kind of dense glass plate used by welders. But even this much light is a drop in the ocean when it is asked to illuminate a whole wall, metres distant. Every photon is precious. The lamps radiate light in all directions. Heat- and light-absorbent linings for the lamp-housing reduce scatter, which would interfere with the clarity of the projected image. A condensing (parabolic) mirror gathers the radiating light from the rear of the housing and orients it towards the business end of the projector, passing it through two condensing semi-convex lenses to concentrate the beam before it travels to the gate where the filmstrip passes through it. Here the light passes through two compound lenses on either side of the filmstrip. The first of these lenses lies between the lamp and the filmstrip, focusing the light as close to parallel as possible so that the whole of the frame is illuminated with as even a light as possible. The second lens diverges the parallel rays at the precise angle required by the architecture of the cinema theatre, refocusing them to illuminate the screen ahead as evenly as possible.

The light then travels to the screen. The small rectangle of piercingly bright light spreads out across as much as fifty metres of space (the 'throw') to illuminate the screen: from 35 millimetres to, in the case of the Odeon Marble Arch (the biggest screen in the UK prior to the 1997 conversion to multiplex), a screen nine metres high and twenty-three metres across. This magnification also magnifies any flaws in the physical filmstrip. Between the filmstrip and the second lens lies the aperture plate, which cuts off the outer edges of the frame, typically 'noisy' where the black framelines intrude on the image, and commonly the zone where microphone booms and other unwanted elements will appear if not masked out. Tabs—black curtains drawn up to the edge of the projected image on screen—and the black surrounds of the screen itself cut off the outer edges, while the cinema screen is perforated to allow sound through and to diminish the effects of air-conditioning on the hanging screen. Even with the silvering used to increase the amount of light reflected, the screen cannot help bouncing light all around the theatre. The amount of light reaching the eyes of the audience is thus far less than that emitted in the lamp-house. The critical sites for minimising the loss are the lenses.

Lenses

A simple lens throws a circular image, one in which, the more the centre is in focus, the poorer the focus towards the edges (and vice versa). The simple convex lens—like those found in magnifying glasses—produces a number of such aberrations: coma (stretching circles into ovals due to focusing different rays from a single object at different distances); spherical aberration (corona effects produced by light travelling different distances through the lens and so being differently refracted); a variety of colour fringing effects ('chromatic aberrations'), caused by different wavelengths travelling at different speeds through the glass; and many others, some shared with the lenses in human eyes. These aberrations are all the worse in standard window glass, which also has a distinct blue-green cast. Projector lenses (like those in use in cameras) employ far purer optical glass. Reducing impurities, however, does not remove all these imperfections, which stem from the curvature required to expand or narrow the focus of light passing through them. To correct them calls for secondary elements to be added to the lens: coatings, and additional glass elements, for the most part also lenses, including some glued together and some which use the air between elements as an operating part of the system. Lens complexity depends on the aperture in relation to the curvature of the prime lens. A wide-angle lens with a large aperture requires more correction, as more of the light passing through the distorting outer area of the lens reaches the light-sensitive areas of the frame. Wide-angle lenses thus require up to fifteen elements to correct and re-correct the distortions the prime lens produces, while a long lens with a small aperture may require as few as two.

As well as air, the differences between types of optical glass are critical. Flint glass has a high lead content and prismatic characteristics, which neatly match and cancel out those of crown glass, a mediaeval invention so called for its shape when blown. In the 1880s the Jena-based company Zeiss began manufacturing new kinds of glass for scientific instruments, which they then commercialised for the photographic market. Paul Rudolph, their master designer, pioneered the practice of gluing different elements, and different glass types, together to form compound elements. He later combined converging with diverging lenses to reduce or amend aberrations. These two techniques proved invaluable, especially in conquering chromatic aberrations. This requires combining a biconvex (positive or converging, with two convex surfaces) lens boasting a high refractive index with a biconcave (negative or diverging, with two concave surfaces) element which refracts the incoming light much less. Zeiss maintained their leading position in lens design after World War I by pioneering the use of anti-reflective coatings to improve the quantities of light travelling to the filmstrip. These were needed because the increasingly complex compound lenses absorbed or reflected an increasing proportion of the available light away from the film surface (Kingslake 1989).

Recent glass and plastic lenses include rare minerals like lanthanides and caesium to control the refractive index and transparency. The interior of the barrel housing the glass elements must also be of the deepest black available. In January 2008 a Rensselaer Polytechnic team announced the blackest material known to science, a forest of carbon nanotubules that absorbed all but 0.045% of visible light (Yang et al. 2008). The first use proposed for it was lining light-sensitive scientific instruments, and cameras. Such contemporary moves to improve lens and housing performance continue to build on century-old design principles. Today, from the moment the lens cap comes off to the retinal wall of audiences' eyes, the aim is to retain the greatest density of information possible, even though we know that, analogue or electronic, the image degrades from the moment light enters the lens of the camera to the moment it leaves the lens of a projector.

The rich history and complexity of lens design is for the most part hidden from users today. This is in part an effect of the 'black-boxing' that occurs as mechanical devices become digital, passing beyond the skills base of the average tinkerer. Yet lens design, except in the use of exotic minerals in glass making, has not fundamentally changed in the transition from analogue to digital photography in the twenty-first century. While Eastman Kodak's 1900 Box Brownie may be said to have started the process of black-boxing for consumer snapshots, professional and pro-am photographers kept their interest in the technological properties of the medium at least as late as the 1950s, when advertising for anastigmatic lenses came to an end (despite the fact that all lenses had been anastigmatic for some decades by this point). The inference of the adverts was that photographers understood the optics of astigmatism (the aberration which makes it impossible to have both horizontal and vertical lines align on the focal plane) and appreciated the engineering required—a minimum of three elements and two types of glass—to correct it. After the 1950s, lens design became even more a matter of branding, the domain of white-coated boffins, removed not only from the snap-shooter but for the most part from the professional photographer as well. The choices for those most intricately involved in the technical aspects of the profession—cinematographers for example—were restricted to the *choice* of lens, or in extreme instances like that of Stan Brakhage, who rejected lenses altogether for *Song XII* (1965), choosing to film through the open aperture of a super 8 camera with no lens mounted (Wees 1992; Davenport 2001–02). In Brakhage and related practices we confront art premised on revolt against the universality and invisibility of the grammar of the lens. We should consider the options for such a revolt today, as we migrate to digital projection. The engineering marvels we encounter should not distract us from increasingly relentless standardization, in direct continuity with the history of analogue projection.

Digital Light Programming

DLP (digital light programming), developed by Texas Instruments for digital projection, is the most common form of projection today. DLP projectors use metal halide arc lamps, either in mercury vapour or in inert noble gas tubes, with infra-red reflective surfaces to concentrate heat at the tips of the arc itself, where the intense light is produced, advancing on but sharing the same fundamental design as the old carbon and xenon arc lamps. This lamp is designed to produce light at as many visible wavelengths as possible; that is, to give the closest technically available approximation to pure white. The light is channelled towards the truly digital element of the projector, the DMD or Digital Micromirror Device. This is a chip (expensive models have three) containing up to 1.3 million digitally controlled mirrors (in 1280 x 1024 resolution machines), each of them 16 micrometers square, or about a fifth of the diameter of a human hair. The micromirrors, which fit on a DMD chip no bigger than the traditional photographic 35mm frame, are capable of ten degrees tilt, with 16 millisecond response times, to reflect light towards or away from the projector lens. 'Black' translates as a turn away from the lens; grey is produced by flickering at a higher rate than the basic 16 milliseconds as appropriate to the shade desired. The unused light has to be trapped, in a 'light sink', using the same kinds of light-absorbent materials as camera housings, so that it does not bounce around the chamber, interfering with the information content of the video signal. It is only after this reflection that we can speak accurately of 'optically programmed light'.

Single chip DLP projectors use rotating filters to send three versions of an image—red, green and blue—to the screen, a process which clearly makes resolution and registration extremely important if fringing and other artefacts are to be avoided. Filters also reduce the amount of light that actually gets to the screen. Thus the kinds of lens technologies we have mentioned are still vitally important to digital projection, and still control and shape the grammar of the projected image. High-end projectors use one DMD chip each for red, green and blue signals, using additive colour to make white, and absence to make black. Later models add a CMYK (cyan, magenta, yellow and black) 'secondary colour' wheel to provide a richer gamut of the subtractive as well as additive colours. These operate on the same basic principles as the tri-pack film used in cinema projection, where the light passes through successive layers of filters to garner the red, green and blue components of the image, corresponding roughly to the three types of cone cells in the human retina. Unlike cinema film, however, video signals (both analogue and digital) do not pass through a negative stage whose dyes are in the complementary subtractive colours, a process more or less universal in cinema after the 1930s, when experimenters with additive colour realised that the addition required far more light than subtractive colour. In all systems, however, colour requires more light than monochrome, which expresses only the 'value' or brightness of a scene. On the other hand, both types of projection find it hard to produce true blacks, given the scattering of light from adjacent illuminated areas of the screen, as well as other light sources in the theatrical environment, such as exit and guide lights. Such matters are of paramount concern in gallery spaces not designed for projection, where the design and building of light-traps is as challenging an aspect of curation as is the management of sound overflow from one installation into the space of another.

Apparent black—an optical impression of blackness as opposed to the actual absence of light—is easier to achieve when the image is denser. The proximity of

DMD cells to one another is far greater than the proximity of pixels in LCD (liquid crystal display) screens, giving a correspondingly greater apparent density. The additional brightness which, by contrast, makes blacks appear deeper, is also needed to make up for the difference in intensity between light sources (like the LED [light-emitting diode] backlights on LCD screens) and merely reflected light: reflection, no matter how finely silvered the screen may be, always absorbs some light, and reflects more away from the perceiver, so is always somewhat less efficient in maximising the light. Maximising the amount of light coming from the lamp itself is crucial.

The same can be said of liquid crystal on silicon (LCOS) projectors, which split the white light from the halide arc prismatically, reflecting it from red, green and blue panels as desired, as in DLP projectors either sequentially (in single-chip projectors, relying on optical mixing in the viewer's eye) or simultaneously (in the more expensive three-chip versions). LCOS pixels are formed from the same liquid crystals used in LCD screens, which untwist when charged to allow polarised light to pass through them, or absorb the light when uncharged, so appearing dark. In LCOS, crystals which respond to red green and blue signals are mounted on highly reflective panels. Older and cheaper LCD projectors do not reflect the light but beam it through LCD panels, in the process losing a great deal of the precious light generated by the metal-halide arc. In all three designs, LCD, DLP and LCOS, focusing the light of the arc lamp towards the projection lens is absolutely critical, and in all three the compound projection lens is tuned to produce a standard cinematic grammar. Even where the projection is at domestic scale, as in rear-projection TVs which provided the first market for LCOS chips, the competition with LCD and plasma screens for brightness and apparent contrast means that maximising the efficient use of light at all stages is a crucial concern.

Much of the old work of the projectionist is automated in digital projectors. Gone are the hand-cut aperture plates of yore. It is impossible to get inside the lens assembly, and the trimming of the cinematic frame to remove the edge effects is done in DVD mastering and digital telecine. Levels of illumination and colour are controlled with a remote rather than by adjusting the lamp, housing and lenses; and a critical issue in projection, key-stoning (the trapezoidal result of distortion caused when the edge of image closest to the projector is shorter than that furthest away) is automatically reset by the projector without interference—in fact getting a digital projector to give anything but a four-square image can require some inventive interaction. The democratisation of projection, as is so often the case with visual technologies, has come at the cost of a loss of control over the operations of the characteristic devices we use.

From Searchlights to Laser

The searchlight, the cine-projector's sibling, makes evident a quality of projected light that would make it foundational for twenty-first century media. The earliest searchlights made their appearance at the Chicago World's Columbian Exposition of 1893, and appear to have derived some of their inspiration from lighthouses, that is as beacons to announce a presence, rather than as defensive devices for identifying attackers. A few even employed the very beautiful Fresnel lenses developed in the lighthouse world to concentrate the light, often of oil lamps, into parallel beams that would be visible in foul weather from ships some distance away. Searchlights also seem to have a heritage in focused lanterns used in navigating the often misty riverways of the Thames and Mississippi among other commercial waterways, as well as early attempts to militarise light in the Franco–Prussian War. The purpose of the condenser lens and the parabolic mirror shared by searchlights and cine-projectors is to produce parallel beams, with as little scatter as possible, making maximum use of the light from the lamp. In the cinema, this is at the service of the flickerless, pin-registered clarity and brilliance of an image. In the searchlight, in its early use in commercial spectacle, the content was either the object illuminated—as in floodlighting today—or the weightless architecture of light brought into miraculous being over World's Fairs and similar spectacular sites. This process meets its apogee in the intangible architecture of the Zeppelin Field devised by Albert Speer for the Nuremberg rallies, where the projected light attains the purity of light without image, light as sheer spatial organisation. In Speer's searchlight architecture the technology is tripped back to its formal essence, light as the contentless medium which Marshall McLuhan proposed in *Understanding Media*—'The electric light is pure information. It is a medium without a message' (McLuhan 1964: 15).

Lyotard, in his 'Acinéma' (1978), painted the apotheosis of cinema in the wasteful, playful figure of a child playing with matches, a trope which echoes the solar excess of Bataille's *Accursed Share* (1988). Its actual apotheosis is the light pillars of the Nuremberg rallies: the symmetry and order of classicism subordinated to the aesthetics of total command. In a chapter titled 'Architectural Megalomania', Speer offers his own description:

The actual effect far surpassed anything I had imagined. The hundred and thirty sharply defined beams, placed around the field at intervals of forty feet, were visible to a height of twenty to twenty-five thousand feet, after which they merged into a general glow. The feeling was of a vast room, with the beams serving as mighty pillars of infinitely high outer walls. Now and then a cloud moved through this wreath of lights, bringing an element of surrealistic surprise to the mirage. I imagine that this 'cathedral of light' was the first luminescent architecture of this type, and for me it remains not only my most beautiful architectural concept but, after its fashion, the only one which has survived the passage of time. (Speer 1970: 59)

The conditions of Nazi Germany were certainly unusual, and it would be wrong to ascribe to the history of light a narrowly fascist ideology. Speer preferred a psychological account of Hitler's personal investment: confronted by plans for immense projects like the Zeppelin Field, 'Possibly at such moments he actually felt a certain awe; but it was directed toward himself and toward his own greatness, which he himself had willed and projected into eternity', further noting that, '[s]uch tendencies, and the urge to demonstrate one's strength on all occasions, are characteristic of quickly acquired wealth' (Speer 1970: 69). The increasing devotion to the control of light should instead be read, as we may understand Nazism itself, as an expression of an underlying demand for order which emerges both in the cult of efficiency (especially remarkable in the early twentieth century cult of the engineer) and in the *rappel à l'ordre* of populist politics in the 1920s and 1930s. Perhaps because the military technology of searchlights was tactically separated from the electrical grid, it was able, very early, to aspire to the autonomous development of the technology of illumination in its purest form, and provide the model for the commercial applications which developed rapidly afterwards.

Some decades later, lasers would take over as the medium of choice for dynamic urban architectures and new spectacular forms such as stadium rock. Light Amplification by Stimulated Emission of Radiation, laser, relies on controlling the random production of light typical of the sun, flames and incandescent lamps. Like flame and incandescent lights, lasers use the photons released by the movement of electrons between states of excitement. Unlike flame or incandescent bulbs, lasers use a form of amplification of light by passing a beam repeatedly between mirrors through a 'gain medium' (usually crystal, glass, metal or inert gases or semiconductors, but also liquids in so-called dye-lasers). In the gain medium the photons, released when electrons from atoms of the same composition and state of excitement release their energy, scatter as usual, but the paired mirrors encourage those photons travelling along their axis to continue bouncing to and fro, as they do so spurring other electrons to release their energy in the same wavelength as the one triggering the release. Thus the laser produces increasing numbers of photons of identical wavelengths tuned to one another ('in phase'). Once this reaches a critical quantity, photons travelling along the axis pass through the half-silvered mirror at one end in the form of an intensely focused beam whose wavelength is a function of the distance between the two 'resonating' mirrors.

Different types of laser use a variety of materials, but it is worth recalling that the first optical lasers—the invention remains the subject of intense patent wars and claims for priority (Hecht 2005)—particularly the ruby laser, work in response to a source of incoherent light, which provides the initial excitation for the electrons. The typical source then, and in many contemporary designs, is a flash tube, electrical devices designed to produce extremely bright, extremely white light for a brief period. The pulsing light may have helped shape the staccato conception of laser as a digital medium. One characteristic links it back to the history of cine-projection: the fact that such light pumps are arc-lights, like the traditional cinema projector, a technology shared in single-use flash tubes (in the UK flash bulb) in photography. Between the single flash photography, the steady but mechanically interrupted light of a projector lamp, and the pulsing flash tubes of laser light pumps there is a direct continuity, one which however leads towards a more radical form of discontinuity than that evidenced by the interruption of intermittent motion and the shutter in the cinema.

Lyotard's figure of pure cinema as the child playing with matches was already inaccurate of cine-projection. In laser technology we can see, however, why Lyotard wanted to hang his hat on the theory of cinema as excess. As distinct from lasers, the controlled light of projectors is nonetheless a playful, human-scaled thing, like fire. In flame, free ions release photons as what even physicists call excess energy; something similar happens in the old arc lamps. In lasers, that excess is cancelled out by the controlled build-up of excitation and release, and the even more authoritarian harmonisation of phase and wavelength. We might see Lyotard then as a late Romantic, continuing a tradition stretching back from Bataille to Nietzsche, Rimbaud, Blake and Hölderlin, in which agony and ecstasy pose themselves as escape routes from the advance of scientific rationalism and industrial standardisation. In critiquing the burning match model of cinema, we must be careful to avoid the simplistic opposition of excess and instrumental reason: spectacular waste is integral to consumer capitalism, even if it is in the carefully managed form of a carnival circumscribed by discipline and anxiety, and formally orchestrated within arithmetic technologies like the laser. At the same time, we should recognise both that artists like Rafael Lozano-Hemmer have found extraordinary ways to release a democratic and liberatory potential in laser technologies, and that the child fascinated by flame is only in danger because she is learning how to control the light. It is not control itself, but the normative power of universal standardisation around a meticulously arithmetic technology that requires our analysis.

Light pumps produce very intense brief bursts of wide-spectrum incandescent light. The laser turns these into coherent waveforms, which differ from incandescent light not only because their colour can be controlled, but because their common phase means that they can function as a carrier wave in the manner of radio transmissions, whose modulations are decipherable as signals. Intensely focused light could be used in many scientific instruments (for example to get an accurate measure of the distance from the Earth to the Moon), and in such applications as laser surgery. Perhaps its most popular instantiation is in laser light shows, which now provide a common device for architectural displays, as found in Las Vegas and other urban entertainment and retail complexes. The proximity to Speer's searchlights scarcely needs underlining. However, it is the signalling capacity of lasers that became the most significant aspect in transitions to digital media. Experiments with airborne transmissions proved too unpredictable for messaging: rain and fog dissipated the signal, even though they made the laser visible in air, the same dissipation as strategically employed in Speer's searchlights. Laser pointers and range-finders as well as entertainment uses would continue the open-air technique in laser technology. Meanwhile Cold War experimenters in the USA, UK, Russia and Japan converged on getting coherent light from lasers to travel through flexible glass pipes.

Fibre optics work on the principle of total internal reflection, a phenomenon already observed and reproduced as a scientific amusement in 1844 (Hecht 1999: 13–14). Here the light from an arc lamp is guided through the curving fall of a jet of water, the light waves bouncing from the inner walls of the jet, reflecting back from the meniscus. An 1881 patent suggested using the same phenomenon in glass rods to deliver light throughout an apartment building (Hecht 1999: 23). Coherent waveforms were much better guided between surfaces when a glass rod of one refractive index was fused inside a glass tube of another, and the two heated and extruded to a fine filament. Already in use over short distances for gastroscopy in the 1950s, the nascent technology was wedded to lasers in the 1960s (Hecht 1999: 88–91). In a return to cinematic technologies, confocal lenses—deliberate 'imperfections' functioning as series of lenses keeping light away from the walls of the fibre—guide and thus amplify the transmission of light through fibre: indeed Brian O'Brien, lead scientist at American Optical, who perfected a number of key fibre optic technologies, took a sabbatical from lasers to work on the Todd-AO widescreen cinema system. The proximity of cinema and fibre optic telecommunications reminds us that the control of light is a constant goal of the emergent visual technologies of the twentieth and twenty-first centuries. In both, the varying qualities of different types of glass are crucial, as are the use of 'doping' to create specific optical qualities, the integration of gaseous states of matter between solids, and the critical development of pulsed lasers which matches the interrupted motion of cine-projection, giving both a common control over the temporal as well as spatial dimensions of beams of light.

The period of invention ended in the 1970s. Further developments improved the strength of signals over intercontinental distances, cheapened the manufacture of bundled cores of fibre, lessened the energy cost of interfacing, sending and receiving equipment with the optical elements, and increased the speed and reliability of transmission in line with the massive infrastructural investment required to make fibre optics the core infrastructure of global digital systems in the twenty-first century. These technologies were in part a response to the threat of nuclear war in the 1950s and 1960s (optics are not damaged in the same way as electromagnetic equipment in the magnetic pulse of an atomic explosion), but were also the heirs of the extraordinary flowering of glass technologies in the nineteenth and twentieth centuries, a field which at first glance seems quite discrete from the development of mechanical and later electronic imaging, but which on reflection is clearly integral to both. The common theme is control, the production and distribution of what laser engineers refer to as coherent light.

To a certain extent, the title of the present work, *Digital Light*, is a misnomer, in that light is light, and only becomes digital in the process of a systematisation which drives through the history of projection and fibre optics. The base principle here is less electronic than formal: the use of enumerable units to parcel out the otherwise formless omnidirectionality of light. The irony is that in one remarkable account of light given by the eleventh century divine Robert Grosseteste, light gave form to the created universe. Taking the Hebrew of *Genesis* literally, Grosseteste argued that the phrase 'without form and void' implied that the world prior to Creation was a formless mass of stuff. God's first words, 'Let there be light', divided the formless: night and day, land and ocean, spreading form by distinguishing, in the double sense of dividing and making visible (Crombie 1953). But the divine radiance is of another quality to the ordering brought about by digitisation. The wave-particle argument that began at the time of Huygens and Newton (Dijksterhuis 2004) helped engender a new interest in glass as a scientific instrument for the analysis of light, and foreshadowed the partition which would overcome it at the end of the nineteenth century. At this stage, the quantum physicists, despite their allegiance to the dual form of wave and particle, opened the doors to technologies which have depended on the unit of light as a measurable, accountable and manageable quantity.

Division, initially undertaken in the shutter mechanism of cine-projection, is integrated into electronics in rough form in the cathode ray tube, increasingly controlled in liquid-crystal displays, and today controlled with extreme efficiency in a fibre optic infrastructure whose norms are governed by the standards promulgated by the International Electrotechnical Commission (IEC), the International Organisation for Standardisation (ISO) and the International Telecommunication Union (ITU). These bodies, mostly originating as professional associations of engineers charged with ensuring the interoperability of national systems, organised their membership on national lines, especially when ITU and ISO entered the United Nations system. More recently, they have been increasingly influenced by corporations (for example, see MacLean 2003), including manufacturers, distributors and retailers, as well as by the competition regulation of the World Trade Organisation. Virulent patent wars have broken out over visual technologies in the wireless world (Reuters 2011), suggesting that under the guise of competition, there has been a powerful convergence of technical specifications in the field. Predominant in the global long-distance market and increasingly in fibre-to-the-door initiatives, the fibre optics backbone of telecommunications networks, has been successfully preserved from such disruptions by the need to ensure a globally functional network from which all carriers, suppliers and equipment manufacturers benefit. Under the auspices of both standards bodies and the Fiber Optics Association, which provides certification and training worldwide, increasing convergence has moved the industry away from the invention phase of the 1970s towards a far more restrained and constrained phase of relatively minor innovation, as the technology has become the essential structural medium of planetary communications. In this, fibre optics regulation follows the lead of the Academy of Motion Picture Arts and Sciences, which, in addition to the Oscar ceremonies, is responsible for standardisation in the film industry since the late 1920s, and the adoption of the Academy Standard screen aspect ratio. Standardising the number of sprockets per frame, the motor speed of projectors, the dimensions of the vision and soundtrack areas of the filmstrip, and of course aspect ratios made the global export of films a major industry in the wake of World War I (Thompson 1985). The comparison between the wireless and fibre optic industries demonstrates that, while there is still competitive advantage to be had in the as yet to mature mobile market, in the infrastructural domain, whether telecommunications or cinema, standardisation is a goal rapidly sought out and carefully guarded.

The specificity of the unit measure is less obviously important, save as a logical extension of digital communications, which depend on the distinction between open and closed channels, whether the flow being controlled is of electrons or photons. The distinction, read in machine code as that between ones and zeros, is however less clear in engineering terms, where the residual refracted light of a previous 'one' will always interfere with the present 'zero': absolute dark, like the absolute absence of electrical charge, is a physical possibility only under extreme laboratory conditions. To produce the effect of difference, which is the crucial feature of digital information, requires careful manipulation of the material form of the wave constituting the passage of a photon through the fibre. The waveforms carrying digital signals through fibre optics share their shape with more and more universally standardising transmission protocols within as well as between devices. As information is promulgated between components of a digital system—from the photosensitive chip of a camera to its storage, for example, or from that store to the editing applications that will work on it, and again from there to encoding for transmission or disc-recording—whether as light or voltage, data is encoded in waves which are tailored for the on–off intelligence of the digital system in the form of the 'square wave'.

Viewed at the microscopic scales at which they occur in fibre, it is clear that square waves are not abrupt switches between on and off but exhibit steep ramps between the on and off states. This quality is eliminated from the reading end of the process, which consistently sees only one of two states. To ensure this happens, the communication must be damped to eliminate 'ringing' effects, in which the remnants of the natural sine wave reverberate with each other and the materials through which they pass. As so often in digital media, the process involves automated approximation algorithms. In this case the Fourier transform used to approximate the two signal strengths to zero and one is itself responsible for the discontinuities which produce the 'ringing' effect, which in turn must be damped to maintain the illusion of a unitary sequence.

If the unit-counting of digital media matches the commodity economy, which maintains the discreteness of each item traded, the approximations match the managerialist or bio-political mode of contemporary power. As we all know, transmission does not differentiate between different content types, only between units (packets, pixels); neither in packet switching nor in routers. All that is important to the TCP/IP (transmission control protocol / internet protocol) suite, and to the functioning of any digital device, is that data be ordered in units, and that the units can be handled as if coherent. Processing—such as the Fourier transform or the square wave—only completes the universalisation of statistical averaging and unit enumeration as the core formal qualities of the information age.

The principle of control emerged in the design of projectors, where control over the random flight of photons in every direction and at every wavelength from any source had to be tamed if a tiny frame of film-stock was to be projected onto a huge screen using any realistically achievable quantity of energy. Shaping the beam through parabolic mirrors and condenser lenses structured other informational uses of light in searchlights and lighthouses. The irony is that the light which is so powerfully constrained in these systems, and which is even more tightly corseted in the internal reflections of fibre optic waveguides, is the medium of twenty-first century telecommunications and network media. The organization of light in projection has found in the twenty-first century an even more precise conformation of light to the requisites of an instinct towards order that has become totalitarian.

Late in his life, affected by the cases of shell shock he had witnessed after World War I and perhaps even more so by the rise of Nazism, Freud proposed the idea of the death instinct. From 1920 to 1930, in *Beyond the Pleasure Principle* to *Civilisation and its Discontents* (Freud 1961a; 1961b), he developed a dense theorisation of a drive towards entropy informing both personal and social structures. The child's fascination with the flaring match illustrates that this drive, like every other, easily oscillates between positive and negative poles: between the drive to destruction and the drive towards order. If at one extreme, this leads to the repetition compulsion and to a collapse into the inorganic, at the other it leads to the kind of pathological command over physical reality which, paradoxically, no longer frees us from the contingency of the laws of physics but enslaves us to their organisation in global technical systems, themselves expressions as well as formative vehicles of an increasingly global order. The historical realisation of Kantian freedom from the laws of nature as foundation of the 'cosmopolitan intent' has in actuality come about not through international law, as he imagined (Kant 1983), but through the kind of normative technical structures underpinning the pursuit of coherent light. This pursuit was undoubtedly experienced in the beginning as an autonomous movement of the nascent techno-science of the late nineteenth century, but has become rigorously integrated into the hardwiring of contemporary global infrastructures. It will be one of the key challenges of the twenty-first century to develop both radical ways of working within this already ossified system, and to invent new modes of working with light that involve not simply freeing it, as an entropic gesture, but finding new ways to create in partnership with light, rather than through its enslavement.

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CHAPTER 3

HD Aesthetics and Digital Cinematography

Terry Flaxton

This chapter is accompanied by a series of online interviews entitled 'A Verbatim History of the Aesthetics, Technology and Techniques of Digital Cinematography'. This online resource seeks to circumscribe and circumlocute the wide variety of interests and usages of incoming digital media with specific relation to the effects of increased resolution being offered by emerging digital technologies and can be found here: www.visualfields.co.uk/indexHDresource.htm

In April 2007 at the National Association of Broadcasters convention in Las Vegas, High Definition Video changed forever. Whereas previous HD cameras had cost half a million dollars, Jim Jannard, a sunglasses manufacturer from Canada, had managed to develop a new camera called the 'Red One,' retailing at $17,500. This development signalled a change in the production of High Definition as it had been first conceived and named. The original title—'High Definition'—was meant to signal a change from standard resolution digital video and align the new technology with film, giving it more of a sense of quest than analogue or digital video, more of a sense of flight, a sense of the arcane and the hidden, thus producing something to aspire to and engendering a sense of being elite—very important for the Directors of Photography, those captains of the ship heading towards the image horizon and in turn, evoking some of film's prior sense of mystery. Now we are in the stable years of

'HD', the title 'HD' has become misleading, mainly because it refers to a line structure that was pertinent to the analogue age (and related to television) but which no longer appropriately characterises the current aspirations for the medium.

A High Definition Image to Recall

I want to introduce an image that may be useful when thinking of HD: as the light falls at dusk and you are driving along, you might notice that the tail lights of the car in front of you seem much brighter than in daylight, and the traffic lights seem too bright and too colourful. The simple explanation for this phenomenon is that your brain is switching between two technologies in your eyes. The first technology is the rods (inherited from our distant ancestors), which evolved for the insect eye to detect movement, and are numerous at around 120 million. Through them you see mainly in black and white. The second technology is much more sensitive to colour: these are the cones, which are far less numerous at around 7 million.

Colour is a phenomenon of mind and eye—what we now perceive as colour, is shape and form rendered as experience. Visible light is electromagnetic radiation with wavelengths between 400 and 700 nanometres. It is remarkable that so many distinct causes of colour should apply to a small band of electromagnetic radiation to which the eye is sensitive, a band less than one 'octave' wide in an electromagnetic spectrum of more than 80 octaves.

Human trichromatic colour vision is a recent evolutionary novelty that first evolved in the common ancestor of the Old World primates. Placental mammals lost both the short and mid-wavelength cones. Human red–green colour blindness occurs because, despite our evolution, the two copies of the red and green opsin genes remain in close proximity on the X chromosome. We have a weak link in our chain with regards to colour. We are not 4 cone tetrochromats; we have three and in some cases only two—in extremely rare cases we have one.

So, there are two technologies—rods and cones—between which there is a physiological yet aesthetic borderland. Keeping this idea in mind, if we apply the potential misreading of eye and mind not to colour, but to our ability to recognize different resolutions, then a similar potential sensorial confusion is possible in the higher resolutions of which we are now capable. In my own experiments with capture and display, it is becoming apparent that a viewer experiences a sensation similar to the illusion that there is more colour at dusk when a certain level of resolution is reached. At that borderline between the lower resolution and the higher resolution, a fluttering occurs as we engage in this step-change of resolution. I have found that at the lower level there is less engagement, as measured by the duration the audience is willing to linger with an image, and at the higher resolution there is more engagement. This is evidence of a switching between two states in the suspension of our disbelief—with higher resolutions eliciting more visual fascination. What is really interesting to me, as an artist, is the boundary between the two states.

The Figures

After the invention of television, it took many years to be able to record the analogue video image. This was finally accomplished through creating a scanned rasta of lines and inscribing what information was present in each line. This was the strategy of analogue video in its two main forms: PAL and NTSC. When computers began to take over, scanning became obsolete (having only been necessitated by the limitations of magnetic control of electron beams and glass technology at that time); so a form of inscribing and recording the information that was independent of the scanned rasta but was grid-like—digital in form and mode—took over. This became the now familiar grid of pixels that every camera sensor has. A progressive image sensor is like a frame of film in that it is exposed in one go, unlike a scanned image, which takes time. But there are many issues with the technology that make it unlike film (like needing to empty a CCD of charge, line by line, or a CMOS chip in one go). Each chip is constructed of many individual photosites that are single light sensitive areas. These then produce information in the form of packets of data that are in turn represented on screen by a changing luminosity and colour identity via a pixel of display.

But let us step back to the moment when analogue video began to give way to the first digital forms. Digital Video was then transforming analogue technology and this moved us closer to High Definition technology. It had 720 x 576 pixels to emulate the 625-line system in analogue video (in PAL at least). It required anamorphising to enable a 16:9 ratio from a near 4:3 pixel count. It confused many of its early adopters because it seemed to disintegrate through multiple copies—yet of course Digital Video was heralded as non-degenerative. The fact was that it was only partially digital, but it gave us a run for its money.

The earliest forms of High Definition were analogue at around 1250 lines, but being on the cusp of the digital revolution, HD soon abandoned the early analogue HD forms as it became digital. In economic terms this meant that the early European systems were being financially trounced by the Japanese and American systems, so the standard eventually became 1920 x 1080 pixels (which had a relationship to the analogue NTSC format).

Standard HD is known as having 2k resolution because it has a resolution of 1920 x 1080 pixels (1920 is near 2000). This has a 16:9 or 1.77:1 aspect ratio, which is common to LCD, LED and plasma television design. Cinema style HD has been called Electronic Cinematography—it is also 2k but has 2048 x 1080 pixels (or sometimes 2048 x 1024). This has a 2:1 aspect ratio. The academy version of 2k has 2048 x 1536 pixels, which is 4:3 aspect ratio. So there are varying requirements concerning the number of pixels in an electronic cinematographic image—agreements still have to be made as to exactly what numbers are involved though this is getting closer with the Academy Colour Encoding System (although this is primarily a system to determine standardised colour through different media, it will have a knock on effect with regard to resolution). There is also one other important difference between Standard or HD resolutions (which are governed by proprietary formats) and Electronic Cinematography. Proprietary forms of HD are generally processed (or data reduced and processed) in camera, whilst Electronic Cinematographic forms are processed mainly in the post-production house. 4k is 4096 x 2160 pixels (2:1) or 4096 x 2304 (16:9), and 8k is 7680 x 4320 (16:9)—this last is NHK's Super Hi-Vision. In conversations with leading designers in the subject area I have established that far higher resolutions than 8k are in development.

It is possible to record most of these formats in a compressed version on a form of memory card, but currently, the highest level of 2k HD image capture requires recording onto solid state discs—and not just any solid disc, but a Redundant Array of Independent Discs—a RAID (the exception is Sony's SR deck, which records data on tape). If you want to record 1920 x 1080 pixels uncompressed, then you need read and write speeds of *over* 440 Megabytes (Mb) per second. The average old style hard drive reads and writes at around 35 Mb —hence you need quite a few of these (though solid state drives record much higher rates you still need several of these too). To understand the idea of the RAID, imagine the following: If I throw you a ball, you might be able to catch it. If I manage to throw you twenty balls at the same time, you have no chance. If I throw twenty balls to you and another nineteen friends—you have a chance of catching them. A RAID Array uses a group of discs to catch large amounts of data.

Criteria for Digital Cinematography

Until recently many manufacturers used small chips of around half to two thirds of an inch in size—each camera used three chips for three colours to reconstruct a colour image (red, green, blue). The chip size was a hangover from 16mm film that generated large depth of field from the smaller optical pathway. When Red Cameras introduced the Red One it began with a 35mm-sized single sensor that used a Bayer filter to extract colour information. Bryce Bayer invented this system for Eastman Kodak in 1976—primarily to extract information from scanned film images.

With the above in mind here is what I consider to be the governing principles for Digital or Data Cinematography:

> a) The optical pathway is 35mm or above (derived from technical and industrial limitations possible at the time of origination for manufacturing photo-chemical negative).
>
> b) It generates a progressively based image flow relating to a specific time-base as opposed to an interlaced image flow (one full frame of information at a time rather than a field-based workflow).
>
> c) Like one of its predecessors, film, it holds the image in a latent state until an act of development (or rendering) is applied—but unlike film it is non-destructive of its prior material state.
>
> d) Its capture mechanism, though generating a non-destructive, non-compressed data pathway from which an image can be reconstructed, does not have this as its sole intent as a medium or method of capture.

These latter three qualities are also base characteristics of many other developing digital technologies—for instance real-time mapping of environments requires a capture of infra-red imaging sources (cameras used as sonar devices) running at around or above 25 fps. Using this criteria, Digital Cinematography is about more than just capturing images—it's a portal onto the digital landscape so far unexplored due to its apparent function as an image capture medium.

What Was the Future, Is Now the Present

The future is governed by Gordon Moore's Law, formulated in 1965, which proposes:

> The complexity for minimum component costs has increased at a rate of roughly a factor of two per year … Certainly over the short term this rate can be expected to continue, if not to increase. Over the longer

> term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least 10 years. That means by 1975, the number of components per integrated circuit for minimum cost will be 65,000. I believe that such a large circuit can be built on a single wafer. (Moore 1965: 114–17)

In 1975, Moore altered his projection to a doubling every *two* years (Moore 1975: 11–13).

In the early 1990s I first came across analogue HD systems (including the European MAC system which used 1250 lines). In 1999 I shot a short on the Sony 900, which was post-produced by Du Art in New York and then output to 35mm for display at festivals. In 2003, NHK, or the Japan Broadcasting Corporation, conducted an experiment that linked a prototype 8k 16:9 aspect ratio camera to 18 one-hour data recorders. The subject of the test was a car ride lasting three minutes. In order to capture it, the SR data recorders ran so fast that they went through one hour's worth of recording during the three-minute shoot—all 18 of them. The resolution of the projected image was immense: imagine a computer display set at around 1280 x 1024 pixels—then imagine a screen of some twenty-seven feet long with the resolution proportionately more detailed. A little more than 100 years earlier, this technological moment had echoes of the Lumière Brothers' screening in January 1896 of a train arriving in a station. At the NHK screening, the Japanese audience were reported to have found the experience so overpowering that many of them experienced nausea. Both of these tales are at the same time apocryphal, yet pleasing.

So now we can place a computer image on a screen of cinema proportions with equivalent or more than cinema resolution (at the time of correction Alfonso Cuaron's Gravity has opened to wide acclaim – a feature of over 90 per cent computer graphic content). So, imagine what it would look like—in fact what it would *feel* like, if the very high density of pixels shot in the NHK experiment were then displayed across that screen as cinema—in the NHK experiment the possibilities of deep engagement and belief in the experience seem to have lead to a physiological reaction. Since this experiment, Super-Hi Vision has been streamed live between Tokyo and Osaka—but of course that act required a high amount of compression.

Technology and Compression

The high levels of data produced in creating digital cinematographic images should beg a primary question in the reader's mind with regard to how we actually achieve data capture. Any serious understanding of High Definition / High Resolution technologies requires a basic understanding of ‘compression’ (and this is without a deeper discussion of ever increasing colour bit depth where veracity of colour and a larger data collection is required to pursue the twentieth century’s primary aesthetic project, that of realist and hyper realist intent). This question should be: How do we accomplish so much with so little?

Light is focused through a lens onto a charged coupled device or sensor, which then emits electrical impulses that are reconstructed as data. Very early on in video production, a question arose for designers when far more data was generated through this process than was recordable. It was from this problem that the idea of throwing ‘unnecessary’ data away took hold. A strategy that commercial producers utilize is that of adopting the idea of GoP structures to compress images—and this practice underpins not only low-level HD recording in camera, but transmission of images over the Internet.

GoP is short for Group of Pictures. The first and last frame in a group of pictures contain all the information: each succeeding picture only contains the changes in the information. If a person is photographed against a background, there is no need to resend the background information again and again—only the information about head, mouth and eye movements. You can see the affects of GoP structure effects when you watch the blocky artefacts in DVD or Blu-ray, or HD transmission occurring—there is a regular beating in the change of the blocks. HDV, P2 and AVC cameras use this system to record images and it is often criticized for being unable to handle motion well. Clearly the shorter the GoP structure, the better this system will handle motion.

The traditional photographic camera manufacturing companies have recently got on the bandwagon, taking advantage of the convergence of still and motion picture imaging. Some DSLRs, but not all, had the benefit of a 35 sized single sensor—but with limited writing speeds were restricted to GoP structure compression. By the end of 2011 Canon brought out the Canon C300 to fully enter the motion imaging market place. However, in an act that could be seen as an attempted spoiler, Red introduced the Scarlet X on the same day at half the price and like its antecedent, the Red One, with full frame recording. Some fans of Red complained that the Scarlet was simply a diminished version of Red’s Epic camera, one that did not value the rapid developments in the area. Others appreciated the gesture of the possibility of the mass availability of the technology.

Other motion image manufacturers lead by Red, Arri, Panavision and now joined by Sony and Panasonic, realize—mostly through pressure by the cinematographic community—that one of the baseline rules necessary to achieve True Digital

Cinematography is to keep all of the data in order to properly describe what is in front of the lens. At the time of writing there are no longer any manufacturers of photo-chemical based film equipment.

So how have impossible amounts of generated data now become recordable?

Wavelets

An accumulation of data in a camera is a representation of the original scene and all representations have levels of veracity with regard the original. Previous SD and HD cameras use a software technology based on Jean Baptiste Joseph Fourier's Discrete Cosine Transforms (DCTs), which break up the image data into tiles, so that each can be treated independently. Recently though, we have seen the arrival of Fourier's Wavelet Transforms. The theories involved were in place by 1807 but not truly understood until about twenty-five years ago. Wavelets have helped prise open a Pandora's box. Here is a description by the astrophysicist Amara Graps:

> Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale. They have advantages over traditional Fourier methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology. Interchanges between these fields during the last ten years have led to many new wavelet applications such as image compression, turbulence, human vision, radar, and earthquake prediction. (1995)

Discrete Cosine Transforms are a sort of 'one-size-fits-all' response to data—a thuggish response requiring intensive computation. This is in contrast to Wavelet Transforms, which interrogate the data coming through them and find the best response from within their algorithm. In effect they intelligently address the data to get the best out of it, while using less computational power. As one Director of Photography put it on the Cinematographers Mailing List: 'ummm, wavelets good, DCT bad.'

Contemporary cameras and post-production systems have been designed with DCTs in mind, and the manufacture of the relevant devices, cameras, proprietary editing and storage systems has been designed and marketed to recoup the large amounts of costly research that has been expended by big corporations. It has simply not been in the interests of the bigger corporations to switch over to the new, more elegant technologies. Yet the pressure exerted by the maverick Red Camera Company had telling effects on corporations like Sony, who marketed the F23 and the F35, followed by Arriflex with their Alexa camera. Sony's naming system bears some investigation: The F23 used a two-thirds inch chip, the F35 a 35mm sized sensor and in 2011 Sony launched the F65, a possible reference to 65mm, which uses an 8k chip that generates a truer 4k image. To obtain a true register at such resolutions one must take two samples to derive a value—this is know as the Niquist Shannon Sampling Theorem—an important factor in Modular Transfer Function or MTF.

With a nod towards Ivan Illych and his studies around systems disorders—in his case with regard to how much allopathic medicine cures and how much illness it induces (known as iatrogenesis), we must also understand that any system has a limiting element within it. In electronics this is referred to as Modular Transform Function.

Modular Transfer Function describes a chain of delivery from capture to display where resolution is defined by the lowest resolution link in the chain (like plumbing where flow is derived from the thinnest of the pipes in the system). For instance in Apple's Final Cut Pro Studio 3, the base architecture limits resolution to 2000 lines. If you shoot 4k, edit through Final Cut and then display on a 4k monitor—the MTF of the system is 2k (however, new iterations of that manufacturer's software and other manufacturers of post software are using resolutions up to 4k and above). With the early Red One's 4k sensor, because of various issues with the Bayer Pattern filter, the MTF of the camera is around 2.8k/3.2k—but of course if you use a lens with less than 2.8k of resolution, then whatever the lens resolution is would then be the limit of the system.

Having said all of the above, a Wavelet Codec, because it deals with curves rather than angles, can intelligently reconstruct large amounts of data from very small samples. Red's own proprietary Redcode 28 can construct a kind of 4k image using only 28 Mb's of recording speed. (RC 36 and RC 42 use 36 Mbs and 42Mbs respectively.) A lossless 2k image should record at 1 gigabyte of data per second (dependent on bit depth etc) so the very idea of recording 4k in 28mbs is astounding and this demonstrates the efficacy of Wavelet Transforms.

The Contemporary Argument About HD Image Control

Currently, film DPs are still brought in to light 2k productions. Though they are becoming familiar with the thinking in Digital Cinematography, previously electronically trained people were brought in to hold their hands; the common ground between the two is the attitude that 'preserving data is all'. At one meeting of the British Society of Cinematographers, there was much wailing and gnashing of teeth as film-oriented DPs stressed their concern over the lack of dependability of the production chains that eventuate in an image. It was argued that it is currently possible to send your data through the same equipment at two different facilities in the same city and obtain different colorations of that image. It has taken 100 years within the practice of photo-chemical film to obtain dependability in the chain of production, and of course the ability of a cinematographer to get that little bit extra, that un-definable advantage in their image making is what adds value to their reputation. However, at the moment, the terrain of Digital or Data Cinematography-based production is still feared because that level of control has yet to be fully realized. Having said that, the American Society of Cinematographers have instituted their Academy Color Encoding Specification and Image Interchange Framework, the intent of which is to introduce full calibration of the process—bringing images from both data and photo-chemical capture, through a reliable framework, right through to display.

Within contemporary cinematographic aesthetics, whether in film, analogue or digital video, or Digital Cinematography, there are a series of tactics used to 'say something' with light. If listed, these tactics become mundane: a warm look for safety and comfort, blue for night, uncomfortableness, then into the greens, sodium or magentas for inducing the uncanny, threat and alienation—and so on. There are some DPs like Vittorio Storaro, who shot *Apocalypse Now* (Francis Ford Coppola, USA, 1979), who step outside of these prosaic colour values. Storaro has his own narrative colour system which works for him and like an extreme system of bidding in the game of Bridge, not too many people can operate it, nor many understand it. Yet many DPs agree, Storaro has 'the touch'. Whereas Storaro works with colour and light, and the physiology of light enmeshed with a psychological narrative, Conrad Hall (born in 1926 and passed away in 2003: *American Beauty*, Sam Mendes, USA, 1999; and *The Day of the Locust*, John Schlesinger, USA, 1975) thought differently to Storaro. His inventiveness and commitment was to the *photographic* within the cinematic arts. As Hall traversed the boundaries of contemporary wisdom about what constitutes good exposure, he influenced a whole generation of DPs. Hall knew that the still image captures something that cinematography rarely does; he was therefore concerned with finding 'the photographic moment' amidst the flow of images. He tried to find the extraordinary within the ordinary. In this quest, Hall pushed film exposure to the limit; this kind of treatment would be ruinous to HD because it does not yet enjoy the exposure of highlights that film does. However, with the arrival of Digital Cinematography this now becomes possible in some ways, though with the coming arrival of Higher Dynamic Range Capture and Display we shall soon be able to capture and display close to the dynamic range of the human eye and brain system.

When I say 'close', within the human system we are capable of seeing fourteen orders of magnitude from the brightest day to the darkest night, but available to us at any given time are five orders of magnitude which we slide up and down the scale of sensory input.

We are all familiar with how our eyes adjust to bright light, or conversely to the dark—that's us making our five orders of sensitivity respond to the spectrum of light which occupies fourteen orders of magnitude in total. HDR Capture shoots two or more simultaneous images, of both highlights and shadows, then merges the result and takes the best of both, in order to display a higher dynamic range image. When displayed on contemporary displays, whether LCD, Plasma, or CRT, the dynamic range of the display space is only between two and three orders of magnitude; hence the description of the image as looking 'plastic' by many DPs. However, the HDR image should be displayed on an HDR display, which is capable of the same level of instantaneous orders of magnitude as the eye/brain. The common response to these new screens is that (to paraphrase) 'it is like looking through a window, with all the attendant clues related to depth'.

Looking Back in Wonder

On a Ridley Scott set in 1983, as he shot the famous 1984 Apple Mac commercial, I was shooting the 'making of' material for Apple (on NTSC betacam video—on tubes). At that time it was not possible to see what kind of images you were obtaining via the medium of film. For that reason the cinematographer, through experience, would be one of the only persons on the set who knew roughly what they would be getting back in the next day's rushes. As we were viewing back our video rushes on our production monitor, checking focus and exposure, I became aware that about 20 people were standing behind us, quietly looking over our shoulders. Usually the film rushes would come back the next day to be viewed by the more select in the hierarchy. The two groups stared at each other—two alien tribes at war—film and video. But this was a film crew that had never before seen what it had been shooting at the same time as shooting it. One of them grinned in pleasure at seeing our footage and suddenly, like the German and British troops in the World War I downing their rifles on

Christmas Day and playing football together, we were friends. From then on they stopped being hostile to us, even sometimes offering to move lights to let us have some illumination—bearing in mind that lights are sacrosanct in film.

Historically, however, in the clash between film and video, the professional film users were seen as artists and craftsmen and video users were seen as artless—even though video art was superseding experimental film at that time. Video was obtainable yet without atmosphere; film was arcane, it was a quest in itself, it had kudos.

Achieving the Filmic Look

In film production, because film stock and lenses eventually had become so sharp, in order to impose an atmosphere, cinematographers have had to constantly distort the colour standards and definitions of film stock. 'Atmosphere', like popcorn, shares a quality that allows the easy suspension of disbelief. If film manufacturers say that development should occur at such and such a temperature, then heating up or cooling down the developer by a few degrees is a means by which the colour, grain or exposure may be changed.

Here is the rub for Digital Cinematography: to get a *look* from a clinically clean medium you have to distress the image and therefore lose data, and as we've established, DPs really don't want to distress an image that is already distressed by being compressed. If you do work on the image in camera, as the traditional film DP has tended to, then you limit how much data is recorded—you have to work in the colour matrix. If you crush the blacks to get a look you automatically reduce the data that is output into the image display. So current practice is to do very little in camera, so that every bit of data is carried back into post-production, where the work on the image—the grading—can begin. But I contend that when you really look at images produced like this, you'll see a thin patina *over* the image and the 'look' itself is not inherent *within* the image. I've spent thirty years shooting video, as well as film, and I know it's possible to generate the look within the image. It is my contention that simply to light well and to leave everything to post-production is an abrogation of the DPs responsibility as a creative artist. I have many friends in the cinematographic community that now believe this to be true.

Original electronic imaging was analogue in form—as was film—yet the formulation of the capturing of an image was different from film. Film has wide latitude—one can make an intelligent 'mistake' and rework the material and formulate a sense of 'atmosphere' within the image. This is commonly known as 'the look'. Analogue video was clean and clinical, and you had to get the exposure right—in the early days, if you didn't get exposure correct, then you didn't get focus. Colour itself was grafted onto an already set formulation of image capture. I shot one of the first features generated on video and transferred to film for theatrical distribution; this was Birmingham Film and Video Workshop's production *Out of Order* (Jonnie Turpie, Birmingham Film and Video Workshop/Channel 4/BFI, 1987), and I approached the task by imagining video as being like a reversal stock—with very little latitude for mistakes in exposure. Nevertheless, what had I to lose? I tried various colour experiments—for instance, at that time creating a white balance that was off-white was not generally done. I discovered that not only could you tip the white balance towards the corrective areas of colour (blue and orange, cold and warm), you could also tip the balance of colour into any complimentary area—for instance, corrupting the look towards the purple to induce green and any variation to be found around the colour wheel. The transfer to film at that time seemed adequate, but when compared to today's digital transfer techniques, it was not good in terms of colour.

With the advent of Digital Cinematography something very important has happened with image capture. In both photochemical and digital cinematography, until the image is developed, the image resides in latent form in both *the silver halides* and the *un-rendered data.* Development—the bringing forth of an image in film—is similar to the rendering of an image in the electronic domain except for the fact that the materialised film image is negative and in digital cinematography the materialised image is positive. The nature of that difference requires fuller investigation at another time.

For now, it is important to note that, in the latter, colour is within the bit-depth of electronic data and is therefore an integral part of its material form. This developing practical understanding in professional practice is counter to arguments that have circulated previously within media theory. For instance, *New Media: A Critical Introduction* (Lister et al. 2003: 13–21; 35–44) claims there is an essential virtuality to new media, with the immateriality of digital media stressed over and over again. However, industrial and professional expertise now challenges academic convention by seeking to re-inscribe digital image making as a material process. Data labs exist and so one can deduce that data also exists. Large companies like Google and Microsoft position server farms within the arctic circle to take advantage of free cooling – the manipulation of data generates heat. There are various other characteristics to the handling of data that enhance its materiality and evidence is mounting of its materiality as a medium. In a conversation with a colourist in London's Soho, I proposed that the analogy of 'warming the photo-chemical developer, to then change the characteristic response of the film that was going through the developing bath'. Likewise, one might also interfere with the material nature of data within its processes so that the look could be created within the image. This is different from simply 'baking in' a look, which then limits manipulation during post-production. Instead I'm describing the possibility of artistic manipulation within the traditional terms of operation of the cinematographer, rather than limiting the possibilities of others in later processes.

In sum, at the beginning of digital video, when data was generated at low levels via proprietary formats, it was possible to regard its limited presence as being immaterial—now we have to think again. In wanting as much detailed information to be retained as possible, Directors of Photography are expressing the desire for verisimilitude with the real world. This attitude must also prompt the re-investigation of the academic trope of thinking of digital information as being immaterial. Many data labs have now grown up around the world to handle the tsunami of data being generated by the attitude of DPs towards their craft. A major argument for the digital as being material resides in the fact that people are employed in its handling; like any other material, its commodification is a sign of its existence.

The Technological Horizon of the Image

Film was developed with the aid of two seminal technologies preceding it. Like all technologies the first had several inventors engaged in its development: Alexander Parkes investigated Cellulose Nitrate and introduced 'Parksine' in 1861 and later an artificial dental material was introduced by the Albany Dental Plate Company in 1870, invented by John Hyatt. Both lead to Celluloid. The other technology was the introduction of 'intermittent mechanisms' with the first functioning sewing machine in 1830. Barthelemy Thimonnier was nearly lynched by a mob of tailors who saw his invention as something that would lose them work. Nevertheless, together these inventions enabled cinema to come into being.

Early frame rates (12, 14, 16, 18fps) were too slow to generate the sensation of smooth motion, so were then enhanced in the projector by introducing a revolving shutter with 4 sections—two were clear, two were covered—so each frame of film was displayed twice per second. Today we produce 48 (or 72 flashes if there are three open sections) if the film runs at 24 fps. Television emulated this flashing of the image by using interlaced technology that split one frame into two fields. Now with increased computational capability, Digital Cinematography can shoot high frame rates and experiments are underway with viewing images at higher frame rates *and* Higher Dynamic Range.

Film has always had a higher dynamic range than digital video and also digital cinematographic equipment—but this is now changing as DC equipment is now around 10–14 stops of latitude, thus coming close to matching photo-chemical film. But Higher Dynamic Range images are now being produced on still cameras. When the two exposures are combined (captured in two different frames at the same moment), around 18–20 stops of dynamic range are produced. One problem with moving image HDR production is that most systems capture each exposure within the HDR image one after the other. This means that the two different exposures are time-displaced and therefore if there's movement in the frame, blurring occurs which will play hell with Greenscreen. However there are now cameras that capture three exposures at once using a beam splitter.

The other principle issue in HDR research is that all contemporary displays use a mechanism that only displays two to three orders of magnitude. This is currently being dealt with by joining both LED and LCD display processes so that newer HDR exhibition systems will display images that have the same dynamic range as the five instantaneous orders of magnitude of the eye brain system.

The resolution of film is said to be 4k but requires scanning into the digital realm at 6k (so that it has 'headroom'). When you previously saw a film image in a cinema it would often have been at 1k resolution as the processes that have been used to create that image have slowly but surely decreased its resolution (interneg, interpos, release prints, the state of older 35mm projectors etc). Therefore the average image captured digitally and then displayed on a 2k cinema projector is 4 times the resolution of film display. Digital Cinema resolution is increasing month by month, year by year, as regards Moore's Law.

All in all, we are now witnessing a tsunami of development in many different areas with regards to motion imaging. In another example, researchers at the University of Bristol in the Departments of Experimental Psychology and Signal Processing have been conducting experiments to discover differences in immersion between 2D and 3D imaging. These tests have lead to the evaluation of motion stereographic imaging as only having seven per cent more immersive capability than 2D images of the same frame rate and the same resolution. So the project we humans are collectively now formulating is in fact the calibration of motion imaging capture and display, as regards frame rate, dynamic range and resolution so that it hits the 'sweet spot' in human eye/brain physiology. We are now in search of the 'perfect picture'.

One fly in the ointment has been pointed out, albeit mischievously, by Mitch Mitchell (2011: 'Verbatim History'), Head of Imaging and Archive Services at

Technicolor London, who argues with a degree of the pedantry born of innovatory thought, that 24 frames per second is more appropriate than much higher frame rates because it allows time between frames to reflect on the emotional and meaningful elements within the frame, thus enabling the generation of significance and wonder in the human brain. Mitchell's perverse argument is derived from Stephen Poster, the DP who shot *Donnie Darko* (Richard Kelly, USA, 2001). Poster argues that since each frame is being flashed for 50% of the viewing time, in a two-hour film, one hour is effectively spent in the dark—thus allowing for plenty of time to think about what you're watching. The serious point of the joke is that if you increase the frame rate, you won't need to flash into black all the time for physiological reasons, so consequently all reflection time will be lost and the romance of film will die.

Artists and resolution

In my own practice I have often been inspired by the simple act of making work with such wonderful technology. This technology functions faster than the eye or mind. Even analogue video takes one 64 millionth of a second to 'write' a line.

'Duration is to consciousness as light is to the eye' (Bill Viola, quoted in Youngblood 2003). In this statement Viola is proposing that the presence of light is what caused the eye to evolve, and in turn, that consciousness evolved to deal with events that had duration. He is proposing that in a medium where time is an essential factor, waiting reveals so much more.

Viola's roots lie in both the symbolism of Renaissance painting and the Buddhist proposition of Dependant Origination—that everything can only arise in relation to everything else. My own roots grew out of the moment that I realized that all things record an image through duration: from a lowly rock which, if left shadowed long enough, records the shadow of an image; to paper that has a leaf left on it in bright sunlight; to celluloid that holds a coating; to tubes, chips and sensors that react to light.

Early Days

My first encounter with videotape was in 1976 with 2-inch analogue quadruplex. One took a razor blade and cut it, just like film, then spliced it together to make an edit. Then re-recording came along, and we set up machines to record the next bit of video in line—thus creating an edit and also consequently, image deterioration.

Around 1982 I was managing a video facility in Soho called Videomakers. The owner of the studio was the son of an electronics inventor and watched while we tried to accomplish a simple dissolve between one image to another for a piece of work I was making. Unable to contain his excitement, he told us that his father had successfully harnessed a computer to 'revolve' a still image. He explained that with a little bit of development the image could be refreshed twelve times per second—so, by doubling and then interlacing, by splitting the image into odd and even lines, a whole second of video and henceforth a moving TV image could be revolved. In this case, through a sole inventor and not a corporation, we groped our way through the late analogue age and into the early neo-digital. Our main concern was how to adjust our thinking processes to cope with the new paradigm: to the fact that with a digital event, one had something that could be infinitely manipulated. One could therefore systematize the process—thus giving rise to 'the operations' as Lev Manovich (2002) has termed them.

Every video artist has enjoyed the accidents that have come about through stressing the parameters of low definition equipment. However, Digital Cinematography offers a different kind of unveiling of form. The major difference is that image capture can be achieved without *necessarily* stressing the media. This then prompts questions about the aesthetics of Digital Cinematography. Given that a primary ingredient of the artist's palette is to find surprises within the medium itself, what new strategies can the artist or practitioner use to unveil a deeper insight into content? Though McLuhan tells us this should not be so, could the message Digital Cinematography delivers be the beginnings of transparency?

To return to Viola: 'Duration is to consciousness as light is to the eye.' But High Definition can deliver not just duration, but articulation. So we might now remember how increased resolutions could affect how and what we see and therefore reformulate his observation like this: 'Definition is to consciousness—as luminosity is to the eye.'

Art and compression

In 1987, John Wyver carried Walter Benjamin's 1936 ideas forward, with the help of Jean Baudrillard and Paul Virilio, in his programme *L'objet d'art a l'age electronique*, broadcast on the satellite station La Sept. He asked: 'Can a reproduction carry any of the authenticity of the original?'. At that time the world was concerned with analogue representations, which decay in their passage from copy to copy, from medium to medium. If one proceeded with digital compression using Fourier's earlier mathematics, then Benjamin's question might unveil a buried insight: *To copy is to decrease.* With digital copying this might still ring true—not only because things are changed and lessened in the act of copying—but because there is a sense in which the representation itself is simply a 'Borg', a copy without feeling, without the 'true' sense of the original.

Over twenty years later, the spirit of the question still stands. Where is meaning, significance and value in the digital domain, given that the medium of reproduction and the medium of origination reside together in the same realm? Has the idea that things can be 'derivative' become defunct? Is not everything both derivative and original at the same time? Is the idea of the 'original' now anachronistic?

Technologies, Aesthetics and Art Converging

As there is a blurring of the lines between form and content, so there is also a blurring of the lines between software, hardware and that nether region of firmware, which tells hardware to *be* something—rather than *do* something. Now, through this blurring, and through a combination of the use of the web and digital media, a new kind of aesthetic is becoming available, in what has been termed convergence. Herman Hesse predicted post-modernism and its bastard digital child 'Convergence' in his 1943 work *The Glass Bead Game*. In the game itself, one might take a bar of Mozart and place it next to a brushstroke by Matisse, a line of poetry by Omar Khayyám and a silk screen by Warhol and so create a new work of art. Here, derivation is all; in fact it has been canonized. Hesse proposes the notion that authenticity is not only present in the copy but that the two are one and the same—that the artwork's weight accumulates with the weight of the addition of other copies and their imbued authenticity and all combine together into new, authentic works of art. In pursuit of such an *aesthetic conglomerate*, the actions of the new technologies *and the way the technology is being innovated* has itself become a developing aesthetic.

Resolution/Revolution

To return to where I began, on 31 August 2007, when Jim Jannard and Red delivered their first complement of twenty-five Red cameras to a selected few, they set the world alight with their offer of cheap and high level wavelet technology (and made it available faster than any previous technological advance of this order). The introduction of 4k was a moment of industrial re-organization. This new technology allowed people who previously would not have had the opportunity to enter into the industry. This resulted in a shift in the industrial hierarchy, one that is part of a cyclical phenomenon that comes in waves about every five years. Overtly it looks like a change in technology; covertly it's also a change in employment functions.

In parallel to such events, there is the ongoing development of User Generated Technology, coming out of an individualist trend that has somehow remained alive through late capitalism. For example, in the early 2000s Jeff Krienes, a Director of Photography in California, was experimenting with a friend from Thomson Grass Valley on a prototype HD Camera. They had become fed up with the slowing of technical innovation emerging from the big corporations; so they tried to create a camera that fulfilled not only their needs, but also their aspirations. They made an aluminium case that contained some electronics and a few chips, had a fitting on the front to take a 35mm lens and, on top, the stripped down carcasses of twenty early iPods to RAID record the high data output. This camera had nearly the same specifications of the Red Camera. Though Red may look like the trailblazers, they are in fact the inheritors of a User-Generated, YouTube-like attitude to the production of technology.

In sum, in contrast to the early sole inventors in Fourier's time, it may appear that we have just been through a long period where corporations, from the late analogue to the current digital cinematographic age have controlled the means of innovation. Yet as the digital reveals its nature it would seem that there is indeed open access to high-level technical innovation *for the individual*. There are recent incidents of companies with only one or two employees (such as the Digital Bolex company, which produces a 2k camera, which has already been brought to market). This apparent individual engagement with technology is a hallmark of our era, and this trend is currently centring on the production of High Definition or Digital Cinematographic technology.

The commonality of information available through the web is also allowing a commonality of aspiration so that the User, and now the Doer, is also the Maker and the Knower of their own world. As we make the transition between old and new states, a fluttering is occurring, a switching between the two states in the suspension of our disbelief. Through these changes, the definition of the self is expanding—the idea of what an individual is being re-defined as it is being up-rezzed to a higher level of definition.

Postscript

Though this chapter has its own specificities, it should be read within the growing understanding of what the digital realm is becoming. This can be aided by viewing a series of online interviews entitled 'A Verbatim History of the Aesthetics, Technology and Techniques of Digital Cinematography', which can be found at: www.visualfields.co.uk/indexHDresource.htm

Film history between 1890 and 1915 is fairly devoid of verbatim reports from the practitioners and designers of the medium. It seemed to me that the development of HD would occur in a mirror period 100 years later between 1990 and 2015 and I wanted to make sure that this absence of original voices did not happen again. This resulted in the 'Verbatim History' project that was part funded by an AHRC Knowledge Transfer Fellowship, and also supported by the University of Bristol, Arts Council England, Watershed Arts Centre and South West Screen.

Whilst making this ongoing resource I have become aware of various disabling predilections within current digital thinking. For instance: ideas around convergent and pervasive media have been developed with a low resolution approach to the world partially due to the available technology which placed a lower demand on the computational resources that were available. Of course higher resolutions demand higher processing and rendering levels, and in the beginning people were more interested in enabling the idea of pervasive media to function to be too worried about the level at which it worked.

Like notions of remediation within incoming media that seek to describe these changes in terms of the medium that is already existent, early forms of technology within a medium are less efficient and less powerful than later versions and therefore aspiration tends toward lower expectations. Yet upon looking deeper at the notion of the convergent, one can see that it points toward a time when higher resolutions will be required—to a time where the idea of the *convergent* will be replaced by the *integrative*. If you are living within a world where gesture can stimulate digital events you will want to make a small gesture with a hand rather than expend energy on waving your whole arm around. This is simply a question of resolution, and that in turn is a question of processing, compression and latency.

The 'Verbatim History', though ostensibly concerned with ideas of image resolution, is actually about the development of the digital domain in general through the viewpoint of motion image creation.

Current Research (2014)

At University of the West of England, the center for Centre for Moving Image Research (C M I R) will be examining developments in moving image technologies. My own current research strategy now centres on human physiological specificity and I've been working, in collaboration with University of Bristol and BBC Research and Development, on extending my earlier investigation into the immersive qualities of the image through increases of resolution, by combining the properties of higher frame rate, higher resolution and higher dynamic range images. In November 2012 we completed the first ever test shoot for this level of motion image production at 50 and 200 frames per second—the latest capture project took place in Bristol in April 2013, the results of which were published in a BBC White Paper at IBC in September 2013 entitled 'The Production of High Dynamic Range Video', by Marc Price, David Bull, Terry Flaxton, Stephen Hinde, Richard Salmon, Alia Sheikh, Graham Thomas and Aaron Zhang.

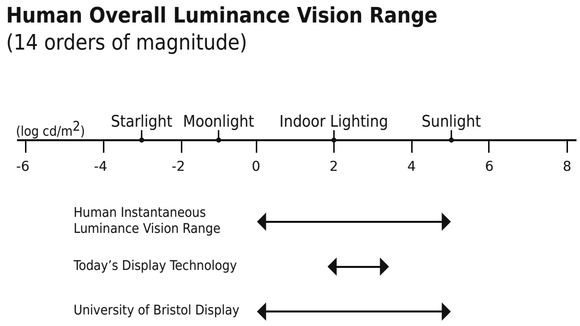

Figure 1. Human Overall Luminance Vision Range.

If you look at figure 1 it shows that the human eye/brain pathway uses 5 out of a 14 order of magnitude scale, sliding this instantaneous facility up and down the scale to deal with starlight at one end and desert sun at the other. All contemporary displays only currently show between 2–3 orders of this scale, but we now have a new prototype which displays across 5 orders and the BBC in turn have created a 200 frame per second projection system. By combining variants of frame rate, resolution and dynamic range, we should be able to effectively produce 'the perfect picture' by then calibrating these functions to produce a combination that best resonates with our eye/brain pathway—and therefore conscious awareness. The proposition is that if we can manipulate *all* the factors of the construction of the digital image then conscious immersion may follow.

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CHAPTER 4

What is Digital Light?

Stephen Jones

The first question that arises is what in the heavens or on earth is 'digital light'? What do we mean by this phrase? Because I don't know. There's no such thing as 'digital light' as far as I can figure it out. There's just light. We all (those of us that can see) know by experience what light is. It is that which we see, and the means by which we see. Its variations, *i.e*. its differences, the qualities (accidents) that it acquires from its sources and through its absorptions and reflections, provide us with the information (sense-data or data) that we use to experience the visually sensible world. That is, these variations mean that it is for us a prime carrier of information about the world.

And in this modern world, light is actually more directly a carrier of information; digital information, through the optic fibres that will become, for example in Australia, the National Broadband Network. However what travels along that pipe is light that we do not see—what we gather from that form of light is information about all sorts of things from finances to messages of love to pictures of anything and everything. Perhaps here is our first hint.

Now, let's suppose that we are discussing light that can be seen, how then can we call it digital? We tend to intuit that light is a continuous variation in colour or brightness such as we see in the shading of objects or in the transition from bright to dark that comes with, say, firelight. But the term digital implies that we are looking at discrete countable objects and when thinking of light we might have to say that it is something that can be turned on and off, and we wouldn't be far wrong here. Thus we might think about two kinds of light, the one being analogue light and the other this mysterious digital light. Moreover, we might further think of a third; the light in an optic fibre, which is coherent (i.e., not scattered)—enabling photonics, rather than electronics, and used for data or signalling.

The first, what I have for convenience termed 'analogue light', raises the question of the physical or quantum nature of light and the second, digital light, raises the question of the digital or the countable or discrete. But ultimately both concepts imply some kind of collection of discrete objects. The quantum, at the bottom end of things, consists of discretised packages, and that's what a quantum actually means. These packages appear to be particulate and, by implication, digital, even though the resolution is so extremely high it's completely beyond us to see it as anything other than a continuous, analogue process.

The quantum of light is the photon, a small probably massless entity gathered from matter/energy that mediates the electromagnetic force. The best description I've found so far comes from *Wikipedia*: *viz.*, photons are 'chunked ripples in a field, or "excitations", that "*look* like" particles' (Wikipedia s.v.; emphasis added). That is, a photon can be considered as a discretely located (within the limits of Heisenberg's 'uncertainty') ripple of greater amplitude within the electromagnetic field. Thus one can speak of particles and waves in the same breath, and it is these 'field quanta' that accord light the capacity to behave as particles in the classical Newtonian manner.

Newton thought of light as being particulate because it travels in straight lines and it is blocked by opaque objects. He placed a prism of glass in the path of a thin 'pencil' or beam of white light and he saw that it divided up into a spectrum of colours, recognising that white light is actually made up of a mix of different colours (Newton 1730). Because the 'particles' of white light are of different frequencies, according to their colour, they have different energies and so, as they cross the boundary from air to the prism, their speed of transmission differs due to the 'optical density' of the glass. The product of the optical density of the glass and the frequencies of the light (which is the 'refractive index' at that frequency) causes a differential dispersion of the light and produces the spectrum of colours that one sees projected onto some surface (see The Physics Classroom n.d.).

The notion that light also exhibits or possesses wavelike properties was argued by others, including Descartes, Hooke and Huygens, in the seventeenth century. This was due to observations that rays of light are not affected by crossing each other (Huygens 1690) and that they are not blocked by transparent solid objects. The wave theory of light was experimentally proven by Thomas Young—at the beginning of the nineteenth century—with his ‘double-slit experiment’, in which interference patterns appeared when light from a single source passed through a pair of closely spaced slits in an opaque barrier (Young [1803] 1804).

Nowadays, quantum theory is almost completely worked out, apart from some mischievous details about measurement and the role of observation. The notion of light, as represented by photons, is that it is somehow both a particle and a wave, somehow discrete and yet spread out everywhere—entangled with the cosmos—depending on the type of observation one makes. However, the classical notions of light as waves informed the work of several Australian artists and I’m now going to dwell briefly on the use of ‘analogue light’ by artists who have used it directly in their artworks.

These begin with the colour organ, c.1912, of A. B. Hector (McFarlane 2002: 292), and then reappear with the German emigré and sculptor Eleonore Lange (Batchen 1994: 49), who greatly influenced Frank Hinder (Free and Henshaw 2011; Jones 2011). Hinder (1906–92) went to the US in 1927 and studied in Chicago and New York and then worked as a lighting and set designer in Boston. On his return to Australia with his wife Margel in 1933 he met Lange who had brought with her the Anthroposophist attitude towards light as both a scientific and spiritual force. Hinder became quite influenced by her and spent a great deal of time over the next several decades trying to understand how he could represent that force of light in paint, and some of that work is spectacularly beautiful. Around 1967 he started working with light boxes with motorised lamps on metal beams, which were driven around inside the box behind a distorted glass screen and reflected off various mirrors or through coloured gels etc. These ‘luminal kinetics’ as he called them, being complex, expressionist, mobile abstracts in light and fluid forms, are among the most interesting work done in analogue light in Australia.

Another artist who was significantly important in this same area is Stan Ostoja-Kotkowski (Jones 2009; Jones 2011). He came from Poland via Germany, where he studied at the Kunst Akademie in Dusseldorf just after World War II. He immigrated to Australia at the end of 1949 and went to the Gallery School at the National Gallery of Victoria in 1950–51. He was essentially an abstract expressionist at that stage. He realised he wasn’t going to win with that in Australia at that point, so he took work in Leigh Creek, South Australia, as a house painter. While there he discovered how extraordinary the light of the Australian desert is; how intense it is and what it does to your perception—it really dazzles—and he began his project to paint with light.

After working at Leigh Creek for a year he moved to Adelaide where he began to play with an old TV set, fiddling around with all the controls. This is around 1960–62, just before Nam June Paik started to do similar things. It wasn't long before Ostoja-Kotkowski began working with several engineers at Philips Research Labs in Adelaide and they assembled a package of oscillators for him, which, with appropriate amplifiers, could be driven into the deflection coils of a TV set. He used this collection of equipment to produce complex, almost sculptural and apparently 3-dimensional electronic images. They are not dissimilar to the complex Lissajous figures that Herbert Franke (1998)[1] and Ben Laposky (1969; see also Leavitt 1976) produced on an oscilloscope screen. However Ostoja-Kotkowski's are in some ways quite different from the work of Franke and Laposky since they are actually made through raster manipulation, becoming images in which the usual 2D surface of the screen is twisted and turned, producing a 3D surface in the process. You could almost say that Ostoja-Kotkowski and the team of engineers that he was working with at Philips more or less assembled the first video synthesiser, although they never packaged it into a single package, but this may be a contentious point (Jones 2011).

At the very beginning of the 1970s Peter Kennedy produced a series of exhibitions using neon light, while Tim Johnson, pretty much in parallel, produced a series of small light sculptures that he thought of as 'unlimiteds'. He also explored the limits of danger in a series of performances using fluorescent tubes and incandescent lights at Inhibodress gallery. Kennedy is one of our major conceptual artists. He was part of Inhibodress with Mike Parr and Tim Johnson (Cramer 1989). He had been a painter, right at the end of that period in painting when geometric abstraction had more or less reached its endgame through minimalism and the white paintings of Ad Reinhardt and Robert Rauschenberg and in Australia of Robert Hunter. That led Kennedy to a complete reappraisal of what artists were doing in making art. What could they do to get past this impasse that they had arrived at around 1969? At this time Kennedy was working as a designer at Claude Neon, who manufactured neon signs, and he started using the neons to make lightworks. He created an installation of neon tubes for Gallery A, Sydney, that exploited the intense neon colours, and which articulated the architecture of the gallery, effectively turning the walls—the white cube—into the canvass. Thus the artwork was not simply the actual objects, it was the whole space; the environment itself became a single artwork (Murphy 2009).

Tim Johnson, also a member of Inhibodress and at that time a renegade from painting (although he returned to it after the Inhibodress period), was producing a body of very interesting conceptual work including a series of extraordinary performances where he took illuminated light bulbs on long extension leads and whirled them around (Cramer 1989; Tunnicliffe and Ewington 2009). As happens when you whirl lights around, they form continuous circles in your visual space because the retention of the image in your retina holds the stimulation and makes a complete circle from it. Then he would let the lead go: Bang! And the lamp would shatter as it hit the floor. A touch dangerous, and you wouldn't want to have been too close when the lamp hit the floor. Fortunately the floor was concrete and not electrically conductive, so that was not an issue.

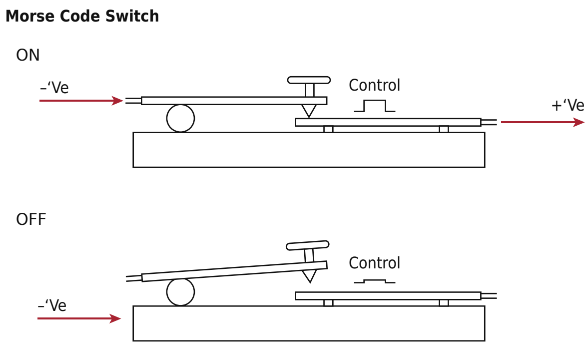

Figure 1. Morse code switch. Digital signals are switched between two states: ON and OFF. This can be done manually by using one's 'digit' or finger to make a connection. The result of the change of state is that current flows along the wire.

All the above examples are of analogue light, and it is the means of their control that distinguishes them from the digital. So let's now look into the digital. The notion of the digital comes from the idea that we can treat objects as being discrete and therefore countable and, since it was with our fingers (our digits) that we began to count them, we have been led to recognise that objects might be represented *digitally*. This notion of the discreteness of things is counterposed to the idea that much of what we actually look at and in other sensory modes hear or feel, exhibits an apparently continuous change in, say, strength (amplitude) or tone (frequency) and can thus be represented by some analogical value in an appropriate measuring scale. The difference between the digital and the analogue is not unlike the difference between the integers and the real numbers. So supposing that this notion of discrete objects—and that we can count them with discrete whole numbers—is what we mean, then it seems to me that the question: 'What is digital light?' can be answered via the act of switching something—in this case light—on and off.

In electrical terms, what digital means is simply switching between two states, one is on (connected), zero is off (disconnected). That's all it means. It comes right back to the telegraph when it was originally developed—by one Charles Morrison of Renfrew, Scotland in 1753 (Mottelay 1922: 208). To send a signal what one did was to take a Leyden Jar, which was your battery, and two pieces of wire. You stuck one end of one of the wires onto the battery and its other end to something that would tell you that a current was flowing (often a small explosive charge), so you were literally just holding the wire onto, or removing it from the battery. The second piece of wire was simply to provide the return to the negative side of the battery. But importantly what is happening is that the wire is carrying pulses of electricity. Over the next eighty years, this action became more sophisticated and evolved into the Morse Key, which does exactly the same thing only now you're pressing the button with your finger, and of course there is that very useful notion of the relation of the digit (as finger) and the number (see fig. 1).

So the telegraph is the first digital process, the first switching of signals on or off. Then, once the electricity supply was strung up through our cities, you have the standard light switch and when you switch the light on at the wall you are performing a digital act (see fig. 2). Now, of course, you can take away the finger and use a piece of electronics to do it. In the early days, with the computers I am about to discuss, you did that with valves. A switching valve is a three electrode device or triode, with a source of electrons (the cathode), a control electrode, which can be switched on or off by an externally supplied voltage, and an electrode that receives the electrons and sends them on their way (see fig. 3). Here one now has electronic switching and this is where binary digital starts in terms of computing. The next stage of this is with transistors, which are essentially exactly the same as triode valves, only much smaller, and we can also control them electronically (see fig. 4). So these become the basis for any kind of digital circuitry.

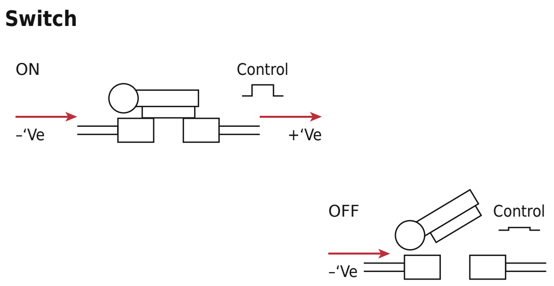

Figure 2. Manual switch. Digital signals are switched between two states: ON and OFF. This can be done manually by using one's 'digit' or finger to flick a switch. The result of the change of state is that current flows to the lamp.

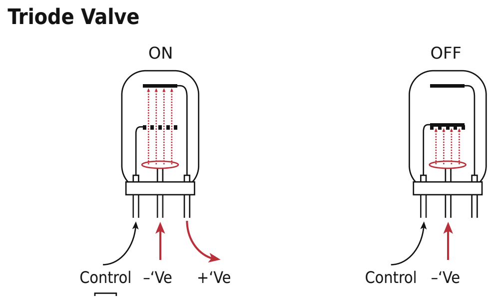

Figure 3. Electron Tube: Digital signals are switched between two states: ON and OFF. This can be done electronically by using a control current to permit the electron flow from the cathode (-'ve) to the anode (+'ve).

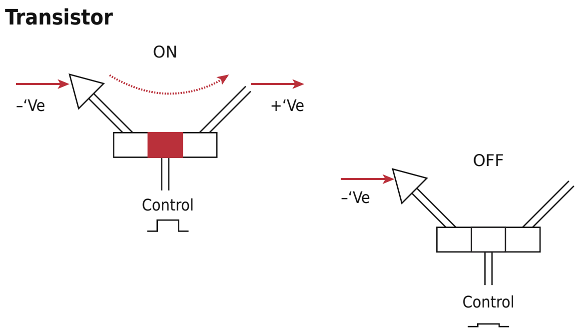

Figure 4. Transistor: Digital signals are switched between two states: ON and OFF. This can be done electronically by using a control current to permit the electron flow from the cathode (-'ve) to the anode (+'ve).

Since the switching has two states it can be used to represent information as binary data. Binary comes from the Chinese via Leibniz, circa 1700. Jesuit diplomats, guests of the Chinese imperial court, sent some documents back to Leibniz because he was an important savant and diplomat in that time. Among them was the *I Ching*, the Chinese prognostication system that uses a six-fold pair of symbols: a broken line, the Receptive (yin), and an unbroken line, the Creative (yang), which could be read as binary; two states. Leibniz was acquainted with combinatorics and recognised that these lines, the hexagrams, produced sixty-four possible results to the throwing of the yarrow sticks (Ryan 1996). He noted that this was a binary number system and that such a system could be used to represent all possible numbers using just two symbols (Leibniz 1703: 85–89).[2] Given that, he went on to establish that all philosophical propositions and thus all philosophical arguments could be represented in symbols which could then be mapped onto binary numbers, allowing them to be tested by mathematical analysis. He proposed a binary calculator at that stage, but it was not implemented.[3]

So binary has a long background. We can use it to count since what happens in numbers is that they come in cycles. If you have a cycle of ten, you count 0, 1, 2, …, 9, and then you have to go up to the next cycle so you add another digit. You do the same with binary, you just add another binary digit or 'bit'. So binary allows you to represent numbers and once you can represent numbers you can represent anything, because you can make agreements with yourself or a larger group of people and say that this particular binary representation means something specific. It doesn't matter what it is; for example, with the evolution of the telegraph came the development of ways of encoding information using sequences of (binary) pulses, something that its original inventor, Morrison, saw as the reason for his experiments. One form of this became the Baudot code, which simply represented the character order in the alphabet as a binary number of 5-bits, and became the basis for ASCII and another, the Morse Code, which represented characters according to their statistical prominence in English. Thus binary could as easily represent a character value in a text document or a colour value in a bit-map.

We can use binary numbers set up as digital control to switch on lights or LEDs much in the same way that any datum is controlled within the logical structure of a digital logic circuit in, for example, a computer. That is, we can digitally control locations in memory and, thereby, store images for display. This is the crux of the matter. This enables Digital Light. It comes about through that kind of control over the production of light that is made possible by some kind of digital electronic device. In other words, light sources that are *switched*, on and off, under digital control. And of course this means that any kind of mechanical, electrical or electronic switch could be called digital because for all classes of digital logic there are two states, on and off. So, if you will allow me, the act of switching a switch on the wall to turn on the light in your lounge room is digital. The finger—the digit—touches the switch and causes it to change state and so the current flows and the light is turned on, or the circuit is broken, the current no longer flows through it and the light goes off. So apart from switching the light on by touching the switch, what we are probably really interested in here is the switching on and off of light sources by the use of some kind of electrically controlled two-state device in which, once either state has been achieved, it remembers that state until another touch of the switch, usually a pulse of control current, flips the switch to its opposite state. This kind of device is often known as a 'flip-flop' and it can consist in a relay or a triode valve or a transistor.

Ultimately it doesn't matter what is doing the switching, the thing about digital light is that the switching is binary, i.e. has two states and that it can be controlled by a third contact, whether that is a finger or an enable line in a logic gate. This gives us digitally controlled current flow. But whence comes the light? Basically any source of heat will produce light, we just need to be able to produce heat that radiates in the visible as well as the infra-red, and that can be switched on and off by an electrically controlled contact. A piece of metal can be heated and will produce light. So a light bulb will do, and if you remember all those early movies about the take over of the world by some 'electronic brain', then the universal sign of a working computer was the little tell-tale lights that winked on and off as it worked through addresses in its memory, with the data changing according to whatever calculation was being carried out. And if one really wants to think of light as being digital, and useful in the sense that it produces, say, images, then memory is essential. What memory does is to store the states of the switches in the computer or other digital electronic machine. The machine's memory contains a map of its state at any instant and of course it can contain the details of what lights (in an array of sufficient resolution) to switch on to make an image. We can display this via an array of lamps, the electron beam in a CRT, or as pixel locations on an LCD, and in answer to my initial question: Digital Light must mean the digital control of the emission of light.

The machine doesn't always have to be a computer. An interesting example of an artwork not driven by a computer, which nevertheless utilises the storage of the states of an array of lamps for its appearance, is David Smith's *Kinetic Kaleidoscope*. It was built in Sydney, Australia, over about a year from 1970–71. It consists of a set of twelve boards, each of which has eight flip-flops set up as a sequential shift register, eight lamp-drivers switched by the state of the flip-flops and the necessary control circuits to set up patterned and random sequences to control the lamps. On its face are the lamps, each with a diffusion screen to even out the filament's bright spot. It could produce all kinds of rippling sequences, shifting blocks, back and forth movements and other patterns. It also offered a degree of interaction in that, by the use of its control panel, one could program it to produce all kinds of controlled kinetic displays (Smith 1972: 59–61; Malina 1974: 157–59). It was probably the first digital electronic artwork made in Australia.

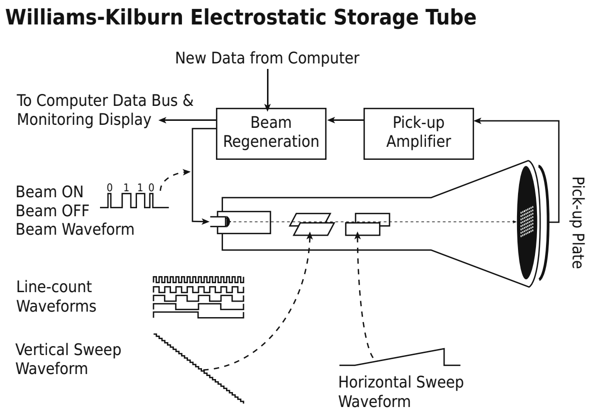

Figure 5. Williams-Kilburn tube Electrostatic Storage Memory. The Line-count and the Vertical Sweep waveforms control the position of the beam spot which is turned on or off by data from the computer. This places a grid of light spots on the screen which last for long enough to be re-generated; and if the Pick-up plate is removed an image can be displayed.

So now I am going to discuss CRTs. The first image produced by an avowedly *digital* electronic device is the image that Tom Kilburn made for his report on the Williams–Kilburn tube, an electrostatic storage device or memory developed at the University of Manchester between 1947–48 (Kilburn 1947) (see fig. 5).[4] It used what are described as 'secondary electrons', or electrons produced by stimulation of the phosphor inside the face of an oscilloscope. While the phosphor primarily produces photons the physical action of the electrons striking the phosphor also produces these secondary electrons, which leak out through the glass face of the tube and can be detected by a metal plate placed in close proximity to the glass of that face. If one taps off the charge that momentarily energises this metal plate and re-circulates it back into the oscilloscope, then timing circuits produced by a computer driving this electrostatic-storage tube can tell the computer the state of a particular location on the tube face while refreshing that state so that it acts as a memory (Williams and Kilburn 1949). Effectively the Williams–Kilburn tube is a form of dynamic RAM but more importantly for us it carries a map of the contents of the computer's memory and if the waveforms utilised by the storage tube are tapped off and used to drive another oscilloscope then we can actually see the contents of memory as a raster or grid (Jones 2011). This is the first bit-map, although its origins can be seen in the Jacquard loom and even before that in the Turkish carpet. But this is the first electronic version and, I argue, it produced the first digital light.[5]

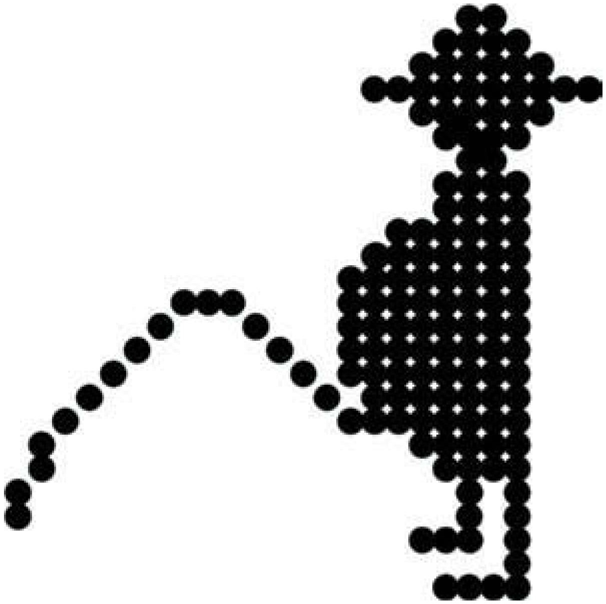

Figure 6. The 'peeing man'. Frame from an animation made by storing the appropriate numbers in the appropriate locations on the face plate of a Williams-Kilburn Tube.

Now, memory is something that is primarily used in computers, and computers are the primary way in which we control the construction and display of digital images (or digital light). The first computer to be built in Australia was the CSIR Mk I, at the CSIRO division of Radiophysics (c.1947–51) on the University of Sydney campus. It was moved to Melbourne in 1956 where it became CSIRAC. The logical design was done by Trevor Pearcey and the hardware design was done by Maston Beard (McCann and Thorne 2000; Deane 1997). It used a different kind of memory known as an acoustic delay-line, but it did use CRTs to display the contents of that memory at the grand resolution of 20 pixels by 16 lines, and it was pretty obvious that if you stored bits at the right locations you could produce a crude image. Given that, the first 'real' (i.e., not done for entertainment purposes) computer graphic produced in Australia was a display of the output of a numerical weather forecasting program written by Ditmar Jenssen for his MSc thesis in meteorology (in 1957). The images are weather maps, the upper one showing the current day's isobars and the lower the isobars for the next day.

The second computer built in Australia was SILLIAC. It was built for the School of Physics at the University of Sydney and was used to do some important work in the physics of the nucleus and in astronomy. It was completed in 1956 and was operated until 1968. It used 40 Williams–Kilburn tubes for memory (giving it 1024 40-bit words), and the operator could tap any word of memory and display it on a monitoring CRT with a resolution of 32 pixels by 32 lines. By filling its memory with the right numbers it could be made to display text. Around 1964 it was replaced by an English Electric KDF-9 and SILLIAC was handed over to the senior computing students who used it for their projects and for entertainment. Of the latter one of the things they did was an animation—done by filling, on a cyclical basis, the appropriate locations in memory with the right numbers. It starts as an outline of a man who lifts his arm and fills himself up with beer, he then puts his arm down and pisses it out (Jones 2011; see fig. 6). It is the only animation that anyone can remember from the time although there were probably more, but its outrageousness did make it memorable.

Vector Display

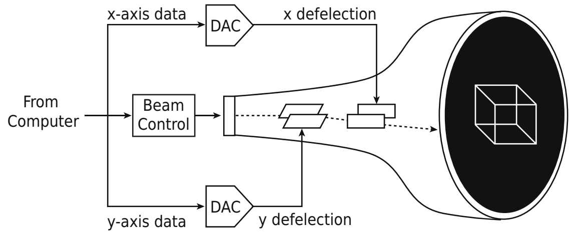

Figure 7. Vector or Calligraphic Display. The beam is pushed directly around the screen according to voltages imposed on the deflection coils by a computer. The images are, thus, line drawings.

So the first digital light produced in Australia came from these two machines. Having established that one could produce images, the next problem was to get a greater resolution and for that, at this period in the history of computing, one had to use a vector (or calligraphic) display. These were CRT displays that functioned more like an oscilloscope and were adapted from the Radar display. They drew by magnetically deflecting the electron beam issuing from the cathode directly around the interior of the tube as it stimulated the phosphor on the inside of the face-plate to give off photons. Thus the vector display inscribed an image in lines onto the face of the CRT (see fig. 7).[6]

Around 1967 the Basser Computing Department of the School of Physics at the University of Sydney, which housed SILLIAC, acquired three other machines, among them being a DEC PDP-8 and its attendant 338 Display, which was a 1024 by 1024 point vector display. It could produce straight and curved lines—which were assembled from short straight lines—at high resolution and in quick succession so that it could build up 3D images and animations more or less in real-time. It took very little computing power to transfer to the display computer (and then onto the screen) the data about where each line or object (an assembly of connected lines) should be. Its limit was that it could only draw lines (vectors) and you couldn't draw shaded areas. But you could produce animated drawings and record them to film.

The PDP-8 and its display were used for projects ranging from scientific visualisation for the Aeronautical Engineering Department at the University of Sydney to animations and still graphics for artists and filmmakers. There was even an attempt to produce TV station IDs with it. The scientific visualisation (produced over 1967–68) was an animation (recorded to 16mm film) of the movement of air molecules at the very low densities encountered at the edge of space and was calculated to show the movement of the molecules as they impacted on each other and the leading edge of an aerofoil. The programming and visualisation were done for Aeronautical Engineering by Doug Richardson of the Computing Department. The different colours of the points representing the molecules indicate the kind of impacts each molecule has undergone. This was the first time anybody had been able to see what was going on, given that you couldn't simulate the molecular densities of the atmosphere at the edge of space with smoke flows in a wind tunnel (Vogenitz et al. 1968).

Previously Richardson had been programming the computing department's KDF-9 to draw on a plotter what are often described as 'Spirograph' type graphics. In 1968 Donald Brook, who was senior lecturer in sculpture at the Fine Arts Department, had recommended to John Bennett, the head of the Computing Department, that he visit the *Cybernetic Serendipity* exhibition at the ICA in London (Reichardt 1968). Bennett returned with a strong interest in the possibilities of computer art and, in 1969, he and Brook decided that they should introduce the use of computers to their students and to the artists at the Fine Arts Workshop (aka the Tin Sheds). So Bennett and Richardson, who was one of Bennett's graduate students, ran a workshop and showed the students and artists of the Tin Sheds what they might do with the computer. However most of the artists felt that it was far too difficult; requiring an understanding of logic and maths that was generally beyond their interest. Consequently Richardson was asked to find out what the artists might need to make it possible for them to use the computer and from the conversations he had he realised that he should write a program that would provide artists with real-time feedback of what they were drawing, rather than having to write and debug a program that described an image (Jones 2011).

So Richardson looked around for a suitable way to do this and settled on Ivan Sutherland's *SketchPad* (Sutherland 1962; 1963a; 1963b), which he re-wrote in PDP-8 assembly language. The project ran over 1970–72 and he then began to make graphics and animations that grew from his mathematical and geometric interests. Importantly he set up the PDP-8 facility as an open shop, inviting anyone who was interested to come and try it out.

Ultimately it was Richardson and Frank Eidlitz, a commercial graphic designer, who worked with the system and produced most of the graphic and animation work. Richardson was interested in the motions of lines and shapes and the evolution of things over time, and his work was generally abstract and spare. His output included many interesting graphics and animations of 3D mathematical objects. Eidlitz had great skill in producing semi-abstract figurative objects with a spare line and multiple layering. The animations were recorded to film using a camera that was controlled by the display computer. But what all of this amounts to is digitally controlled light coming from the display. It is controlled by a computer, which drives the electron beam in the CRT around the screen, and it's that that is doing the drawing.

Other users of Richardson's system included the experimental video collective, Bush Video. Some of them were interested in the mystical symbology of the mandalas of Hindu Tantric geometry and similar graphic material which was also generated on Richardson's PDP-8 system. Along with oscilloscope drawn Lissajous figures, the Tantra images were then used in mixdowns of various videos by Bush Video (Jones, 2013).

Meanwhile in 1972, the dancer Philippa Cullen had been exploring the use of the theremin as an interactive interface to allow dancers to make their own music. She had collected a set of dances notated in Laban notation, which is a complex form of drawn description of the choreography of dance. But she couldn't read the notation, so she asked John Bennett if the computers in the Computing Department could be made to show in figure animation what the notated choreography would look like. This was no trivial process and had never been tried before so Bennett asked one of the department's lecturers, Don Herbison-Evans, to see if he could do it. Herbison-Evans decided that the animation of the dancing figures should be based on the use of ellipses to represent the major parts of the body: torso, arms, legs and head. An ellipse is a circle in which the centre has been divided and the, now two, foci pulled apart. If you use the foci at either end of the ellipse as joints then you can represent the motion of an arm, leg, or torso (Herbison-Evans 1974). This developed into a program called a Numerical Utility Displaying Ellipsoid Solids (NUDES), which could animate the dances Cullen had brought to him (Herbison-Evans 1976). The project ran for some years and in 1983 one half of an animated duet was recorded to film which was then rear projected onto a screen in front of which the dancer danced the other part of the duet. The original performance occurred at the 1983 Australian Computer Conference and in 1985 it was reconstructed using chroma-key techniques at the University of Sydney TV Service (Herbison-Evans 1988).

Several interesting developments in the electronic arts followed, partly from Richardson's initial computer graphic project and from on-going work by Cullen and her collaborators as well as from the general exploration of video. In 1975 Richardson organised an exhibition of much of the computer art, electronic video and sound synthesis, interactive dance and sculpture that was being produced in Australia. The exhibition, called *Computers and Electronics in the Arts* was held in Canberra, over a week in March 1975, as part of *Australia 75, Festival of the Creative Arts and Sciences*. Artists who presented work included Richardson, Cullen and her dancers, Greg Schiemer and Phil Connor, a group led by Iain McLeod from the

Figure 8. Images from the video screens at Australia 75: Computers and Electronics in the Arts. The image is produced by a computer reading and displaying the positions of four dancers on a set of pressure sensitive floors.

Australian National University (ANU) Research School of Physical Sciences, Harvey Dillon, Steven Dunstan and musicians from the Melbourne-based New Music Centre, John Hansen, Ariel and Joseph El Khouri from Bush Video, and Stan Ostoja-Kotkowski.

Due to the breakdown of a computer-controlled patching system built for Cullen by Connor and Schiemer, it became necessary to attach her pressure sensitive floors—another interactive device she had had built—to a DEC PDP-11 and an associated digital frame-buffer that could hold an image of 512 x 512 pixels by 4-bits per pixel (thus R, G, B and Intensity). The frame-buffer had originally been built by the ANU team to assist its work in Landsat image interpretation but was brought along to the exhibition to show off a paint package and drawing tablet that they had also developed (Ellyard and Macleod 1975). The situation led to the PDP-11 being enlisted to read the signals from the floors through its Analogue to Digital Converter (ADC), and to generate an image in the frame-buffer of the recent history of the dancers' movements on the floors. The RGB signals from the frame-buffer were then sent to John Hansen's video synthesiser and mixed with live camera images of the performance, and the whole spontaneous collaboration is an early example of interactive video and the use of digital images to generate video light (see fig. 8).

After the Canberra show, Hansen returned to Melbourne and continued to work in image synthesis, building a second video synthesiser that used one of the newly available Intel 8080 microprocessor chips to control the ADC and the signal patching. The project then evolved into a computer graphics system based on the vector techniques of computer-aided design applications. Over the next few years he and his colleague, Chris Ellyard, whom he had met in Canberra, assembled a 2D drawing and paint program called Conjure. It originally ran on a Z80-based Matrox graphics card system and then in 1982 was ported to an IBM PC-XT. The images were stored as lists of vectors in the computer so that they were scale independent and the results could be rasterised for video display. With this approach the displayed graphic was a bit-map but the source was still vectors and shading was not easy (see fig. 9). However, as with 3D graphics the vectors are where you do the work and then you project the results onto the 2D plane, and the rasteriser performed that projection. Conjure's main output formats thus became video and corporate A-V slide production (Hansen 1998), and while Hansen's work is fairly early we all know what can happen given all the developments that have taken place since then. One small example is the use of Conjure in music videos that were made through Heuristic Video, an independent and experimental post-production facility in Sydney.

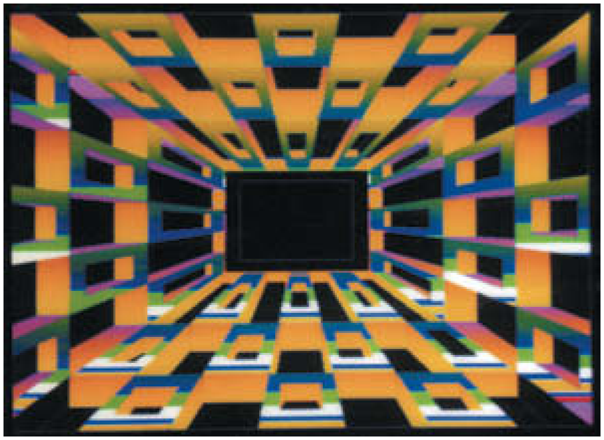

Figure 9. Image produced on the Conjure system for raster display. Calculations could be scaled to either a video raster display card or to a film recorder for slide production. Courtesy of Martha McKelvey.

I want to briefly mention two other developments. One is the appearance of the Silicon Graphics IRIS system and the purchase of two of them by the Video Paint Brush Company (VPB) in Melbourne in 1983–84. They used animation software from Wavefront which, interestingly enough, given our topic 'was named after the term which describes the front edge of a wave of light' (Carlson n.d.) on the IRIS machines. The IRIS machines were rapidly followed by the Quantel Paintbox. Both systems were used to produce TV commercials and some computer art. Some of the operators were Jean-Marc le Pechoux (who established the company), Sally Pryor, Andrew Quinn and Jon McCormack, all of whom had trained at the Swinburne Institute of Technology and Felicity Coonan who worked at the Sydney branch. Artists who used the systems at VPB included Jill Scott.

The other development is Tom Ellard's work with the Amiga 1000. His band Severed Heads was established in 1979 and he worked with some of the very early domestic computers including the Commodore 64. Around 1983 he teamed up with the author to produce video clips for the band and in 1986 began to use the Commodore Amiga 1000 in that project (Ellard 1998). The Amiga was an especially important domestic level computer because of its innovative architecture. Commodore developed two special purpose integrated circuits and the bus architecture placed the image memory in the same address structure as the microprocessor's memory. With the aid of the *Agnes* address generator chip, the *Denise* graphics chip had direct access to the image memory and this meant that getting a reasonable resolution graphic animation out of the machine could be done in real-time, making

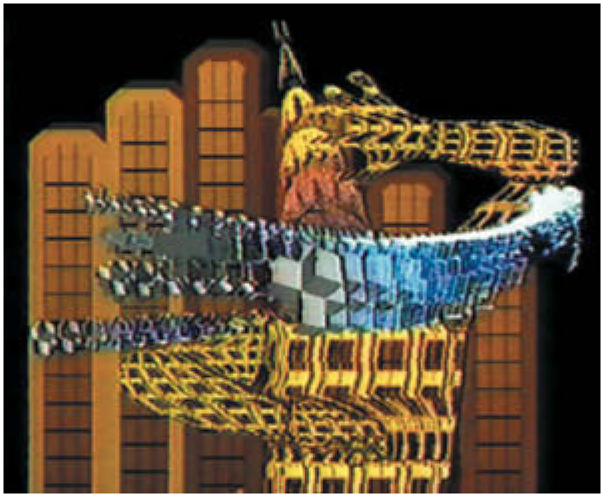

Figure 10. Image produced on the Amiga 1000 and the Conjure at Heuristic Video. Courtesy of Tom Ellard.

it excellent for use in video animation and titling, and making clips at Heuristic Video for Severed Heads (sometimes in conjunction with their Conjure system). The software that Ellard initially used was D-Paint II and this gave him the facility to create some quite complex 2D modelling with the capacity to translate and rotate images around the screen (see fig. 10). Together we produced a considerable number of video clips using all sorts of devices ranging from the second of my video synthesisers to a Richmond Hill vision mixing desk with upstream re-entry, the Conjure system and of course the Amiga 1000 which was later replaced by an Amiga 2000. It wasn't important in the Severed Heads work what kind of machine, analogue or digital, produced the visuals just that they worked with the ideas and melodic structure of the music that Ellard recorded.

So finally, in answer to my opening question: What is Digital Light? I argue that it is simply image-producing light that is organised by and controlled through the use of digital electronics, particularly computers. The key idea is the digital switch and its potential to function as a storage device in which a signal controls the switching on of a light source.

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Notes

1. For images see 'Translab[4]: Algorithm & Code / VI. Visual Aesthetics In Early Computing (1950–80).' http://translab.burundi.sk/code/vzx/.
2. Leibniz comments: 'But in lieu of the progression of tens in tens, I have employed for several years the simplest progression of all, which goes by two in twos, having found that it offers a basis for the perfection of the science of Numbers. In this manner I do not use characters other than 0 and 1, and then on reaching two, I recommence. This is why two is written as 10, and two times two or four as 100, and two times four or eight as 1000, and two times eight or sixteen as 10000, and so on' (quoted in Gerhardt 1962: 224; translated by Stephen Jones).
3. Leibniz's discussion of the binary in philosophy and the binary calculator is covered in Leibniz (1679) and mentioned in Swetz (2003).
4. The Williams-Kilburn tube memory storage device was used in the first 'stored-program' computer, which was being built at the University of Manchester under the direction of Max Newman and called the Small-Scale Experimental Machine (SSEM). It became the Manchester Baby for which Alan Turing wrote many of the programs and grew into the Manchester Mark 1 which was commercialised as the Ferranti Mark 1*. From that follows the history of computing.
5. Oddly enough television in its original form was also digital but we'll leave that to another discussion.
6. We should note that the kind of display we call a TV or 'raster' monitor is in fact just a very carefully controlled vector display in which the image is embedded as changes in the amount of current flowing from the cathode onto the phosphor.

CHAPTER 5

Lillian Schwartz and Digital Art at Bell Laboratories, 1965–1984[1]

Carolyn L. Kane

That digital computing was ever used to produce luminous colours in something called ‘computer art’, and later ‘digital imaging’ or ‘graphic design’, was never foreseen in the blueprints of the former number-crunching and statistic-processing devices. And yet, due to unexpected collaborations between artists, programmers, and computer scientists, places like AT&T’s Bell Laboratories produced a prolific number of innovative digital art and experimental colour systems between 1965 and 1984. However, due to government regulation, at Bell Labs this work was in certain cases hidden from public view and at times, denied altogether. Paradoxically, in 1984, when AT&T lifted its restrictions on creative work not related to telephone technologies, the atmosphere had changed so dramatically that despite the relaxed regulation, cutting-edge projects had already been abandoned. This chapter focuses on the digital art made at Bell Labs between 1965 and 1984, including the struggles encountered in interdisciplinary collaborations—between visionary artists like Lillian Schwartz and computer scientists like Ken Knowlton and A. Michael Noll—and the challenge to use new computing technology to make experimental art during this unique time period, only now being restored to the history of new media art.

Bell Telephone Laboratories

Since 1899, AT&T (formerly Bell Telephone Laboratories) had been a shareholder-owned public utility service. AT&T made an agreement with the government to connect independent telephone companies to its network and refrain from competitive or commercial endeavours. However, in 1949 an anti-trust suit was filed against AT&T. This led to a 1956 consent decree between AT&T and the Department of Justice whereby AT&T agreed more explicitly to ‘restrict its activities to the regulated business of the national telephone system and government work’ (AT&T 2005). While this decree stipulated that AT&T (at the time still known as Bell Telephone Laboratories) limit its research to telephone communications, the company was ultimately shielded from market pressures which, on the level of research, amounted to freedom in research endeavours. In the words of Mervin Kelly, one of many open-minded and innovative presidents at Bell Labs during this era, the laboratory was ‘an institute of creative technology’.[2] Or, in the words of Bell Labs’ then Acoustical and Behavioral Research Center Director, Max Mathews, ‘We had a freedom that few places had. Unlike at universities, where everyone seems to be competing with each other for scarce resources, we could cooperate. It made it a very pleasant place to work as well as richly productive’ (Kurcewicz).

This openness and freedom from market pressures, or ‘golden era’ at the Labs as computer scientist A. Michael Noll refers to it, lasted until 1984 when a second antitrust suit was settled wherein AT&T agreed to give up its monopoly on the telephone systems and compete in the marketplace with other communications companies. After this juncture, ‘the Bell System was dead’. AT&T and seven regional Bell operating companies (the RBOCs) replaced it. In exchange, the U.S. Department of Justice agreed to lift the constraints of the 1956 decree, thus allowing research at the Labs to be conducted in areas not restricted to the telephone, such as emerging media (Kurcewicz). At the same time, because AT&T now had to compete commercially, profit became a primary goal. As a result, experimental musician and composer Laurie Spiegel, who worked at the labs in the 1960s and 1970s, explains, ‘… a lot of pure research with questionable long-term economic benefit went by the wayside in favor of things that would bring in revenue … [the Labs] had to sell stock and compete with each in the market and fund their own research…’. Thus many of the visionary pioneers left, such as Michael Noll and Ken Knowlton, and new people came in who were ‘not the self-motivated type’ as before, but who could instead ‘be assigned to a project that management thought was a good thing to do’. After 1984, just when research into emerging media forms was legitimated, very few visionaries were left to push it in new and creative directions. Even according to AT&T, their ‘top 10 innovations’ were made prior to 1984. Under these conditions, between 1956 and 1984, researchers at the Labs enjoyed a great amount of freedom and leeway in the activities and projects they chose to pursue (Kurcewicz; Kane 2008a).

Furthermore, the end of World War II brought fresh talent, new technologies and a sense of future optimism to the United States and to Bell Labs in particular. During this time a prolific amount of innovative experimentation was conducted in a relatively open environment, laying the foundation for ‘computer art’, or simply, what has become known as new media aesthetics, a project that began ‘on the side’ of the official research projects. As Ken Knowlton describes it, ‘practitioners’ at the Labs were ‘tethered on long leashes if at all … earnestly seeking enigmatic solutions to arcane puzzles. What happened there would have baffled millions of telephone subscribers who, knowingly or not, agreeably or not, supported the quiet circus’ (Knowlton 2005: 8).

Many of the exciting crossovers between computing and art that began in the 1960s can be attributed to electrical engineer Billy Klüver, then positioned at Bell Labs in the Communication Research Department and co-founder of E.A.T. (Experiments in Art and Technology), along with Fred Waldhauer (who was also on staff at the Labs from 1956 to 1987) and artists Robert Rauschenberg and Robert Whitman. For E.A.T.’s infamous *9 Evenings*: *Theatre and Engineering* performances, held at Manhattan’s 69th Regiment Armory in October of 1966, Klüver set up collaborations between many of the Labs’ engineers including Béla Julesz, Max Mathews, John Pierce, Manfred Schroeder, and experimentally minded artists John Cage, Merce Cunningham, Andy Warhol, Deborah Hay, and Steve Paxton. Klüver had been promoting artist-engineer collaborations by ‘courting downtown New York artists for some time’, Fred Turner notes, and by 1966, ‘by his own estimate [he] had taken perhaps a hundred artists on tours of Bell Labs’ (Hultén and Königsberg 1966; Turner 2008: 19).

In sum, the surplus of post-war computing technology, influx of talent to the Labs, and freedom from market pressures, in conjunction with the culture of the late 1960s presented to many the necessary ingredients for an optimism and visionary outlook on the future; a world of human and machine fusions characterized by an aesthetic of vibrant, electric colours fuelled by cybernetic systems that would lead to positive changes for the future of humankind. With the aid of electronic technologies, both new and yet to be formed, many people believed that a new ecological consciousness would connect all of humanity in what Marshall McLuhan coined a techno-tribal 'global village'. Much of this decade's magic and innervation constellated at Bell Laboratories, as this chapter addresses.

At the same time, there were a few instances when this leeway and freedom was tested. As long as news of these nonofficial, on-the-side experimental and artistic pursuits with colour and visual computing did not get back to certain bureaucratic sectors of the Labs' management, many employees, including several prominent department heads, supported and gave significant leeway to what they perceived as good-spirited endeavours.

It is possible that new media technologies would have progressed in directions more fruitful for both Bell Labs and those involved if the creative 'artwork' of the artists and researchers of the 1960s and 1970s had been more widely known and acknowledged. This, however, was not the case. Their brief moment has passed, and today these works are only now being recognized in restorative histories and related media archaeologies. A fuller understanding of the conditions and challenges that faced the creators of these unique and ephemeral productions serves to enrich mainstream histories of digital art and new media. In particular, in this chapter I focus on key computer artworks created by artist and long-time 'resident visitor' at Bell Labs, Lillian Schwartz, who worked on computer films and visual art at the Labs for the most part concealed from public view.

There were occasional screenings of Schwartz's work and some artists caught wind of what was going on at Bell Labs. One such artist was Salvador Dalí.

Interlude with Salvador Dalí

One day in 1970, American graphic artist, sculptor, and painter, Lillian Schwartz (born in 1927) answered the telephone in her New Jersey home (Schwartz and Schwartz 1992: 4–5; 10). The man on the other end mysteriously identified himself as 'Salvador Dalí's Major'. A prank call she assumed. But then the voice told her to be at the St. Regis Hotel at 7:30 that evening and to 'dress in your most beautiful gown' (Schwartz *LIL*: Chapter V, 15–16).

The Major found Schwartz in the lobby fifteen minutes early, accompanied by her son and a disguised German TV crew prepared to audiotape the exchange. She wore her 'colored striped knitted gown' and 'long pink and purple Mylar earrings'. The Major (Dalí's business man) was wearing a full military outfit because Dalí felt safer around the military. He escorted them into a darkened hall where Dalí was seated on a throne wearing 'black tails, a silk top-hat, and black cape lined with white satin'. He was surrounded by blonds in equally spectacular flowing white crepe dresses. When Schwartz came in, Dalí stood up, ‘adjusted his cape, twirled his moustache’ and walked towards her ‘with his cane pointing straight in front of him’. He motioned for her entourage to sit down behind her and then signalled for her to sit in a chair closer to his throne. He marched over to the table beside her chair where a man appeared with three white boxes. He talked rapidly in French and Spanish and the man interpreted: ‘Dalí said he had received messages through his moustache, his antennae, that you and he would work together on four projects’ (Schwartz *LIL*: Chapter V, 17–18).

Only one of these projects panned out, the subject of the first white box. Dalí pushed this now open box towards her with his cane. He talked again in two languages. The interpreter explained, ‘Dalí wants you to examine the pen in the box, you may pick up the pen, but you must keep the cotton under it and not touch the pen’. Dalí’s voice became louder and faster. The little man continued to decode, ‘Turn the pen in different directions. Dalí wants you to see the wonderful sparks, the gleaming, and the rays of light shooting off and out of the pen. He wants you to videotape this pen. He knows the results will be spectacular, magnificent bursts of light’ (Schwartz *LIL*: Chapter V, 17–18).

Schwartz suggested that the particular candle lighting in the room was responsible for the gleam off the surface of the pen. This comment triggered Dalí into volatile tirade of ‘Spanish, French, and some English’. But then he suddenly changed tones. The translator imparted, ‘Dalí wants you to know that he urinated on this pen every morning for one year. The encrustation, the crystals on the pen catch the light like diamonds. He wants you to record this pen, to make a tape that will catch the brilliance of this phenomenon and give it permanence. Dalí’s creation will be a great visual experience. It is your job to make a permanent record’ (Schwartz *LIL*: Chapter V, 17–22).

Also that night, Dalí took Schwartz upstairs to show her his ‘jewels’, a collection of live miniature beetles and insects crawling on stones. When she realized that these little black dots were alive, she recalls feeling an ‘eerie sensation that my hand was cut open and ants were crawling out, just as in Dalí’s painting’. Dalí wanted Schwartz to create many extraordinary projects for him. However, for various reasons she denied the requests for the other projects, save for the video of the urinated pen, which, she reports, turned out better than she expected (Schwartz *LIL*: Chapter V, 20–21).

But what was it about this relatively unknown artist that caught and sustained Dalí’s attention? Dalí’s work was from another era in art history: Modernism and its grand epoch of the genius artist, now threatened by the advent of computer art.

In contrast, Schwartz' work, like others at the time, was focused on the future. The new art spoke to unknown alliances between humans and electronic machines. Many could not yet understand how or what this new breed of computer artists were up to, yet they at least recognized that there was something powerful and visionary in their work. One other such person was Bell Labs' engineer, Leon Harmon.

Figure 1. Metal catalogue cover from Pontus Hultén's 1968 landmark exhibition, The Machine as Seen at the End of the Mechanical Age. The exhibition was in part supported by Experiments in Art and Technology (E.A.T.) and held at New York's The Museum of Modern Art from 25 November, 1968 through 9 February, 1969.

The Machine at the End of the Mechanical Age

Leon Harmon met Lillian Schwartz at the opening of Pontus Hultén's 1968 landmark exhibition, *The Machine as Seen at the End of the Mechanical Age*, an exhibition supported in part by Experiments in Art and Technology (E.A.T.) and held at the New York Museum of Modern Art from 25 November, 1968 through 9 February, 1969 (Schwartz *LIL*: Chapter V, 1; see fig. 1).

On display at the opening night of the MoMA exhibition was Leon Harmon and Kenneth C. Knowlton's important entry: *Studies in Perception No. 1* (1966), dubbed the 'Nude': a 5 by 12-foot computer-generated nude made in one of the first computer graphic languages made for raster film, BEFLIX (an acronym for Bell Flicks) (see fig. 2). BEFLIX was the first specialized computer animation language written to produce mosaic composition languages, or simply, a computer language that could be used for pixel animation and bitmap sequences (Youngblood 1970: 246). Knowlton wrote BEFLIX in 1963 using a high-level set of macro-instructions or MACRO-FAP, FAP was the machine language native to the IBM 7094 machine that they were using at the time and MACRO-FAP indicated an additional ability to, as Knowlton puts it, 'accept a definition of a common sequence of operations, for example, you could write min(a,b,c) to establish the value of the smallest of three numbers instead of writing each time the required sequence of half a dozen FAP instructions' (Knowlton 1964; Kane 2008b; Carlson 2003a).[3] BEFLIX was capable of drawing straight lines from dots, drawing curves, copying regions, moving regions, doing a solid fill in specific areas, zooming in specific area, and dissolves and image transitions. After writing the programming language and using it to compose *Studies in Perception No. 1*, Knowlton output the piece in eight sections, using a Stromberg-Carlson 4020 printer. At the time, each minute of output cost approximately $500 (Reichardt 1971: 77; Kane 2008b; Youngblood 1970: 246).

The final *Studies in Perception No. 1* image consisted of many tiny electronic symbols including multiplication and division signs, transistors, zener diodes, vacuum tubes, resistors, tape reels, and writing crossovers used to compose 11 x 11 arrays. The genius of the piece was the visual effect it created wherein, when viewed close up, it consisted of thousands of these tiny black and white symbols, but when viewed from a distance, another picture to come into view: a 12-foot female nude. Programming was complex and involved many tedious hours plotting numbers on graph paper, transferring them to punch cards, taking the punch cards down to the processor room, waiting in line, feeding the cards through the processor, and finally, returning the next day or later to see what you got. Often referred to as 'blind programming', one didn't see what one had until the end of cycle, at which point, one usually saw errors and had to repeat the entire process.

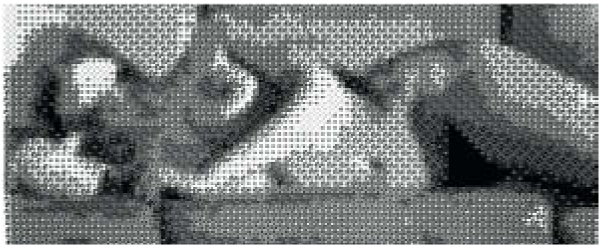

Figure 2. Leon Harmon and Kenneth C. Knowlton. 'Nude', or Studies in Perception #1 (1967), featured in the MoMA's Machine Show. Bell Labs demanded that the artists dissociate the work from the Labs, until it appeared on the front cover of The New York Times, when they changed their original directive. Image courtesy of Ken Knowlton.

At the MoMA exhibition, Harmon was intrigued by Schwartz's entry, *Proxima Centauri* (1968) (Schwartz *LIL*: Chapter V, 1), engineered by Dutch born Per Biorn. Biorn began working with artists during E.A.T.'s infamous *Nine Evenings* held at the armory in 1966 (Experiments in Art and Technology 1998: 7; Biorn; Schwartz 1969). *Proxima*, unlike the nude, was a mechanical and kinetic light-based sculpture, perched on a 55" x 30" x 30" black plastic base with a white translucent dome on top. The guts consisted of an old singer sewing machine and proximity detector pads so when it was approached by a viewer, four switches turned on a motor that lowered the dome as it changed colour from blue to red. There was also a projector located inside the black box which automatically alternated between eighty-one abstract slides projected onto a mirror that reflected the image onto the interior surface of the frosted dome, also mediated through a water-filled ripple tank. The tank was agitated for five seconds every minute, allowing the image to appear to settle before moving to the next one (Biorn; Coffey 1984; Schwartz 'Description of *Proxima Centauri*'; Schwartz 'Mechanical to Electrical Computer').

Despite the complex mechanical setup, from the viewer's perspective, the piece appears simple and elegant. When reassembling *Proxima* during my archival research in 2008, I found it remarkable that the complex set-up had been entirely concealed behind a plain black façade and white dome. Its hidden technical sophistication enhanced the careful game of hide-and-seek that it played with visitors: as one approaches the dome, it turned from a luminous blue into an alarmed red and began to sink back down into a hidden position in its base, remerging as a calm blue only when the viewer walked away.

In comparison to Harmon and Knowlton's black and white computer generated nude, the two pieces in the MoMA exhibition could not be more different. The former, while it was based in complicated mathematics and a pioneering project in digital graphics and optical perception, nonetheless consisted of static, geometric, and black and white monochrome characters printed on flat white paper. In contrast, *Proxima* was a kinetic sculpture, mechanically engineered, ushering out the 'end of the mechanical age' in luminous colour. Where the former was technically progressive and computationally innovative, the latter was aesthetically in tune with avant-garde techniques for colour in film and multi-sensory media. On this evening of mutual fascination and intrigue, the two worlds came together. That night Leon Harmon invited Lillian Schwartz to visit New Jersey's Bell Laboratories the following Thursday, after which she remained at the Labs for several years, working on computer art and colour experiments in digital computing (Schwartz *LIL*: Chapter V, 4).

Confrontations with the Labs' 'Computer Art'

As noted, as long as news of these nonofficial, on-the-side experimental and artistic pursuits did not get back to certain bureaucratic sectors of the Labs' management, many employees, including several prominent department heads, supported and gave significant leeway to what they perceived as good-spirited endeavours. There were however a few instances when this leeway was tested. In 1968, for instance, when Michael Noll was working on the picture phone (a precursor to such products as video Skype or iChat), he accepted an invitation to use the device in a sequence

Figure 3. A. Michael Noll's picture phone in phone booth, featured in Stanley Kubrick's *2001: A Space Odyssey* (1968), daringly bearing the 1968 Bell Labs logo.

of Stanley Kubrick's landmark film, *2001: A Space Odyssey* (1968). Despite the movie's futuristic edge, when news of the scene got back to the Labs, 'AT&T was furious' because the public relations department deeply opposed the Labs being associated with commercial media (Kane 2008c; see fig. 3).

Another instance occurred earlier, in 1965, when the Howard Wise Gallery asked Noll and Labs' researcher and scientist Béla Julesz to hang some of their work, some of the first computer generated images ever produced, in their upcoming art exhibition, *'Computer-Generated Pictures'*. Once the Labs caught wind of the event they 'made an effort to halt the exhibit' but it was too late. The Labs thus instructed Noll and Julesz to take out a copyright on the pictures in their own names so the 'art' would not be associated with the Labs. However, the Library of Congress refused to grant the copyright to them 'since a machine had generated the work' and this, the Library of Congress informed them, was 'not acceptable'. Noll explained to the LOC that it was humans who programmed the machine. This explanation failed. In a third attempt he finally received the copyright (Noll 1994: 41). Noll is also quick to note that while the piece was not issued a copyright until 1965, it was 'actually made in 1962', making it, not the computer art produced by the Germans, Noll is proud to report, the first work of computer art (Kane 2008c). Computer historian Margit Rosen suggests, however, that there is no known date or 'birth year' for the origins of computer art, as there is with photography and film, 'however fictitious such dates may be'. Nonetheless, she also observes that in 1960, Kurd Alseben with physicist Cord Passow drew four plotter drawings using an analogue computer at the German Electron-Synchotron research centre in Hamburg, throwing the origin date into question once again (Rosen 2011: 9). Regardless, Noll's encounter with the LOC illustrates the foreignness of using computers to create 'art' during this era. And thus, while this kind of work has since become banal and naturalized in contemporary imaging, and to a large degree invisible (hence the reason why we no longer refer to such work as 'Computer Art', but instead as 'Art', 'Design' or 'New Media Art' at best), it is nonetheless important to observe how radically different this perspective on computer art was only a few decades ago where the term itself was rejected on multiple levels not only within certain sectors of Bell Labs, but also beyond it, in the art world and aesthetic practices in general.[4]

Yet another example of these tensions between management and computer art, involved Knowlton's and Harmon's 'Nude'. Originally made as a joke for one their colleagues and pasted to his office wall while he was away, when the public relations department at Bell Labs caught glimpse of the image, 'They scowled and warned if you must "circulate this thing be sure that you do NOT associate the name of Bell Labs with it."' Nonetheless, shortly after the warning memo was issued, the nude debuted at Robert Rauschenberg's loft for an E.A.T. press conference. The next morning, it appeared on the first page of the second section of *The New York Times*, which, Knowlton notes, 'made not the slightest effort to conceal its birthplace' (Knowlton 2005: 10). After the 'Nude's' public debut, the Labs management sent a revised statement: 'You may indeed distribute and display it, but be sure that you let people know that it was produced at Bell Telephone Laboratories, Inc'. Knowlton suggests the dramatic change in attitude was due to the 'venerable' status of *The New York Times*, not an acceptance of the fact that the Labs' resources were being allotted to 'computer art' (Knowlton 2005: 11). At any rate, Knowlton had by this time learned to tell people that his computer art was 'made in the research lab of a large, nation-wide telephone company that wishes to remain anonymous' (Kane 2008a; see fig. 2).

Lillian Schwartz at Bell Labs

While at Bell Laboratories, Lillian Schwartz worked with Kenneth Knowlton. In this section, I discuss two computer art pieces produced during this time: *UFOs* (1971) and *Enigma* (1972) (Schwartz and Schwartz 1992: 152 and 166; Rush 1999: 176–77; Lehmann 1972; City University of New York 1975: 4 and 6).

Gene Youngblood's foundational text, *Expanded Cinema* (1970) defined the radical art movements and practices emerging in the 1960s and 1970s. The art he analyzed was synaesthetic, cosmic, colourful, and mystical, seeking to integrate computers and electronic circuits with human cognition and sense perception. While *UFOs* and *Enigma* are not mentioned in Youngblood's otherwise comprehensive text, I show here how they nonetheless speak directly to and within this once expanding perceptual field.

UFOs and *Enigma* accomplished several things for colour in early computing: the integration of colour techniques from painting and graphic design; the use of optical science and studies in perception in computer art; and third, an exploration of humans and machines as analogous yet distinct drawing and perceiving systems. *UFOs* begins with an upbeat, quick pace. Images of solid circles and half-moon graphics flash on and off the screen in red, yellow, blue, and green, alternating between colours. Occasionally the images appear to overlap or they are overlaid with other computer-generated, horizontal lines. Soon enough the pace quickens to the psychedelic sound track created by Emmanuel Ghent and the coloured shapes become animated to such a rapid speed that one looses track of which colour one is looking at (Vogel in Schwartz *LIL*: Chapter VI, 7–9; Schwartz *LIL*: Chapter VI: 5; Digital Art Museum). Both luminous colour and music gain acceleration, becoming so intense that the image transforms into something else, something hypnotic and alien, but alien to what it is still unclear.

While editing *UFOs* in 1971, Schwartz found an editing technique that *increased* colour saturation. She found that inserting a black frame between every four coloured ones helped to 'keep the viewer's eyes refreshed' while the black frames remained 'undetected during projection' (Schwartz and Schwartz 1992: 114). After a 1972 screening of *UFOs* at the Whitney Museum of American Art, audience members reported hallucinations and headaches and in one case 'uncrossed a case of chronically crossed eyes' (Schwartz and Schwartz 1992: 115). The computer film, as explained in the Whitney's 1972 press release for the 'New American Filmmakers Series', employed the computer to create a 'nearly subliminal experience of abstract reality. The stroboscopic spheres in the second half … have been specifically created to affect the viewer's brain rhythm and induce a mild state of alpha consciousness' (Whitney Museum of American Art 1972: 8).

The Whitney's description is significant because it points to an important and often overlooked connection between the expanded cinema and human neurology. Alpha waves are meditative and associated with idleness, relaxation, and synchronized and coherent neural activity; oscillating within a frequency range of 8–12

Hertz. In contrast, beta waves are associated with normal neural activity, which is also to say more active mental activity and they run between 12 and 30 Hertz (Geiger 2003). Television's radiant light (and by extension a computer screen) can induce a mild state of alpha consciousness, as observed in McLuhan's analysis of television as a cool medium, or in artworks like Nam June Paik's *Zen TV* (1965) (Moore 2001: 61–63). And thus, when McLuhan claimed that television was an extension of our central nervous system, creating an auto-amputation or, 'narcissistic trance', neurologically, he was correct. Moreover the fact that electronic colour transmissions (regardless of content) induce a mild state of alpha consciousness further supports McLuhan's dictum that the medium *is* in fact the message, not to mention Nietzsche's claim, contra Wagner, that after 1900 aesthetics had become nothing but 'applied physiology' (Nietzsche [1895] 2001: 104).

Accordingly, *UFOs* asks how normative (human) perception can be expanded to see what is *already* in computation, but not yet known or visible? And thus there is something both foreign and welcoming about it. *UFOs* is disarming and strange; an assault on visual perception and traditional modes of cinematic viewing, using visual effects that were not uncommon at the time.[5] And this is perhaps why Bob Lehmann in 1972 wrote of *UFOs*, 'It is strange to feel your body physically moving, directed only by the gravitational effect of a moving two dimentional image … In addition to being creative, inventive and extremely colorful, the manipulating of the mind that goes on in some of the films of Schwartz and Knowlton is interesting and even a bit frightening' (Lehmann 1972: 6). In 1971, critic Amos Vogel wrote that the 'stroboscopic effects' in *UFOs* were 'unsettling'. 'Even more ominously', he continues, 'while [its] design and action are programmed by humans, the *result* in any particular sequence is neither entirely predictable … being created at a rate faster and in concatenations more complex than eye and mind can follow or initiate' (quoted in Schwartz *LIL*: Chapter VI, 7–9). *UFOs*, like many Op Art works at the time, perceptually trains audiences for increasingly rapid visual experiences, ones that have become more and more common in recent years.[6]

UFOs achieved a breakthrough in editing and effects research. It not only introduced a new style and colour technique that digital videos and commercials now mimic, but also, it brought colour into a medium that did not have it. This was done in two ways. The first was the use of optical techniques to intensify the colours through black frame inserts. The black frames functioned on the level of subjective perception, providing a temporary reprieve for the eyes, which allowed the other colours to stay crisp and fresh. In reference to a later but very similar computer art film, *Googoplex*, Bob Lehmann explains, 'Schwartz and Knowlton have gone further in that they activate the brain to receive this black and white film in color and also, apparently, alert the brain to follow a mathematical progression which I interpreted to be creating a new (deciphering a lost?) language' (Lehmann 1972: 6). Indeed, a new 'language' that learns to speak or more appropriately, teaches viewers to 'scan' the logic of computation in visual form. Second, colour was brought into the work using colour alteration techniques common in avant-garde and experimental film practices (Schwartz and Schwartz 1992: 115). In order to fully appreciate the first—the adaptation of optical research into computer art—I will discuss the 1972 computer art film, *Enigma*.

In *Enigma*, a series of black and white checkered, striped, and patterned squares flash on and off the screen. Eventually colour appears *within* and *in between* the black and white images. These colours are much softer than the bold and intense hues of *UFOs*, painted in calm but self-assured muted primary colours (reds, greens, and blues). At first the speed of the colour animation seems slower than *UFOs*, but eventually the black and white stripes begin to move fast, too fast to focus on any single one.

For this piece Schwartz drew on the techniques from Polaroid's co-founder Edwin H. Land (Schwartz and Schwartz 1992: 116), then giving lectures on colour perception at the Labs (*Googolplex* [1972] was also based on Land's experiments to affect the viewer's sensory perceptions) (Schwartz 'Selected Art Films'). The goal was to produce an animated digital work that integrated experimental research in optics and simulated the perceptual effects of colour intensification (Schwartz and Schwartz 1992: 116). The result was *Enigma*:

> *Enigma* created the illusion of saturated colors even though it was shot in black and white. Dark frames and texture frames were inserted in a determined order in the black and white section of *Enigma* to provoke color … Color replaced the black-and white sequences in the same order as those provoked by the black-and-white sequences, resulting in the maintenance of a more saturated appearance of colors … If the lines moved and intersected enough, an observer would start to perceive saturated colors between the lines. (Schwartz and Schwartz 1992: 114; 116)

While the application of this effect into computer art was new, the effect itself was not. As noted, inspiration for *Enigma* came from the research on colour perception produced by Land, who was in turn influenced by nineteenth century physicist James Clerk Maxwell whose childhood toy—a spinning top—produced the same phenomenon of optical colour mixing. Second, Maxwell's colour experiments are in fact attributed to Goethe who, in his landmark *Theory of Colours* (1810), prioritized subjective colour mixing over Newton's objective colour analysis (see fig. 4). Goethe proposed the 'edge theory' of colour, a thesis that correctly argued that colour is not *in* light, but in fact emerges *in between* black and white, a hypothesis that actually originates with Aristotle, who argued that 'all hue is to be considered as half light, since it is in every case lighter than black and darker than white' (Gowing 1978: 55). In the nineteenth century, Maxwell and his peers, including Hermann von Helmholtz and Gustav Fechner, were inspired by Goethe's work, as were the Op and light artists in the twentieth century. What appealed to them in Goethe's colour theory was the way in which colour was seen and theorized on the *edges* of perception, and thus visual experience became highly subjective. Subjective perception and optical colour theories remained à la mode in avant-garde film and computer art throughout the 1960s and 1970s. However, as I argue elsewhere, by the 1990s and 2000s these subjective techniques fall out of fashion.[7]

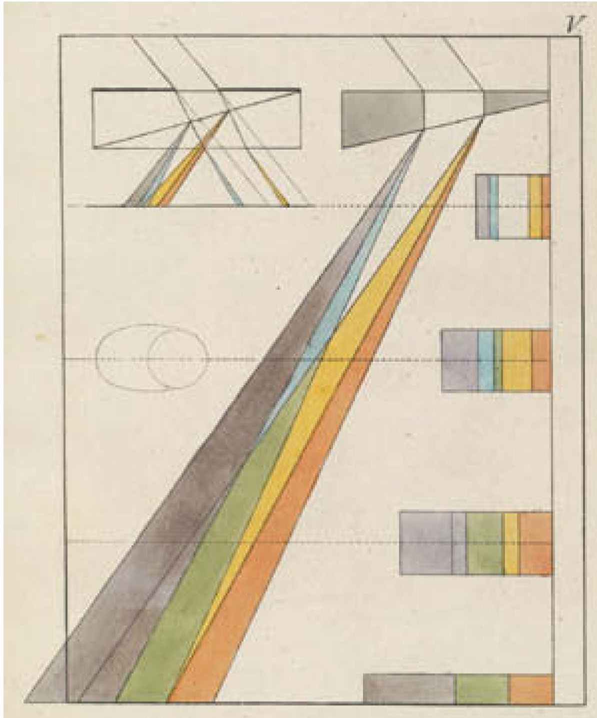

Figure 4. J. W. von Goethe. Diagram from Theory of Colours (1810). Goethe's edge theory demonstrates that colour is not in light (as Newton argued), but in fact emerges from overlaps and through edges.

The second technique used to generate colour in *Enigma* was accomplished through colour intensification, as discussed above. As colour appeared, more actual colour was added, accentuating the effects of the illusionary colour.[8] In addition to building on research in optics and colour perception, *Enigma*, like *UFOs*, expanded the perceptual field in early computer art. Much of this was possible because colour knowledge was brought into the world of early computer graphics (Schwartz 'Description of Computer Films'). Both of these computer art projects use rapid, stroboscopic computer animations to generate colour in subjective perception. *Enigma* highlights how colour exists in between the (objective) screen and the (subjective) human. Its blueprint was created during programming, editing, and production, but the work itself only comes to life when it is being watched; expanding perception.

To approach colour in this way—through its material-technical *and* subjective attributes—is to embrace the paradox of colour as its root. In *Enigma*, both sacred colour and synthetic colour form constitutive tensions for the work to *work* (where sacred colour tends to bear anthropocentric associations, while synthetic colour tends to denote artificial and machine-made colour). However, sacred must not be confused with anti-scientific, naïve, or romantic notions of colour. Rather, as this work clearly demonstrates, both sacred and synthetic colours co-exist, in this particular historical and cultural moment of technological intrigue, along with a fascination with the future, and progressive social and political attitudes towards the human-machine consciousness. It may even be the case that it is *only* in these moments prior to a colour's standardization and democratization that such co-existence is visible or possible.

Moreover, much of what this piece has to offer has yet to be realized (or properly documented) in media art histories. For instance one of the Bell Labs' technical reports for *Enigma* notes how it was an 'Experiment combining various filters to produce the spectrum of color. The sequences used to induce psychological and physical effects could eventually be part of a computer language and coded into the final programming' (Schwartz 'Motion Picture/Computer System'). Such a program (for better or worse) has yet to be seized by commercial or artistic endeavours, yet this kind of software could potentially provide fascinating possibilities.

1984

By the late 1970s and early 1980s, political conservatism and corporate ambition had infiltrated the Labs, bringing an end to the golden era of liberal experimentation that took place in the 1960s and early 1970s. In 1981 Ken Knowlton wanted to patent a new technology that was a direct precursor to today's text messaging systems, but the Labs' (now AT&T's) public relations department answered 'No'. They did not want him 'to talk or lecture about it anymore'. When he then asked them, 'What is my job here?' they couldn't name it. They said 'we don't know'. At that point it was clear to him that things had dramatically changed and, being one of the last creative experimental technologists remaining, Knowlton subsequently took a job at the Stanford Research Institute (now SRI International) (Kane 2008b).

Bell Labs' temporary denial of this early experimental work in an area that is today not only central to 'telephone' communication technologies but to almost all digital media, reflects the Labs' status as a government owned monopoly, a status that only ended with the deregulation in the 1980s. Thus, while this protected status temporarily shielded the researchers from market pressures, it may have also cost the Labs an innovative edge in the new media industries and international notoriety. Bell Labs was one of several U.S. research centres that, like Xerox PARC and IBM, have since been overrun by market influence and changing political and economic tides, including the ubiquity of the personal computer, mass-produced and template-driven 'shrink wrap' software, and the rise of digital media centres and computer art programs in the 1980s and 1990s. Three interrelated factors explain how this happened. Prior to 1984, even if Bell Labs saw a future in computer graphics, the pressure of the government's 1956 decree that restricted the Labs to carrying out only those research projects related to the telephone meant that it may have been unfruitful to pursue patents on these developments. (So even if this kind of work was being conducted at the Labs, which it was, it was best not to publicly announce this to taxpayers.) Second, even when those working at the Labs wanted to claim authorship, if a project was too 'artsy' or too far beyond what could be defined as 'telephone communication', it was not publicized as one the Labs' proud achievements, and increasingly so by the late 1960s and 1970s. And third, because these artworks were a product of collaborations that were sometimes unknown, even if the artists had wanted substantial recognition, pursuing it was (and remains to be) precarious. Finally, a number of these extensive collaborations spanned several undocumented years and at times involved participants who left little to no trace or record of their work.

All of these factors explain why some pioneering works of computer art had for many years gone unrecognized, beyond the occasional footnote, in computer and media art histories. Telling the story of Lillian Schwartz and her colleagues at Bell Labs, within the context of the technological achievements of the 1960s and 1970s, continues to enrich the cultural and aesthetic histories of early computing technologies, the role of women in these histories, the newly emerging subfield of colour studies in the media arts, and the major aesthetic histories and new media practices today. These revisionary histories, however, are only now being written.

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Notes

1. This chapter has been adapted and reprinted from 'Digital Art, and Experimental Color Systems at Bell Laboratories, 1965––1984: Restoring Interdisciplinary Innovations to Media History.' *Leonardo* 43, 1 (February 2010): 19, 53–58, with material that also appeared in Chapter 4 of Carolyn Kane, *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code* (University of Chicago Press, 2014).
2. Mervin was president between 1951 and 1959. James B. Fisk was president from 1959–1973, and William O. Baker from 1973 to 1979 (Gertner 2012: 3).
3. BEFLIX was also used to produce the Stan VanDerBeek / Ken Knowlton *Poem Fields* artworks and was later used as the base for building TARPS, a 2Dimensional alphanumeric processing language.
4. For more on the problematic reception of computer art in the art world see the excellent work of Grant Taylor.

5. For example, the many psychedelic and stroboscopic experiments being developed throughout the United States and abroad (see Geiger 2003).
6. This does not refer to the stroboscopic animations, which remain challenging for viewers to watch. I thank Mimi White at Northwestern University for pointing this out.
7. For more on this see chapters 5 through the postscript in Carolyn L. Kane, *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code* (University of Chicago Press, 2014).
8. This was likely done using an optical bench and animation stand, as used in some of the other computer films (Schwartz and Schwartz 1992: 114; 120; 153; Schwartz *LIL*: Chapter VI, 4).

CHAPTER 6

Digital Photography and the Operational Archive

Scott McQuire

The camera has been implicated in crime scenes at least since the late nineteenth century. However, in the 1980s this took a novel turn, as photography found itself the victim in a murder apparently committed by computers. According to Nicholas Mirzoeff:

> After a century and a half of recording and memorializing death, photography met its own death some time in the 1980s at the hands of computer imaging. The ability to alter a photograph digitally has undone the fundamental condition of photography—that something must have been in front of the lens when the shutter opened, even if questions remained as to the 'authenticity' of what was recorded. It is now possible to create 'photographs' of scenes that never existed without the fakery being directly observable. … The point is the photograph is no longer an index of reality. (1999: 86)

Mirzoeff's statement represents a familiar ambit claim from the period, amalgamating assertions about the impending demise of photographic referentiality with concerns about the status of photographic meaning (authenticity). Well-known writers such as Fred Ritchin (former picture editor of *The New York Times Magazine*) voiced similar concerns about compromised journalistic ethics and the evisceration of photography's evidentiary value (Ritchin 1990). The suddenness of the shift in debate is starkly visualized by Google's Ngram Viewer (which allows text string search of Google's database of books). If you type in the phrase 'death of photography', the graph suddenly spikes around 1990.

Two decades later, claims about the death of photography are less fashionable. In part, this is undoubtedly because, as Peter Osborne (2010) argues, some aspects of what he calls the *ontological* anxiety surrounding the arrival of digital photography were simply misplaced. Dividing photography into phases of capture and image production, Osborne argues that digital capture in fact '*retains* both the causal and deictic aspects of photographic indexicality' (2010: 63).[1] He goes on to suggest that the anxiety about photography's relation to 'the real' arises, at least partially, from the constitutive disjunction between capture and production—which, of course, was also characteristic of analogue photography.[2] In fact, similar arguments were occasionally voiced at the highpoint of the 'death of photography' discourse. In his introduction to *The Photographic Image In Digital Culture*, Martin Lister (1995) pointed out the long tradition of image manipulation in chemical photography, and underlined the way that the strong body of critical writing on photography emerging in the 1970s and 1980s had already undermined the authority of reductive claims about photography's privileged relation to 'the real' *prior* to the arrival of digital cameras.

Perceived continuities between analogue and digital imaging has led some critics to reject the entire thesis that the digital constitutes a fundamental change in photographic practice (for example, see Batchen 2011). However, while this stance may have been a welcome corrective to the peculiar combination of marketing and theoretical zeal that surrounded digital photography in the dotcom 1990s, it seems less convincing in the present. Even accepting Osborne's contention that digital photography retains key attributes of indexicality, and acknowledging that instability in the meaning of photographic images is scarcely new, I still want to argue that the uptake of digital cameras *has* driven fundamental changes in photography. While these changes are directly related to widespread uptake of digital cameras, it is important to emphasize that they are not driven simply by changes in *camera* technology. Nor, one might add, are they purely technological. Perhaps for this reason, they were largely absent in the first generation debates about digital photography. Rather than relating to the nature of the image, manifested in the demise of referentiality or the apparent loss of evidentiary value in professionally-made images, the transformation I am concerned with here concerns the integration of photography into the network milieu, and particularly the emergence of new practices for circulating and archiving everyday images.[3]

A Matter of Size

To situate this shift in focus, consider the following trajectory. While it was well recognized in the 1990s that digital cameras were making image capture progressively cheaper and easier, the implications of this transition were not fully appreciated. The emergence and rapid uptake of photo-sharing websites such as Flickr (established in 2004) was one sign.[4] A less evident but equally powerful signal was the millions of personal computers that were starting to overflow with digital images. This is the first line of differentiation I want to mark in considering the transition from analogue to digital photography: dramatic growth in the *volume* of photographs. In some respects, this growth can be explained by the fact that digital capture meant that amateur photographers could increasingly adopt the shooting practices used for decades by professionals (keep shooting and select the usable images later). Another powerful driver was the fact that large numbers of people were now carrying a ‘camera’ in many more situations than had previously been the case. It is no surprise to learn that the most popular ‘camera’ used for uploading images to Flickr at the time of writing is, in fact, the iPhone 5.[5] (Of course, such pragmatic explanations for the growing numbers of images captured offer little purchase in explaining *why* making and circulating photographs has become increasingly integral to contemporary experience.)

Growth in the number of digital images captured has driven the emergence of new practices of archiving and circulation. By August 2011, Flickr reported that it hosted some 6 billion images.[6] To put this number into context, one of the world’s major public image archives—the US Library of Congress—held just over 12.5 million photographs in 2009.[7] While I am not making any claim about the value of the content housed in the respective archives, it is worth noting that the Library of Congress has been operating for more than two centuries, while Flickr has amassed an image collection 500 times larger in a mere seven years. And, of course, Flickr’s photo archive is itself dwarfed by the scale and explosive growth of the image collection held by social network contemporary Facebook. While it is difficult to get accurate ‘official’ figures, let alone to verify them, Facebook is undoubtedly the biggest image archive on the Internet by a considerable factor. Various company blog posts track the growth in the volume of uploads, from some 850 million per month in mid-2009 to 2.5 billion per month in early 2010.[8] By August 2011, this had grown to 250 million photos uploaded *each day*, equating to a staggering 7 billion per month.[9] Estimates of the total image archive held by Facebook vary from the 90 billion claimed by Facebook engineer Justin Mitchell on quora.com to the 140 billion claimed by Good (2011).[10] But the volume of daily uploads would indicate that this figure may itself nearly double in the coming year.

Fortunately, given the brittleness and especially the volatility of such statistics, it is not the precise number of images but the trajectory that concerns me most here. There is clearly a major disjunction between the scale of traditional image archives and their digital counterparts. Such a disjunction poses the familiar question: does size matter? Is this, as philosophers once liked to ask, a change of 'kind' or merely a change of 'degree'? Without accepting the stability of this binary, I am suggesting that, in this instance at least, size can function to index a fundamental change in the social relations of the photographic image. Moreover, rapid expansion in volume is near inseparable from the new modalities of storage and circulation. In this nexus, we are witnessing the transition of the photograph from its historical existence as a visual artefact where meaning is governed by an aesthetic-interpretative process of 'reading' to a condition in which the image increasingly functions as a form of *data* regulated by statistical/algorithmical processes.

Photography in context: The Problem of Meaning

Having stated my basic argument, I now want to approach the issue from another direction. As I noted above, one aspect of the concern directed at digital photography in the 1990s was a perceived loss of 'authenticity'. How can the photographic image continue to 'guarantee' the existence of what it shows when pixel by pixel manipulation allows the seamless modification of appearances beyond the threshold of human perception? But the disarming ease of digital modulation should not itself disguise the extent to which it has always been problematic to treat photographic appearances as self-evident. This problem has been central to long-standing arguments over photographic objectivity and the stability of photographic meaning. As John Berger noted three decades ago, the camera altered our relation to the world, first, by introducing an unprecedented temporality in its recording of the visible, and, second, by rendering those recorded appearances mobile:

> Photographs preserve instant appearances. Habit now protects us against the shock involved in such preservation. Compare the exposure time of a film with the life of the print made, and let us assume the print only lasts for ten years: the ratio for an average modern photograph would be approximately 20 000 000 to 1. Perhaps that can serve as a reminder of the violence of the fission whereby

appearances are separated by the camera from their function. (Berger and Mohr 1982: 51)

Separation between the moments of 'capture' and 'production', manifested as the gulf between the moment represented and the moment of viewing, have led to frequent demands for restoring the 'context' of the photograph. Loss of context is the fundamental danger that animates Susan Sontag's (1977) poetic but ultimately pessimistic elegy on photography.[11] Other such as John Tagg and Allan Sekula emphasized the importance of institutional and discursive contexts for establishing photographic authority and shaping photographic meaning. In his influential essay on the archive of photographs assembled by a mining company, Sekula argued that archives constitute a '*territory of images*', adding 'not only are the pictures in archives often *literally* for sale, but their meanings are up for grabs' (1989: 116). Back in the 1930s, Walter Benjamin advocated the use of captions as a means of ensuring the correct *tendency* of the otherwise promiscuous photograph. (Interestingly, this is close to the strategy advocated by Ritchin (2008) in a recent book, where he moves beyond the 'shock of the new' to embrace aspects of digital photography, including captioning and tagging, as means of providing context). Roland Barthes, on the other hand, remained far more sceptical of textual anchors, suggesting that their use was symptomatic of the general poverty of the sort of press photography which remained in a purely *illustrative* register (1983: 204).[12]

Photographic history is littered with images that have had their meaning altered by entry into a new setting. Digital images, with their easy availability for 'photoshopping', are ready targets for modes of appropriation that reinforce clichéd interpretations and reductive stereotypes. And when every famous image—and many ordinary ones—seem to end up in the maw of advertising, it is all too easy to become cynical about photography in general. Against this heading, and determined to retain the sense of a possible political project for photography, John Berger argues: 'All photographs are possible contributions to history, and any photograph, under certain circumstances, can be used to break the monopoly which history today has over time' (Berger and Mohr 1982: 109). While recognizing the inherent openness of the image, Berger reminds us that the determination of a 'context' in which a particular image will be read is a matter of agonistic struggle rather than one resolved by general protocols.

In some respects, Berger's position reminds me of the ambiguity articulated by Siegfried Kracauer in his 1927 essay 'Photography'. Kracauer (1995) memorably describes photography—or rather the emergence of a modern image culture based on technical reproducibility—as the ‘go-for-broke game of history’. This assessment was premised on photography’s novel and rapacious capacity to turn the entire world into a stock of images—a warehouse for all of nature—coupled to its promiscuous overturning of traditional categories of interpretation, such as art historical genres. This is the nub of Kracauer’s ‘gamble’: photography’s unprecedented ability to treat the existing order of things with indifference carries enormous potential to delegitimize established forms of social and political authority, and to allow a radical re-assessment. However, failure to seize the historic opportunity presented by the transition from a traditional to a modern image culture could have dire consequences extending well beyond photography. Without radical political change, ‘the nature that [photography] failed to penetrate would sit down at the very table consciousness had abandoned’ (Kracauer 1995: 61). Here the ‘indifference’ of photography would feed the victory of commodity culture, lending its force to a spectacular society in which images become the ultimate commodity. However, if capitalism were overthrown, ‘then liberated consciousness would be given an incomparable opportunity. Less enmeshed in natural bonds than ever before, it could prove its power in dealing with them. The turn to photography is the *go-for-broke game* of history’ (Kracauer 1995: 61).

While both Kracauer and Berger consistently emphasize the ambiguity of photographic appearances, it is important to underline that this ambiguity is irreducible. No photograph can guarantee its own meaning and every image is susceptible to re-use. Providing a new context for an image may enable it to respond to Berger’s call for ‘breaking the monopoly of history over time’. But it is vital to recognize that this is never a matter of ‘restoring’ some presumably original context, as if there were only one. This would amount to fetishizing ‘context’ as the means for apparently controlling the polysemy of photographic meaning. Part of the ‘modernity’ of photography is precisely the way it foregrounds the impossibility of providing what Derrida (1982) terms a ‘fully saturated’ context.[13] There is always a remainder, something left over, the possibility for re-interpretation in a new context. This possibility, which is the very condition of communication, is becoming susceptible to new forces in the digital present.

Image Torrents

If photographic meaning has always been unstable, the unmooring of images from their diversity of contexts—the events they represent, their conditions of capture, their histories of production as image files, their routes of circulation and pathways of reception—has arguably become even more complex and volatile in a culture of cut, paste and forward. Numerous accounts of contemporary media culture stress the sheer force of numbers. Todd Gitlin (2001), for instance, appeals to natural metaphors such as 'torrent' and 'deluge' to signal a media system out of control. But this is merely the flip side of the common use of similar terms as the general appellation for digital files accessed over the Internet. (Plug the word 'torrent' into a search engine and what appears is a list of clients such BitTorrent or sites such as ThePirateBay.)

In fact, perceptions that we are subjected to an excessive number of images have been with us for some time. Sontag (1977) concludes *On Photography* with a call for an 'ecology of images', while Kracauer described the illustrated magazines of the 1920s as unleashing a 'blizzard of photographs' (1995: 58). The counterpoint to the more recent variants of these arguments is Clay Shirky's (2008) pithy observation that the issue is not information overload but 'filter failure'. Despite his rather reductive techno-optimism, Shirky situates an important aspect of the transition from analogue to digital images. The digital image is now only partly a 'picture' in the classical sense. It is also becoming an element of a dataflow. In this context, new modalities for regulating meaning, and new rules for providing order in the 'deluge' of images are emerging.

Lev Manovich's recent work on cultural analytics (2011a, 2011b) situates some of the stakes at play in this shift. As particular institutional collections of digital images grow into massive data sets, they can become subject to new forms of analysis. The emergence of so-called 'big data'[14] in the form of image archives is itself a subset of the more general shift to what might be dubbed a 'database society'. In June 2008, *Wired* ran a special issue on 'the Petabyte age', arguing that: 'Our ability to capture, warehouse and understand massive amounts of data is changing science, medicine, business and technology' (Wired 2008). Whereas Kracauer's earlier reference to the 'warehousing of nature' through photography evoked the transfer of industrial techniques for the production of goods onto the realm of images, here the transfer involves *industrial* techniques of computing—what UC Berkeley Professor Joe Hellerstein (2008) calls the 'industrial revolution of data'—in which data is literally *warehoused* in temperature controlled server farms situated in strategic (tax-effective, network-efficient) locations.

'Big data' society carries profound implications for traditions of knowledge and research that extend well beyond my present concerns (Latour 2007; Savage and Burrows 2007; 2009). These debates do, however, help to indicate some of the ways that the process of constructing photographic meaning is beginning to change as large-scale image sets become searchable and researchable according to a range of different criteria determined by software applications. In particular, the old division between surface and depth analysis (aggregating shallow data gained from many examples versus multi-layered data sourced from fewer) that animated historical distinctions between statistics/social sciences and hermeneutics/humanities has begun to lose some of its purchase in a context where 'sampling' is starting to give way to 'whole population' monitoring.[15] 'Reading' an image as part of a pictorial tradition can be complemented or even replaced by processing images as data.

It's worth unpacking this trajectory in more detail. The concept of treating photographic images in relation to statistics is not in itself novel. Drawing on Georg Simmel's observation concerning the displacement of qualitative by quantitative differences in the context of the modern city, Walter Benjamin perceptively placed photography alongside statistics as a novel technique of 'reality-testing' in the mid-1930s. Benjamin (1999: 255–56) argued:

> Uniqueness and permanence are as closely entwined in the [artwork] as are transitoriness and repeatability in the [reproduction]. The stripping of the veil from the object, the destruction of the aura, is the signature of a perception whose 'sense of sameness in the world' has so increased that, by means of reproduction, it extracts sameness even from what is unique. Thus is manifested in the field of perception what in the theoretical field is noticeable in the increasing significance of statistics.[16]

For Benjamin, it is the ease of reproduction coupled to the radical indifference of the photographic image towards what it shows, and the way this indifferent multiplicity privileges exhibition value over ritual use, that underpins the general transformation of modern perception. Like statistics, photography functions as a great leveller of phenomena: in Kracauer's terms, photography's capacity to warehouse all of nature allows everything to be related, if only as a set of images. Paul Virilio's analysis of the use of photography in aerial reconnaissance in World War I similarly foregrounds the emergence of images as an *information flow* capable of mapping the highly mutable terrain of the frontline under high-explosive bombardment. Elsewhere (McQuire 2008), I have argued that the image sets generated by Charles Marville during his role as the photographer of the city of Paris as it underwent radical modernization at the hands of Haussmann also pioneered a proto-statistical approach to images. What links these particular instances to Benjamin's analysis of the statistical 'logic' of technological reproducibility is that they exemplify early settings in which the photographic image came to function less as a group of independent pictures, in which each photograph constitutes its own 'event', than as sets of relational data. Once the image begins to be *conceived* from the point of view of its membership in a series, meaning is no longer a function of singular and apparently autonomous pictures but is constituted as a relation between serial images. Photography becomes a means of constructing a database.

These incipient uses of photography correspond to the formation of what Hacking (1990) calls 'statistical society', referring to the way that new modes of knowledge emerging in the nineteenth century contributed to the reconstitution of the social bond, the reconfiguration of individual identity, and the recasting of the relation of citizens to the state, and to each other. Photography is directly implicated in this transformation, not least through its formal role in constituting the official visual memory bank of various disciplinary institutions, including the police force, the asylum, the prison and so on. Allan Sekula (1986) has argued that, historically, two primary methodological axes emerged for using photographic images to define and regulate social differences in disciplinary society. The first corresponds to what he calls *generalization*, where photographic contingency is converted into typicality by making the photograph into an 'example' of some broader tendency. The second is a process of *individualization* which depends on a 'machine' (a filing system and clerical apparatus) to retrieve a particular instance from the archive's infinite bounds.[17]

In fact, the first approach proved more controversial and, perhaps for this reason, was adopted more rarely within science.[18] There were occasional forays into using photographs for scientific generalization, such as Francis Galton's (Darwin's cousin and founder of eugenics) use of photographic superimposition to create supposedly generic images of social and racial 'types'[19]. But these pseudo-scientific uses were easily outweighed by more 'aesthetic' practices in which individual images, selected for newspapers, books, or exhibitions, were saddled with the impossible task of summing up an event, era or generation.[20] It is Sekula's second axis of individualization that proliferates in concert with the other techniques of the disciplinary *dispositif*. Sekula's primary example of this trajectory is Alphonse Bertillon who was so central to the adoption of photography in police work in the late nineteenth century. Bertillon's system, in which photographic images were regulated through formal protocols for shooting and display, coupled to specific forms of annotation and mechanisms of filing and retrieval, exemplifies the process of translating individual instances into populations that could be statistically regulated, according to the innovative process that Hacking aptly describes as 'making up people' (1990: 3). Despite the displacement of the Bertillon system by fingerprint identification, photographic archives charged with the task of securing bodies to identities have continued to exert enormous and even growing power into the highly surveilled and increasingly securitized present. However, the 'machine' that Sekula referred to is no longer a filing cabinet but a computer, and the 'clerical apparatus' has been replaced by the new assemblage of software and a multitude of users.

In this context, archives held by various government authorities and contemporary user-generated photo archives such as those held by Facebook and Flickr lose their distinctiveness, as even the 'personal images' that were once stored in privately housed photo-albums can now be treated as 'populations' subject to pattern recognition. Growing use of automated systems to organise digital photographs has made explicit something that was, arguably, always an 'affordance' of photography: namely that, as the first industrialized image, photography was never simply an extension of the drawing and painting to which it was so often compared, but was the prototype of visual *data*. Today, as visual data is digitized and thus made increasingly susceptible to algorithmical operations, Peter Galison's (1997) important historical distinction between 'visual' and 'logical' or counting machines is eroding, and photo-archives move onto an *operational* footing.

The Social Protocols of Photography as Big Data

In his response to Susan Sontag's *On photography*, John Berger (1984) was moved to make a distinction between photographs that belong to private experience and those which are used publicly. Berger understands the private photograph—prototypically a photograph taken by one of the people viewing it, or which represents people, places or events familiar to its viewers—as one that is read within the context of the lives that thereby inform its testimony. Because the private photograph's 'quote from appearances' is read in the context of lived experience, it does not have to function in isolation but is drawn into a network of associations. It intersects multiple narratives. Looking at our own photographs or those of friends or family members is frequently an incitement to storytelling, an occasion for circulating and exchanging tales of what we felt and what others remember. Instead of being overburdened with demands to provide evidence, a photograph in this context can be treated lightly, a touchstone for recollection and recounting rather than a positive token of proof.

In contrast, Berger argues that the contemporary public image, such as those seen every day in a newspaper, on the Internet, or on television, frequently arrives from so far outside the experience of those who view it that the gulf separating appearance from significance defies the capacity of imagination. This doesn't mean the image therefore has no meaning; rather, that meaning is all too easily channelled in particular directions, heavily reliant on stereotypes. Berger memorably likens the effect of the contemporary public photograph to the bewilderment of being exposed to the memory of a stranger: 'It records an instant in which this stranger has shouted: Look!' (1984: 52). Treating the world as a sequence of such bewildering moments corresponds to the logic of spectacle, producing the lack of specificity and attenuated significance for which contemporary media culture has become notorious. In this setting, the camera's potential to redistribute cultural and experiential horizons is less an interruption to established political contours than the confirmation of their present order.

Berger's distinction between public and private images is not without tensions. Private images can never be neatly divided from public images; first, because any private image can always be republished in a public context; and second, because many of our camera practices, including our sense of 'moment' as it relates to photographing the routines and rituals of everyday life, are learnt and internalized from the public image world. Private images always refract social mores. We know, for instance, that at least since the 1950s, parents have been the most fervent photographers, and it is impossible to fully demarcate 'natural emotion' from the effect of a long history of marketing campaigns in the desire to photograph one's children. Bourdieu's pioneering study argued that the family photograph was simultaneously an index of family unity and a tool to achieve that unity: 'Photographic practice only exists and subsists for most of the time by virtue of its *family function* of reinforcing the integration of the family group by reasserting the sense it has both of itself and its unity' (1990: 19). But the family photograph arguably assumes its full—*fetishistic*—force only when it represents a family unit that has all but disappeared. As Sontag observed barely a generation later: 'A family's photograph album is generally about the extended family—and often is all that remains of it' (1977: 9).

These remarks offer a useful frame for beginning to address the new image archives accumulating on social network sites such as Facebook and photo-sharing sites such Flickr. Many of the images uploaded to these sites—especially on Facebook—correspond to what Berger describes as images belonging to private experience.[21] In other words, the photographs were uploaded for viewing by (relatively) limited circles of family and 'friends'. This distinctive mode of circulation runs counter to most modern forms of commercial publishing which sought broad and undefined audiences (even if they didn't always find them). The capacity to give private photographs limited circulation within defined networks explains the level of trust many users invest in social network and photo-sharing platforms. In such a setting, people may well circulate images showing unflattering, risky, dubious or even illegal behaviour, in part to symbolize and enact the trust that they collectively share as ‘friends’. But, of course, ‘friends’ is an intensely ambiguous term in this context, and one that demands further consideration. While many users trust their photographs to social network platforms, it is the (always slippery) difference between private and public contexts and uses that situates the widespread and intense concern expressed over the loss of control of ‘their’ photographs when they are uploaded to a site such as Facebook. This is not a matter of Facebook claiming ‘ownership’ over user images, as is frequently asserted. (It doesn’t, although it does arrogate certain rights to itself.) Rather, it concerns the inability of users to exercise precisely graduated control over the image, or to understand the implications of failing to do so. Putting aside cases when images are accessed improperly, a common concern is the inability to set effective controls on the actions of others. For example, sharing photographs with ‘friends’ can result in them being made available to ‘friends of friends’ with less restrictions than were mandated by the original uploader. And, once uploaded, it has been shown to be near impossible to ensure that unwanted images are actually deleted from websites such as Facebook (Cheng 2012). (This touches the broader issue of data portability in relation to privately-owned, commercial websites in general.)

I will give one example drawn from a small-scale ethnographic project examining the way users employ Facebook to negotiate personal identity (Lambert 2011). Interviews revealed that a number of Facebook users had experienced situations where they felt they were cast as ‘voyeurs’ into a near stranger’s intimate life. This was an indirect function of the breadth and diversity of the ‘friends’ they had accrued over time, resulting in them being made privy to streams of personal photographs from people who were casual acquaintances. Seeing such personal photographs—ones that they felt they *shouldn’t* see—was described in terms that mixed discomfort and fascination. If this experience has some echoes of the commercial exchange in which a ‘celebrity’ sells the image rights to an intimate aspect of their ‘private life’ (such as the birth of a child), it differs in its peculiar combination of selectivity (on Facebook, even as a relative stranger, you are part of a distinct network) and anonymity (who *are* these people?). More disturbingly for some users, it also raises the spectre of others looking into *their* personal photographs in this way.

This example should not be read simply as an argument against using platforms such as Facebook to circulate personal images. Rather, it is to underline the extent to which the social practices accruing around photo-sharing sites still remain a ‘black box’. There is an urgent need for empirical research regarding the sort of photographs people actually choose to post and circulate, and for understanding the different meanings such images have for different viewers. There is also need for detailed analysis of the emergence of new lexicons employing online annotation, tags and other element to provide narrative contexts for reading such images (see Button 2009).

Concern over the way that Facebook's rules constrain user agency, including the capacity to exercise effective control over their own photographs or images in which they appear, has aroused some public controversy. However, the growing *operationality* of the image archive, and its availability, not to other users, but to the platform owner, has aroused less concern from users. The placement of large numbers of personal photographs onto privately owned platforms means that a whole reservoir of once private life is now being opened up to corporate scrutiny. In the past, few would dream of showing their family photo albums to a company, or grant them permission to perform unspecified analyses on this corpus. Yet this is precisely what is happening today on a large scale.

Is this a problem? What sort of analysis can digital images be subject to? Here we might distinguish common forms of data mining including registration and profile data, transactional data, user logs (which can provide analyses of social network ties) from the harvesting of metadata uploaded with photographs, and visual data from the photographs themselves. Image archives have always been searchable but, in the era of analogue photographs, this capability was limited by the physical logistics of classification and retrieval. Computerized archives of digital images sidestep these difficulties by enabling more flexible processes of categorization through metadata and user-generated tags, and by providing new protocols for searching and retrieving images. Today, metadata and tags are being supplemented by sophisticated forms of pattern recognition software, including facial recognition. Historically, these sorts of techniques were first deployed in relation to various official image archives, such as police databases of fingerprints: in other words, in relation to various classes of 'abnormal' subjects.[22] Numerous current popular software applications for processing, storing and sharing images, including Google's Picasa, Apple's iPhoto, Sony's Picture Motion Browser (PMB), Windows Live Photo Gallery and, of course, Facebook now include facial recognition systems. In the process, the capacity to analyse image qualities is normalized and extended into the general population.

In his work on 'media visualization' of large-scale image sets, Manovich suggests that automatic digital image processing techniques, aggregating qualities such as average brightness and saturation, number and properties of shapes, number and orientation of edges, colours, can be deployed in conjunction with commonly available metadata such as date/time and place to perform tasks such as mapping stylistic changes in news photography over history.[23] While excited by such possibilities, he further argues there is a need to actively prise the field away from its current leaders, in which analysis is seen primarily through a marketing lens. Such an ambition presages the need for greater understanding and public discussion of the protocols of the operational image archive. Manovich's vision is predicated on the new availability of data sources via various social media platforms.

> For the first time, we can follow imaginations, opinions, ideas, and feelings of hundreds of millions of people. We can see the images and the videos they create and comment on, monitor the conversations they are engaged in, read their blog posts and tweets, navigate their maps, listen to their track lists, and follow their trajectories in physical space. And we don't need to ask their permission to do this, since they themselves encourage us to do by making all this data public. (2011a)

Part of the problem I am pointing to is precisely the fact that no one—and especially not the platform owners—needs to ask permission, even in relation to images that users categorize with the highest 'privacy' settings. The much-discussed trade-off between access to the service in return for the provision of personal data raises a raft of social, political and ethical issues that will not be easily or quickly resolved. In the current settings, capacity to search the new photo archives varies significantly, depending on who is doing the searching. For example, anyone can search Flickr's public photographs using various key words, or general categories such as 'most popular'. Similarly, anyone can access public images on Facebook. However, even where a sizeable archive is publicly available (for instance the 5,668 photos on the 1,000,000 FACEBOOK ARTISTS page), they can only be displayed according to a standard grid format. This limits the capacity of independent researchers to treat the archive as 'big data'.

Some websites, including Flickr, have open Application Programming Interfaces (APIs) that allow access to certain image archives.[24] This has led to novel public research projects such as 'Mapping the world's photos' which employed a dataset of about 35 million images collected from Flickr to plot the 'spatial distribution of where people take photos' and 'to define a relational structure between the photos that are taken at popular places' (Crandall et al. 2009). Manovich (2011) argues these new modes of analysis based on automated pattern recognition techniques can be productively used to 'defamiliarize' the media environment around us. However, the political implications of these undertakings remain ambiguous. Much data remains hidden behind private corporate walls. In this sense at least, the 'torrent' suggested by raw numbers can be misleading. The estimated 140 billion images held by Facebook do not constitute *an* archive in the sense that anyone can access that entire data set. Rather, that total is comprised by a multitude of micro-archives to which no one has complete access. The exception to this rule is, of course, Facebook itself. It is only from the optic of the platform host that 'whole of population' analysis becomes possible.

Part of the problem is that something like Facebook's photographic archive has been created in a context where few can really claim to understand how it is being used in the present, let alone how it might be used in the future. As Mark Andrejevic wrote in a cogent online post:

> There is an asymmetry to the so-called 'end of privacy': users are subjected to it, whereas those who control the commercial platforms are exempted in significant ways. … We don't have a clear idea of the experiments being conducted on us, the range of data collected about us, or how this data is used because these practices are not open and available to us. (2011)

Andrejevic adds:

> There are huge emerging asymmetries in the terabyte world of 'super crunching': those with access to the databases and the tools for managing them can use data in quite different ways than those without access. (2011)

This highlights the fact that it is not simply possession of data but possession combined with capacity to process data that is the key to power and prosperity in the digital milieu. For marketers, the visual archive harvested through social media is a new frontier, wide open for new analytic experiments. Imagine a scenario in which you have uploaded photographs to a social network website that incidentally reveal your private living space, including the clothes you wear, your furniture and appliances, the art works on your wall, and so on. Such image attributes could easily become analysable data, used in profile building and on-sold to third party advertisers. The worn fabric of your couch could become the basis for receiving a customised ad about a special deal available on a similar item nearby. While some might welcome such targeting, the full implications of an unrestrained 'knowing capitalism' (Thrift 2005) are disturbing.

Control of data is fundamental, not only to the business strategies of web 2.0 companies, but to all companies in the 'web squared' world (O'Reilly and Battelle 2009). The ability to access and manipulate data has become increasingly integral to the exercise of contemporary power (Lash 2010). The scale and depth of Facebook's growing image archive suggests there is an urgent need to develop protocols for corporate 'stewardship' of such data collections that go well beyond current conceptions of protecting *individual* privacy. Even without fully accepting Latour's (2007: 10) claims about the ability to read the individual 'imagination' from data traces, the corporate control of this enormous reservoir of data—'freely' contributed to by hundreds of millions of individual users—raises issues whose significance and scope might one day be compared to corporate ownership of the human genome.

In concluding, I want to finally note the way that digital image archives are now popularizing certain standardized settings for organizing the 'torrent' of images. Common forms of metadata captured with digital photographs include date, time, place, camera type, and even camera settings such as aperture and exposure time.[25] These values can all become grids for delimiting distinct sets of images. Two of the most popular modes of organization are geotagging and name-tagging (naming the people shown in the image). Increasingly, these operations can be automated via pattern and face recognition software. Services such as Google's Panoramio and Microsoft's Photosynth enable geotagged images uploaded to the web to be automatically integrated into 'panoramic' vistas of particular sites. Along another axis, Facebook (2011) recently automated the process for tagging 'friends' using face recognition software.

Automation of tagging functions may well prove popular, and, as with so much other technology, is inevitably presented as time-saving and efficient. However, as Thrift (2005) notes, automated technological settings all too easily disappear from consciousness. In some respects, the appearance of automated systems for organizing photographs may be understood as a response to the problem of excess; they offer a convenient way of dealing with the torrent of images. But such a shift to automation also involves arrogating a portion of the difficult decisions about photographic meaning to software. Making the world's geographical co-ordinates a default setting for organizing images offers another twist in the endlessly fraught relation between photography and the physical world. Where the photograph was initially thought to guarantee the real as its objective image, and later was felt to be part of the world's de-realization according to Baudrillard's rather Borgesian formulation in which the map overtakes the territory, it is once again the world that now apparently functions to anchor the blizzard of photographs. Or, rather it is the abstraction of *place* into digital geographical co-ordinates that becomes the key frame for locating photographs. The old problem of 'reference'—of how the image relates to the world it re-presents—is displaced onto the terrain of metadata and algorithmic analysis.

Automated name-tagging using facial recognition software is currently generating some disquiet among users, presumably because of its proximity to official techniques of biometric surveillance. It remains to be seen to what extent the 'convenience' of this new colonization of intimate life will be accepted and internalized. But the mere fact of the expansion of biometric techniques into archives of ostensibly personal images indicates the extent to which the 'operational archive' of digital images no longer belongs to the disciplinary institutions in which it had its origins in the nineteenth century. Rather, it is symptomatic of the new user-generated mode of governmentality that Lash (2010) calls 'intensive culture', in which the exercise of power is mobilized through data that is not gathered from above, but is largely self-generated and self-organized in an ongoing process. Like the routine of photography in the age of always-on, always-available mobile phones, data gathering no longer depends on the scrutiny of 'special', ostensibly abnormal subjects or activities, but has become co-extensive with 'life'.

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Notes

1. Osborne adds the caveat: 'but without the iconic aspect of perceptual resemblance previously associated with them' (2010: 64).
2. Osborne further argues that the emergence of ontological anxiety surrounding the photograph is distinct to the deployment of digital images, but is rooted elsewhere—in social relations of abstract exchange.
3. I would immediately add that any distinction between 'professional' and 'everyday' images is not hard and fast, and the digital threshold is, in part, defined by increasing porosity between the two. However, as will become clear below, my primary concern in this essay is with 'private' rather than 'public' images.
4. Flickr was launched by Ludicorp in 2004 and acquired by Internet giant Yahoo one year later.
5. See http://www.flickr.com/cameras, accessed 6 December, 2013. The figures are only accurate to the extent that Flickr can automatically detect the camera used, which it reports as about two-thirds of the time.
6. http://blog.flickr.net/en/2011/08/04/6000000000/
7. See Library of Congress 2010: x. This number is exclusive of moving images, posters, prints and drawings.
8. The May 2009 figure is at http://www.facebook.com/blog.php?post=87157517130
The February 2010 figure is http://blog.facebook.com/blog.php?post=206178097130
9. The figure is given in a blog post by Justin Shaffer (26 August, 2011) available at http://blog.facebook.com/blog.php?post=10150262684247131
10. In response to the question 'How many photos are uploaded to Facebook each day?', Mitchell, who identifies himself as a Facebook engineer, writes: 'We currently have over 200 million photos uploaded per day, or around 6 billion per month. There are currently almost 90 billion photos total on Facebook. This means we are, by far, the largest photos site on the Internet' (response dated 26 January, 2011). http://www.quora.com/How-many-photos-are-uploaded-to-Facebook-each-day/all_comments/Justin-Mitchell
11. Sontag writes: 'A photograph is only a fragment, and with the passage of time its moorings come unstuck. It drifts away into a soft abstract pastness, open to any kind of reading' (1977: 71).
12. Barthes argued: 'It is not the image which comes to elucidate or "realize" the text, but the latter which comes to sublimate, patheticize, or rationalize the image' (1983: 204).
13. Elsewhere I have argued that photographic culture played a major, if often unacknowledged, role in establishing the conditions in which semiotic openness and textual polysemy move from the margins to the mainstream of contemporary thought (McQuire 1998).
14. Manovich offers the standard computer science definition of 'big data' as 'data sets whose size is beyond the ability of commonly used software tools to capture, manage and process … within a tolerable elapsed time' (2011a).

15. Latour (2007) argues that the entire divide between social and psychological modes of research is becoming less relevant. Similarly, Savage and Burrows suggest: 'Our point was rather that these familiar debates—quantitative versus qualitative—are now much less salient in a world of digitized information with much more interplay between numbers, narratives and images' (2009: 765). For *Wired* (2008), the equation is far simpler, amounting to the end of theory itself: 'This is a world where massive amounts of data and applied mathematics replace every other tool that might be brought to bear. Out with every theory of human behavior, from linguistics to sociology. Forget taxonomy, ontology, and psychology. Who knows why people do what they do? The point is they do it, and we can track and measure it with unprecedented fidelity. With enough data, the numbers speak for themselves.'
16. Benjamin is quoting Danish writer Johannes Jensen (1999: 276).
17. Sekula argues: 'These two semantic paths are so fundamental to the culture of photographic realism that their very existence is usually ignored' (1986: 18).
18. When Charles Darwin used seven sets of photographs in his *The Expression of the Emotions in Man and Animals* (1872: vi), he argued they 'are much superior for my purpose to any drawing, however carefully executed'. However, the excessive particularity of photo-realism, in comparison to more traditional engravings whose function was to synthesize a multiplicity of possible examples into an 'ideal' representation, aroused considerable debate in the scientific community.
19. One of one Galton's images formed the frontispiece of Havelock Ellis' *The Criminal* (Sekula 1986: 40–46)
20. Digital photography revives the old 'generalist' trajectory in distinct ways. The cover illustration of *Time* (1993), headlined 'The new face of America', shows a woman's face 'created by computer from a mix of several races'. Inside we read that this very Kuleshovian 'new woman' is a composite creature created through digital 'morphing' of specified amounts of ethnicity: 15% Anglo-Saxon, 17.5% Middle Eastern, 17.5% African, 7.5% Asian, 35% Southern European, and 7.5% Hispanic. See http://www.time.com/time/covers/0,16641,19931118,00.html. Today, rather than merely updating Galton's procedure with reference to demographic statistics, such an image could potentially be created by direct analysis of a large scale image archive.
21. Both Flickr and Facebook offer variable settings in terms of 'public' and 'private' display. As a dedicated photo-sharing website, Flickr is heavily patronised by photo-enthusiasts and professional photographers who make many of their images publicly accessible. Conversely, the bulk of Facebook's user-generated image archive is not accessible to the public.
22. Automatic Fingerprint Identification System (AFIS) was introduced from the late 1970s. Facial recognition systems were initiated in the 1960s, but did not enter widespread until the 1990s, surfing the same socio-technological wave that drove the upsurge of personal computers and digital cameras.
23. Manovich distinguishes media visualization from data visualization in terms of process and output: 'Typical information visualization involves first translating the world into numbers and then visualizing relations between these numbers. In contrast, media visualization involves translating a set of images into a new image which can reveal

patterns in the set. In short, pictures are translated into pictures' (2011b). However, it should be acknowledge that the security of this distinction is compromised in an era in which (digital) pictures are fundamentally comprised of numbers.

24. See http://www.flickr.com/services/apps/about

25. As O'Reilly and Battelle comment: 'Initially users taught their computers the association between photos and locations by tagging them. When cameras know where they are, every photo will be geotagged, with far greater precision than the humans are likely to provide' (2009: 5).

CHAPTER 7

Lights, Camera, Algorithm: Digital Photography's Algorithmic Conditions

Daniel Palmer

Even as its symbolic apparitions are endlessly animated across the cultural field, photography as we once knew it is all but over. Cameras have become computers, and mobile phones have become cameras, and in the process the idea and practice of photography has been thoroughly, if not completely, transformed. Computerisation entails a fundamental and well understood shift that barely needs repeating—from photography as the transcription of light onto a light sensitive material surface to photography as the translation of light into digital data. Camera phones introduce new levels of ubiquity and immediacy. But the implications of these developments are continually unfolding. For obvious reasons, critical attention has turned from a focus on the importance of manipulability and photography's supposed truth status that preoccupied writers on digital photography in the 1990s (Mitchell 1992), to questions about photography's practices and circulation, particularly on the Internet (Hand 2012; Lister 2013). Increasing attention is now also being directed towards the role of algorithms, those step-by-step procedures for calculations which lie at the core of all data processing. Thus William Uricchio (2011) has recently described imaging software such as Photosynth as part of an 'algorithmic turn', specifically concerned to understand new computationally enhanced viewing positions enabled by the aggregation of location-tagged photographs, while Daniel Rubinstein and Katrina Sluis argue that 'the image has to be considered as a kind of program, a process expressed *as*, *with*, *in* or *through* software' (2013: 29, original emphasis). In this chapter, I wish to explore what I am calling photography's algorithmic conditions, that is, the image's near total dependence or conditionality on the algorithmic.

Compositional Conditions: From the Decisive Moment to the Expanded Frame

For the famed French photojournalist Henri Cartier-Bresson, the narrow rectangle of the Leica 35mm viewfinder opened up a new world and a new kind of seeing—one that was spontaneous and unpredictable. Thus in *Images à la sauvette*, his influential 1952 book of photographs, he elevated 'snap shooting' to the level of a refined and disciplined art. At its core was the notion of the 'decisive moment', in which all the formal compositional elements of the picture come together at the right moment. The photographer, he wrote, 'composes a picture in very nearly the same amount of time it takes to click the shutter, at the speed of a reflex action' (Cartier-Bresson 1999: 33). Thus, in this account, the aesthetic faculties of modern photographers have accelerated to match the speed of their apparatus amid the bustling world of the twentieth century. Cartier-Bresson summarized his aesthetic approach: 'to take photographs means to recognize—simultaneously and within a fraction of a second—both the fact itself and the rigorous organization of visually perceived forms that give it meaning' (1999: 16). In a sense, Cartier-Bresson was engaging in a form of what we might now call pattern recognition.

Cartier-Bresson's style of photography is still possible, still practiced and celebrated, but its importance is marginal. With the digital universe, other types of photography have become more culturally significant, ones which often involve a shift from the single moment of capture to the expanded moments of post-production. We can see this most dramatically in the work of artists, particularly in the work of Andreas Gursky and Jeff Wall, two figures who have perhaps most successfully capitalised on the visual potential of the digital photograph. Both Gursky and Wall were pioneers of the use of digital imaging at the start of the 1990s. The German artist, Gursky, started to work digitally after finding traditional documentary photography was 'no longer credible' (Gursky, quoted in Ohlin 2002: 29), and is now closely associated with a form of heightened, or hyper, realism which emphasises formal elements and is often interpreted as making visible the invisible flows of global capital. Wall, a Canadian artist, is more invested in the history of picture making in art history, and his use of digital imaging is more subtle. Consider his monumental

Figure 1. Oscar Rejlander, *The Two Ways of Life*, 1857, combination print from multiple negatives.

work *A Sudden Gust of Wind (after Hokusai)* (1993). A transparency in light box that stands at nearly four metres wide (250 x 397), it is one of Wall's most ambitious and complex 'cinematographic' works, making a direct allusion to art history, remaking a colour woodcut by Japanese artist Katsushika Hokusai in contemporary Vancouver. Perhaps most importantly, *Sudden Gust* is a photograph that juxtaposes movement and stasis. In any of the many texts you might read about this work, one will learn that it was constructed from at least fifty separate images—one hundred, according to some critics—shot from the same single camera position, taken over the course of one year. Indeed, Wall told me himself that the reason it took a year is that he had forgotten to photograph the leaves on the ground, so—in a curious concession to nature—he had to return a year later. Finally, the multiple photographic elements have been assembled in the computer, and digitally montaged, to produce a seamless effect.

There are, of course, countless precedents for the montage process, going back right to the earliest uses of photography. For his elaborate allegorical work *The Two Ways of Life* from 1857, Oscar Rejlander combined at least thirty negatives to produce one of the best-known and most infamous combination prints. The various pieces were carefully joined, and then rephotographed to create the illusion of a single scene. Even in the field of documentary, manipulation has a long history long before Photoshop—as any student of the history of photography knows. For instance, Mia Fineman (2013) tells the story of how, following the end of the American Civil

War, photographer Matthew Brady made a group portrait, *Sherman and His Generals* (1865). Brady asked Sherman and his chiefs of staff if he could make a group portrait, but unfortunately one of the generals was late. When everyone, exhausted from the battles, needed to go home to their families, Brady took a picture and later, when the tardy general showed up, he photographed him alone before carefully combining the two negatives in the darkroom to produce the single group picture. Interestingly, as Fineman points out, when Nancy Pelosi organised a group portrait of the Democratic Women of Congress in January 2013, and an identical solution was used to overcome a similarly late sitter, it generated considerable controversy. However, at one level, both Brady's image and the image of the Women of Congress could be said to be accurate representations, in that they do 'not represent a single moment in time, but a single moment in history' (Fineman 2013).

Wall's work is not concerned with photographic truth. However, *Sudden Gust of Wind* is a particularly arresting image in terms of the aesthetics of photographic composition, because it conspicuously relies on photography's ability to capture a fleeting moment. By deploying the idea of the papers flying in the wind, the picture 'clearly place[s] itself in the tradition of the aesthetic of the instant', as Laura Mulvey (2007: 30) has astutely observed, and thus also of the spontaneity and realism of the 'decisive moment' school of photography embodied by Cartier-Bresson. It has even been suggested that *Sudden Gust* 'could be taken as a joke at the expense of snapshot photography' since 'here spontaneity is not caught by the photographer-hunter, but constructed using the most patient and unspontaneous means' (Newman 2007: 148). To be sure, as in many of Wall's works, the goal appears to be that of creating a tension in the image, distilling a moment of action. However, *Sudden Gust* breaks with the conventional idea of a photographic temporality, the capital 'T' Time that Barthes invests in, as a piece of a past moment that exists in the present. Instead, the image is now composed of multiple moments. The final image is a 'synthetic combination of multiple indexes' (Van Gelder and Westgeest 2011: 38). It departs fundamentally from 'the tiny spark of contingency, of the Here and Now, with which reality has seared the subject', as Walter Benjamin famously described photography ([1931] 1979: 243). Instead, through seamless pictorial unification, Wall creates what he has called a 'complex illusion of instantaneousness' (Wall 1996: 87). In so doing, as Mulvey puts it, the work 'inscribes the temporality of pre-photography on to the temporality of post-photography', wherein '[j]ust as Hokusai could only aspire to the instantaneity of photography, Wall commemorates its loss' (2007: 37).

The treatment of the *wind* in Wall's photograph is particularly suggestive. Wind is a constant presence in photography, even where it is not identified as its subject.

Figure 2. Patrick Pound, Portrait of the Wind, 2010 (detail). Courtesy of the artist and Stills Gallery.

The Australian artist Patrick Pound has collected an entire series of found photographs that involve the wind, to produce a collage work called *Portrait of the Wind* (2011), featuring women with billowing dresses and men with tousled hair and wayward ties. Of course, the wind is not itself visible in these images, only its effects. Indeed, in Wall's work, given the image is digitally montaged, it is in fact possible that the wind may have never have existed at all, and that we are witnessing effects without a 'natural' cause. Sure enough, the 'sudden gust' was produced by a wind machine, and the hat was tied to a stick with nylon thread. As Wall says:

> The montage is composed of acts of photography, even if there is no simple photographed moment. I don't think any photographic qualities are eliminated, except the single moment in which the entire image was made. I admit that may be the decisive absence, but I like to make a picture that derives from that absence and contemplates it. (Quoted in Tumlir 2001: 116)

Here, the decisive moment has thus become the decisive absence, precisely as photographic space has expanded and multiplied indefinitely. This is now the condition under which all photographs are potentially produced. I am reminded of this fact whenever I take a photograph with my iPhone using the High Dynamic Range (HDR) setting, which automatically blends together three differently exposed versions of the 'same' scene in an effort to improve details in the shadows and highlights. Since the world does not usually stand still to be photographed, movement in the frame leads to unusual repetitions, ghostings and dismemberments. Even stranger results were generated in the glitchy Apple Maps app in 2012, when cities were peppered with warped buildings and distorted bridges in the effort to render 3D geometries from 2D images. Galleries of these misfit renders can now be found on the Internet, as an ode to 'algorithmically-authored oddities' (Vanhmert 2013).

Figure 3. An example of 'ghosting' using the iPhone 4S's HDR exposure setting. Photo: Daniel Palmer.

Camera Conditions: From Apertures to Augmented Reality

Over forty years ago, in a famous work of photo-conceptualism, the British artist John Hilliard laid out what he understood to be the fundamental procedures of photography. The work, *Camera Recording Its Own Condition (7 Apertures, 10 Speeds, 2 Mirrors)* (1971) comprises a gridded display of seventy photographs, arrayed in ten rows of seven across, taken by a camera aimed at a mirror, showing itself at the moment of exposure. As the second part of the title of the work indicates, the snapshot-style images, which move from pure white to pure black, are the result of all the possible combinations of aperture size and shutter speed in Hilliard's camera, an East German made Praktica. In the grid, the artist has positioned the optimal 'correct' exposures in a diagonal line from the top right to bottom left. This changing of the mechanics of each shot reveals the intention of the unseen photographer. Importantly, Hilliard's fingers can be seen operating the camera. Hilliard also holds up a smaller mirror which reflects and makes legible the camera's setting and controls, making it a self-portrait of sorts.

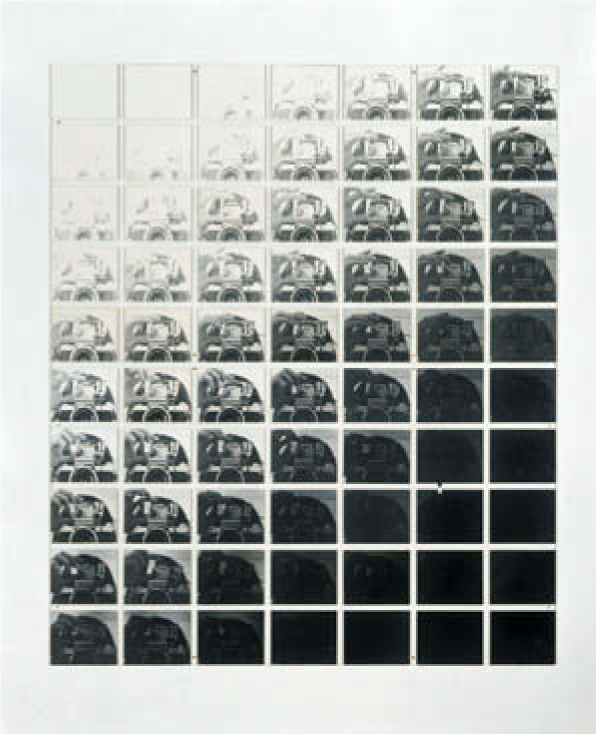

Figure 4. John Hilliard, Camera Recording Its Own Condition (7 Apertures, 10 Speeds, 2 Mirrors), 1971. Courtesy of the artist and the Tate.

Hilliard's work is open to various possible interpretations. It is clearly a commentary on the camera's supposed access to an objective depiction of the real world. By demonstrating the basic operating controls of the camera, focusing on the technical and chemical conditions, and revealing the processes that cause a photograph to appear as it does, Hilliard shows that reality is depicted according to predetermined technical conditions. Notably, the work does not consider focus as one of these 'conditions', nor does it consider film stock or the passage from the negative to the print (we simply assume that Hilliard's photographs are all printed in the same way). As the catalogue entry at the Tate notes, 'Photography is both the medium and the subject of the work, giving not a picture of "reality", but different versions of reality' (Tate). In addition to questioning photographic objectivity, as a work of conceptual art, it is likely, as photographer Jeff Wall has argued, that Hilliard's work is also a critical commentary on what many artists at the time saw as 'an excessive subjectivism in the then-reigning versions of art photography' (2012: 698). This is the famous deadpan (non-)aesthetic of conceptual photography, particularly that which operated in serial mode, in which the individual creative agency of the photographer is purposely downplayed: here, the camera is simply 'recording', as if it has an agency of its own (Palmer 2013).

Viewing Hilliard's work today, however, with the knowledge of the increasingly sophisticated automation of cameras that was about to occur, starting with basic electronic controls in the 1970s and massively expanded with digital cameras since the 1990s, we can now interpret this piece afresh. Arguably, what the work becomes now, above all, is a homage to the economic simplicity of the camera's 'condition' in the classic age of 35mm *analogue photography*. Today, the activity of taking photographs—of using a camera—is at once both simpler and more complex than the conditions depicted in Hilliard's work. Taking a correctly exposed and focused photograph is certainly simpler, to the extent that most cameras are now completely automated. Most people who use a camera today simply do not concern themselves with aperture, shutter speed or focus. To be sure, this has been the case since Kodak pioneered its brilliant logic of 'you press the button we do the rest' at the end of the nineteenth century. However, automatic here effectively meant fixed (aperture and shutter speeds)—Box Brownie cameras could not automatically respond to changing conditions. Moreover, the 'we' in Kodak's statement has now shifted from a company producing prints for a consumer to the algorithmic software in which photography is now embedded (from camera design to online photosharing tools).

The design of digital cameras is superficially similar to traditional cameras. Some of the available options—such as auto-focus—were pioneered in electronic cameras from the 1970s. However, a film camera could never interpret a visual scene with anything that might be called intelligence. In a digital camera, given that the data collected by the sensor array in response to a pattern of illumination is essentially a string of digits, the level of intelligence is limited only by the software, that is, the algorithmic processes that operate on the raw data. Thus auto-white balance, face-recognition and enhancing the sharpness of an image became standard features on digital cameras almost immediately, not to mention the default compression protocol of the JPEG and its universal standardisation of metadata. But the possibilities of intelligent operations are expanding in range and effect, given that new algorithms are constantly being developed. As cameras are increasingly networked to the Internet, software is now available that can 'learn' to fix up pixelated photos, and even 'complete' scenes in photographs, through the analysis of millions of related images in a database. Google's social media site has implemented sophisticated facial recognition so it can more finely auto-tune images to fix a person's blemishes or skin tones. As with so much algorithmic calculation, all of these techniques rely on laws of averaging (for example, to fix noise, the software measures the statistical properties of images and creates an algorithm that determines what is or is not 'noise' in any given photograph).

For a camera user, these actions can happen more or less seamlessly. But the processes by which these actions happen are usually opaque. Vilém Flusser (2000) famously wrote of the camera as the archetypal black box, or more specifically as a programmable apparatus that paradoxically programs the photographers (functionaries) who use it. However, Flusser's critique is more complex than often recognized, counterbalanced as it is by his praise for what he calls 'experimental photography':

'to create a space for human intention in a world dominated by apparatuses' (2000: 75). Ironically, his optimism in this regard now reads as a relic of the analogue era. For as the photograph becomes a data object, it also becomes part of networked visual culture online, such that the camera's 'condition' is no longer separable from the networked image culture in which it is enmeshed. This helps to explain why camera manufacturers now increasingly market their products not only on the quality of their hardware (such as lenses, traditionally the benchmark of quality, now increasingly interchangeable), but on the quality or features of their software (algorithms). I have written elsewhere of the marketing for the Olympus OM-D, released in 2012, which presents itself as a camera that 'aims to change the way in which you experience photography' specifically on the basis of innovative software that enables creative intervention at the point of capture (Palmer 2013). Needless to say, such algorithms involve complex patents and are closely guarded commercial secrets.

For the everyday user of a camera—particularly those embedded in mobile phones, which have quickly become the majority—the nature of the labour involved in taking a photograph is dramatically changing. In her famous moral critique in the 1970s, Susan Sontag argued that 'through the camera people become customers or tourists of reality' and that photography's 'main effect is to convert the world into a department store or museum-without-walls in which every subject is depreciated into an article of consumption, promoted into an item for aesthetic appreciation' (1977: 110). This critique still holds, but has intensified. Today, aesthetic appreciation is not even required for the world photographed to become a consumption point. On the one hand, photography today has become increasingly conversational and transactional (as in all the ephemeral photo-messages sent by phone). But on the other hand, photography has become more instrumental, and the act of photographing has increasingly become a consumer event—whether because inserted into an online entertainment activity (common on mobile phones), or as a vehicle for augmented reality that in its dominant forms (QR codes) is better described as 'augmented advertising'. When geo-location is added to the equation, urban space has become available for commodification and consumption in new ways, in the guise of photographic activity. For instance, Nokia City Lens, a typical piece of augmented reality software, 'gives dynamic information about users' surroundings such as shops, restaurants, and points of interest, shown as virtual signs overlaid on or above buildings.' Apps like these are challenging the very definition of photography itself.

Meanwhile, for the erstwhile creative photographer, as we have already seen above, decision making can increasingly be left until after the moment of exposure

(Palmer 2013). When, after all, is a photograph 'made'? As Geoffrey Batchen has observed, the answer to this question has always been complex:

> Is it when the photographer depresses the camera shutter, submitting a chosen scene to the stasis of framed exposure? Is it when the photographer singles out this exposure for printing, thereby investing a latent image with the personal significance of selection, labour, and most crucial of all, visibility? Or it when that image is first exposed to the public gaze. (2001: 83)

In light of this, we can recognise that the emphasis on pre-visualisation, the imaginative period before the moment of exposure, associated most closely with Ansel Adams, is not that different from Cartier-Bresson's 'decisive moment' with its emphasis on the fraction of a second involved in choreographing a photograph. In reality, both of these approaches involve a certain myth-making around the creative visionary engaged in a poetic encounter with the world. Each downplays the mediating process, including the crucial activity of editing, preferring to emphasis an artistic method of subjective intuition. At the opposite extreme to Adams and Cartier-Bresson is the photographer Garry Winogrand, who famously claimed to photograph to see what the world looks like in photographs, and eventually turned to a motor-winder to speed up the process of capture, ensuring that editing became the critical part of his creative process. Notably, the topic of editing has been largely overlooked in photographic history and theory (Campany 2013).

With digital tools, the deferral of creative decision making can take many unexpected directions. Photographers have long lived with the possibility that negatives may be able to be printed in new (not necessarily better) ways in the future. It has often been possible to print higher quality versions of images than when they were original taken (or in the photographer's own lifetime), thanks to technological advances in lenses and paper quality. Today, these potential improvements have been virtualised. Thus the most recent version of Photoshop can process RAW files better than the previous versions of Photoshop. That is, there is now always the promise that RAW sensor data might be processed better in the future, giving a new meaning to the conventional notion of the latent image. Furthermore, the image might not just be produced at a higher quality, but the data could be interpreted in completely new, as yet unrealised, ways. Thus the image operates 'in a constant state of deferral' of its potential (Rubinstein and Sluis 2013: 29).

A very different recent example of the use of algorithms gives a taste of where editing might be heading in the age of digital automation. Google recently announced the introduction of new photography features in Google+, in an effort to compete with Facebook and their takeover of Instagram. Google's pitch is an attempt to make the human labour of editing unnecessary or obsolete. By using algorithms, a feature called Auto Highlight will skip over blurry photos, duplicates, and underexposed shots, and choose the 'best' photographs to display and share. The example is given of uploading hundreds of new vacation photographs:

> Google Plus [*sic*] will surface the best ones to share with others by eliminating blurry or unfocused photos and even analyzing whether people look happy. Using Knowledge Graph, it might recognize where a person is located and prioritize photos taken at important landmarks. It will also prioritize photos of people recognized to be in a user's close Google Plus circles, like family members. (Leber 2013)

In other words, drawing upon the computing power, machine learning, algorithms, semantics analysis and other innovations that have established Google's search engine as the most influential force on the Internet, the company is effectively offering to edit your photographs for you. Taking 'smile detection' to another level, one feature promises to automatically stitch together a single image from several, for example from a sequence of photos of a group of people, so that everyone's eyes are open and everyone is smiling. The innovation here lies at the level of automation. All of this is designed to save people the time and trouble of choosing and editing photos, premised on the claim, as Google representative Vic Gundotra puts it, that: 'if we are honest with each other photos are very labor intensive' (quoted in Liedtke 2013). The plans even include 'a photo rating system' which is being trained by hundreds of human raters, designed to help the photo engine begin to account for 'aesthetics and human tastes' (Gundotra, quoted in Leber 2013).

Temporal Conditions: From Emanations of the Past to Calculations of the Future

If we accept Google's anticipation of consumer expectations, photography is no longer exclusively concerned with recording a past moment. Indeed, the temporal question in photography can now be said to also include both the time involved in editing and sharing those moments. And that whole process must aspire to be as automated and instantaneous as speech itself at least superficially appears to be. One is reminded of a 2011 commercial for Apple iCloud in which a child rushes inside a house to view photographs on an iPad that have just been taken of him playing outside with an iPhone. They have seamlessly and remotely synchronised themselves from the capture device to a different display screen. Moreover, they have been uploaded to the network and then downloaded again—which in practice can entail some delay, not that you would know this from the Apple commercial, with its reassuring voiceover 'capture the moment here, and it's waiting for you there'. The so-called 'Photo Stream' is indeed designed to automate the sharing of photographs not only between devices but also between family and friends (using Shared Photo Streams). The seamless nature of the process evokes a fantasy of instantaneous distribution and ubiquitous photographic presence. But even Apple's digital universe is not without its asynchronous moments. Recently, during an attempted viewing, an error message appeared on my display screen which read: 'Error. Time is over a day old.' This nonsensical yet strangely poetic phrase, generated without warning or further explanation by the software of my Apple TV unit, raises the question: can time be old? In computerisation, where now is the only time that matters, it certainly appears that time can indeed be too old.

Figure 5. Apple TV Error Message, 2013. Photo: Daniel Palmer.

For many of its most important theorists, time is the very essence of photography. Not the now nearly instantaneous time between recording and displaying, but the very possibility of a time-travelling encounter between the past and the present. Thus in his classic formulation of the particular quality of (analogue) photography, Roland Barthes famously wrote:

> The photograph is literally an emanation of the referent. From a real body, which was there, proceed radiations which ultimately touch me, who am here; the duration of the transmission is insignificant; the photograph of the missing being, as Sontag says, will touch me like the delayed rays of a star. (1984: 80–81)

This passage is of course an enthusiastic defence of photography's specific indexical and temporal qualities. Barthes' use of the word *emanation* is self-consciously Romantic, with its overtones of cosmology and certain religious systems (the word derives from the Latin *emanare* meaning 'to flow from' or 'to pour forth or out of', as the mode by which all things are derived from the First Reality, or God). It is true that the referent, in this case the 'real body', has caused a particular reflection of light that has in turn caused a specific reaction on the part of chemical materials that made the photograph. However, Barthes makes a poetic leap to suggest that the photograph somehow relays radiations of the past body to the living body who views a photograph at a later date. Needless to say, what we actually see when we look at a photograph is something less than an emanation; traditionally, we see a mere piece of paper, a flattened, two-dimensional, often black-and-white image of the world that bears an impression of light according to the specific optical and chemical technologies that brought that image into being. Today, we more likely view an arrangement of pixels on a screen.

Nevertheless, Barthes' seductive notion of the *delayed* rays of the star remains highly suggestive. Since the light from our closest stars (beyond the sun) takes over four years to reach the earth—and that of distant stars may take thousands or even millions—when we look at stars we are, in a sense, looking back in time. We are indeed looking at *old light*. While the finite speed of light has been known for centuries (photons travel at a constant speed of about 300,000 kilometres per second) we tend to assume its instantaneity, forgetting the gap between reality and its appearance—which in this case is large indeed. Translated to photography, this idea of time-travelling 'radiations' forms a crucial part of Barthes' broader ontology of photography, by which photographs offer a co-presence with the past, the famous 'that-has-been' tense of photography (Barthes 1984: 96). A photograph records the time at which reflected light strikes the film or plate, and is thus both an indexical trace of the object and a certified document of time itself. This is the ultimate, overarching philosophy of photography in *Camera Lucida*: that the essence of photography is Time itself (Barthes 1984: 96). Indeed, in almost all classical accounts of photography, it is a retrospective medium, charged exclusively with looking back—with history, memory and nostalgia.

All of this remains true of many forms of digital photography, to the extent to which they continue to serve the aim of documenting moments of time. However, digital photography is also capable of functioning in very different ways. We have already seen that the 'duration of the transmission', contra Barthes, is now extremely significant. In its new calculative and distributed dimensions, photographic images can behave in much more dynamic and performative ways. By way of a dramatic example, consider a recent Australian smart phone app developed to prevent graffiti tagging, VandalTrak (www.vandaltrak.com.au). As we know, the native camera app on an iPhone, or any other smartphone, is just one piece of software among hundreds that can engage the camera hardware. Apps are simply small pieces of software that add functionality to a digital device, and in the case of photo apps they tend to have two main purposes: first, to make images more 'artistic' or aesthetically distinctive (such as Hipstamatic); and second, to facilitate the distribution or publication of photographs (such as Snapchat). The most successful of all, Instagram, does both. VandalTrak belongs to a subset of the second category. Like many apps, it takes advantage of the distinctive feature of camera phones, such as the iPhone, to automatically tag photographs with their GPS location in the metadata, allowing images to be browsed and arranged geographically, and for software to aggregate them for various purpose. A number of photo-sharing websites, such as Flickr (www.flickr.com) and Panoramio (www.panoramio.com), now provide large collections of publicly available, accurately geo-tagged images.

The VandalTrak app has been developed on the assumption that graffiti is a significant problem, 'reducing the value and image of our communities and neighbourhoods', as the website claims. It works by using an online system that seeks to log, track and manage graffiti incidents in one place. Members of the public can take photographs of graffiti when they see it and upload it to the VandalTrak online database, where it is automatically logged by its location, catalogued by the traits of the tag (using pattern recognition software) and provided to police, council and other organisations (Olding 2013). Thus, with its citizen policing logic, VandalTrak is part of a wave of what has been called 'participatory sensing' enabled by mobile media, using embedded devices to capture data about oneself and one's community (often extending earlier histories of citizen science projects). As Kate Shilton has argued, participatory sensing is an emerging form of mass data collection that may, under appropriate conditions, be conceived as a form of 'empowering' self-surveillance—an opportunity for individuals and groups to 'provide possibilities for self-exploration, community discovery, and new knowledge creation' (2010: 132). For instance, people can use a mobile phone's sensor capacities, of which the camera is one, to work together for specific purposes, from such simple projects as mapping local pollution to targeting and identifying invasive plant species in national parks. VandalTrak is indeed a form of community intelligence-gathering, and has been embraced by the Australian police who encourage the public to anonymously provide information about the identity of taggers.

The contrast between the photographs that Barthes write about in *Camera Lucida* and the digital images produced for VandalTrak could not be greater. The latter operates in a purely instrumental manner, existing only to be communicated as evidence, and put to work in an economy of power (Tagg 1988). Many writers have suggested that the move to digital involves a shift from thinking about photography exclusively as *representation* and increasingly as *information*. Perhaps it is better to think of this in terms of a *bias*, given that photographs have long been used as information within institutional archives. But with VandalTrak the significance of the new bias is clear. What matters is not the individual viewer of the photographs, as in Barthes' phenomenological method, but that digital light—or the electrical signals that produce the picture elements (pixels) that we see on the screen—are here distributed across databases and interpreted by computer algorithms. Rather than the delayed rays of a star, the more accurate comparison is the real-time screen of radar, which as Lev Manovich observes is the precursor to today's real-time screen image (2001: 99). These real-time screens are capable of instant changes in output, generating dynamic images experienced without delay and typically driven by some form of user interactivity. They alternate between windows and control panels, between the dimensions of 'representation' and 'control', in which the subject oscillates between the roles of viewer and user—inviting us to be both witness and participant (Manovich 2001: 207). In this way, with the real-time image generated in the time of the viewer, the computer screen becomes a space of performativity. That is, rather than emanations of the past, photography has become a performative calculation, where temporality is not so much historical as recursive.

Commercial Conditions: From Film Sales to Algorithms

Finally, I want to turn briefly to a less commonly discussed aspect of digital photography: its underlying economics. Here it is worth beginning with the story of Kodak's failure to capitalise on its innovations in the field of digital photography. Already the stuff of legend and myth, the main points in the narrative are clear. Kodak's research laboratories developed the world's first digital camera in 1975, in a team headed by Steve Sassoon. Its development, however, was stunted—confined to government clients and limited professional partnerships in the 1980s—because the reusable camera storage medium posed a fatal threat to film sales. The threat was real, given that film was 'Kodak's cash cow', with an 80% profit margin (DeMoulin 2009). Raymond DeMoulin, a retired Vice President of the Eastman Kodak Company, describes how the company kept to being a 'film company' rather than expanding into an 'imaging company'. Thus at the 1982 Photokina show in Cologne, Kodak demonstrated a display of digitized images, to show its seriousness in digital imaging. But it also announced a new film with so-called 'T' grain, promising finer grain and faster speeds, explicitly 'to delay the impact of digital' (DeMoulin 2009: 3). Former

Kodak Vice President Don Strickland claims he left the company in 1993 after he failed to get backing from within the company to release a digital camera. He told BBC News in 2012, 'We developed the world's first consumer digital camera and Kodak could have launched it in 1992. … [but] We could not get approval to launch or sell it because of fear of the cannibalisation of film' (BBC 2012). Antonio Perez, the most recent CEO of Kodak, has said that the company was still in denial as late as 2003 (DeMoulin 2009: 14). He recalls that when he started at Kodak, a banner in his office read 'expand the benefits of film', which he promptly took down, before closing eleven of fourteen factories dedicated to film in the next few years. But it was too late. Kodak's stock price declined from US$94 in 1997 to US$16 by 2008 to as low as 36 cents before the company filed for bankruptcy in 2012.

The question is: what has replaced film as the cash cow of consumer photography? Certainly ink and paper are profitable products. But Kodak's revenues, insofar as they exist, are now derived almost exclusively from the patents they own in digital research (which continue to feature in almost every camera used today). Meanwhile, for the consumer, taking photographs is an apparently cost-free activity, since even the purchase of dedicated cameras has become optional now that lenses are embedded in mobile phones. The fact that the most popular photo app, Instagram, is free to download gives us a clue as to what is happening. Photographs have themselves become a kind of currency, in that the circulation and exchange of photographic images now generates surplus value. On sites like Facebook—who paid US$1 billion for Instagram in 2012—the circulation of photographs creates value for shareholders through the attraction of users. Of course, algorithms are at the heart of this new expropriation of symbolic communicability. The right algorithms are valuable commodities (think of Google's search engine ranking system). We saw above how Google+ are attempting to attract users away from Facebook, by dramatically investing in their photosharing software. Flickr's attempt to patent the algorithm for their 'interestingness' ranking is instructive, since the ranking of a photograph on Flickr is highly dependent on user-supplied metadata such as tagging. Thus, what we are currently witnessing is the normalisation of forms of image organisation via a combination of human tagging and non-human calculation that are then returned back to us in the race for eyeballs.

As we have seen, it is now abundantly clear that algorithms pertain to the circumstances affecting how photography is made, circulated and experienced. This is hardly surprising, since algorithms are now integrated into our everyday lives more broadly at a variety of other levels, from predictive policing to financial trading (Steiner 2012). Algorithms are not in themselves a problem, but they raise new questions about the way decisions are made, issues such as privacy and commercial data-mining and the more general commodification of communication itself. This latter point is very clearly pertinent to photography, which has always been subject to technological developments. Photography's traditional single-authored logic has been supplemented by new conditions that make it more like a social currency, more ubiquitous than ever, but most valuable in its aggregations. Given all of this, it has recently been argued we need new forms of *metaphotography*, involving 'people who can figure out effective and timely ways to curate the enormous numbers of images online from all sources—amateur and professional alike', and which 'contextualizes, authenticates, and makes sense of' the online archive (Ritchin 2013). While this may indeed be desirable, such curatorial activities are bound to require computers for their success. Indeed, as Boris Groys has argued, curating and digital images are bound together:

> Digitalization, that is, the writing of the image, helps the image become reproducible, to circulate freely, to distribute itself … But at the same time the digitalized image becomes even more infected with non-identity—with the necessity of presenting the image as dissimilar to itself, which means that supplementary curing of the image—its curating—becomes unavoidable. (2008: 87)

Algorithms, we might say, are conditioning photography into both particular states of existence and desired states for use, and they operate at the speed of light, much faster than humans can edit, make sense of, or 'cure' them.

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CHAPTER 8

Simulated Translucency

Cathryn Vasseleu

We perceive translucency as the intermingling of matter and light within media. All materials except metals are translucent in varying degrees. Their capacity to diffuse light inside them has many magical and supernatural associations. Translucent substances have an inner glow that can imply interiority, or even the evanescent presence of an embodied soul. The ability to emulate these subtleties is a goal of photorealistic digital image synthesis. To date the best results have been achieved using an appearance modelling approach. Appearance models are algorithms for rendering the appearance of all kinds of materials, including those with varying degrees of translucency, such as ocean water, tree leaves, milk, marble, paper and skin. The aim is to produce a computer model that approximates the appearance of an object made of a translucent substance so closely that the photorealistic rendering elicits more or less the same visual response as to a photograph of the physical object. What matters in appearance modelling is that the computer model's formulation process is not detectable at a sensory level. How then might we begin to aesthetically acknowledge or engage critically and creatively with its synthetic inner glow? As will be elaborated, the difference that cannot be seen lies within the sensibility of simulated translucency.[1]

Models for depicting photo-realistic translucency are just one of many light rendering techniques, including shadow casting, ray tracing and radiosity. These programs do not simulate the way light is recorded in photosensitive media. They simulate the way light rays interact with shapes, material surfaces and with each other. Light rendering programs raise questions about how their process can be read in the context of multiple codes of realism (pictorial, three-dimensional, photographic and cinematic, video, etc.). However, the aspect of photorealistic image synthesis that most relates to the sensibility of simulated translucency is that in the digitally rendered image the signs of realism are not written in light. Light is written in code.

Appearance models render the appearance of different materials naturalistically, based on codified empirical indices of their optical characteristics. Whether simulations appear realistic, or life-like, because they capture and reconstruct the essential physical arrangement of the empirically measurable world, or whether perceptual processes and/or discursive practices determine our experience of simulated photorealism, are well-worn topics of debate among scientists, artists and media theorists. In order to consider how we *get* a model of life-like translucency (both technically and as a perceived effect), it is necessary to take a more specific approach. This first involves distinguishing translucency from transparency. Transparency was pursued as a guiding characteristic and perceived effect of Modernist aesthetics. Within Modernism and subsequent related movements, translucency has been understood in relation to transparency, defined as either an optical or a perceptual quality. With alternative ways of understanding the unique consistency of translucent media in hand we can, in turn, elaborate on the perceived translucency of a computer model.

Differences Between Translucency and Transparency

A transparent substance is one that is capable of transmitting light as though there is no intervening matter. Transparency, understood as a sensibility of both eye and mind, is the condition of optical surety and abstract clarity, secured by light passing freely though the concrete. As such transparency has aided idealist philosophy in its articulation of metaphysical vision, the spiritual soul and metaphoric illumination (through a light that illuminates matter but is refractory to incorporation).

In modern thought, matter’s capacity to transmit light in this way became a key factor in the explication of aesthetic concepts in painting, photography, film, sculpture and architecture. For example the ‘see-through’ effect took a luminous turn in art criticism that championed transparency in construction and critical reflection. Understood as the experiencing of things ‘being what they are’ (Sontag 1966:

13–14), transparency was a liberating, luminous clarity. It applied to minimalist art that is open to, and addressed directly to, the transformative exercise of our senses, rather than thick with hidden crafting and meaningful content. Transparency was also an emblem of the social, corporate and political ideals of structural and operational transparency, or openness. I will offer only the briefest sketch of transparency here, setting aside discussion of the ‘myth’ of transparency that haunted Modernity (revealed in all its opacity by Breton, Benjamin and Duchamp).[2]

Architectural transparency was, in its material sense, a guiding construction principle of Modernism. At its simplest, a fascination with the space-defining properties of transparency was translated into arrangements of glass and other materials that transmit light in such a way as to be able to see through them, or designs that involved unobstructed flows between interior and exterior spaces. The painter Robert Slutzky and architect Colin Rowe famously elucidated a distinction between the architectural interpretation of transparency in this literal sense, and phenomenal transparency, where transparency is elaborated corporeally and conceptually rather than optically (Rowe [1955–56] 1976: 160–62).[3] As well as being an inherent quality of a substance, it could also be a quality of organization. Material explorations of phenomenal transparency extended the optical characteristic to space, or the simultaneous perception of different spatial points within a dynamic field of view. The spatio–temporal complexities of phenomenal transparency were (and still are) interrogated in the exploration of fluctuating perceptual phenomena such as emerging and receding figures and ground, reflections and shadows, and implied or revealed surfaces, shallows and depths. Here transparency can apply to opaque objects, and to the semi-opacity of translucency. Both are implicated in phenomenal interpretations, as levels of transparency.

With eyes still trained on Modernism and its signature aesthetics of transparency, postmodern aestheticians initially focused on the superficiality of simulacra in their characterizations of the digital medium. Examples include Baudrillard’s articulation of the play of appearances of the ‘superficial abyss’ and Brummett’s interrogation of the ‘prophylactic whiteness’ or occluded interior of electronic images, devices interfaces and systems (Darley 2000: 58–77). Transparency and all it signified was obliterated by the computer interface according to such analyses. However the quality continued to figure as a key feature of ‘Supermodernism’, which conceives of architectural space as an ‘empty medium’, purposefully striving for transparency (Hans Ibelings 1998). Rather than communicating a message, supermodernist architecture works like an invisible, enveloping medium that creates a unique sensory experience.

Lev Manovich (2007) extends this aesthetics to the dissolution of personal technological devices into ambient objects in the era of ubiquitous computing. Machines disappear as they become implanted inside other objects, materials and surfaces. In Manovich's analysis transparency and translucency are regarded synonymously as the aesthetic signature of the boundless flexibility of the computer as an all-in-one meta-machine. On closer examination, his analysis relies on a difference between these two qualities. The transparency of the enveloping medium requires qualification of some kind, insofar as its aesthetic signature is not abysmal emptiness, but a comforting, sensual, enveloping shell. It is translucency, understood as a medium's capacity for incorporation and diffusion of other media, which metaphorically aids product designers' articulation of the computer as an embracing, universal simulation machine.

This brings us to an aspect of phenomenal transparency that is taken for granted. Its transparency cannot be separated from the order of matter, or a translucent materiality. The tendency of light to thicken and matter to dematerialize in translucency is associated with the appearance of a dynamic material universe. This association is made and developed in philosophical accounts of perception by Maurice Merleau-Ponty and Henri Bergson.

Merleau-Ponty gives a unique inflection to the partial opacity of translucency. He regards matter as the invisible condition of seeing rather than an obstacle to perception. For example, looking into an ornamental garden pool and observing the tiling clearly visible below, Merleau-Ponty reflects: 'I do not see it *despite* the water and the reflection there; I see it through them and because of them' (Merleau-Ponty 1962: 182). Here, the tiling materializes for the viewer in the intervening thickness of water: 'If there were no distortions, no ripples of sunlight, if it were without this flesh that I saw the geometry of the tiles, then I would cease to see it *as* it is and where it is—which is to say, beyond any identical, specific place' (Merleau-Ponty 1962: 182). Merleau-Ponty's account of visual perception is anti-optical. It runs counter to a representational view of the empirical world, or a merely physical-optical relation in which vision is based on optical surety. For Merleau-Ponty the 'see through' quality of transparency is related to a translucent materiality, not immateriality. What transparency means for Merleau-Ponty is the ability to see through the intervening thickness of media.

While Merleau-Ponty equates transparency with a voluminous translucence, he understands the dynamics of translucency in terms of mirroring:

> every object is the mirror of all the others … I can … see an object in so far as objects form a system or a world, and in so far as each one treats the others round it as spectators of its hidden aspects and as guarantee of the permanence of those aspects. (1962: 68–69)

Thus reflected, translucency is the condition of the apprehension of the visible as a system or universe of beings that disclose themselves in and to each other as a whole (a world of implicated figures and grounds explored in phenomenal elaborations of architectural transparency). The visible is not a formless multiplicity of perceived objects-in-general that are foremost given over to abstraction and clarification. Any seeing of an object is a participation in the translucence, that is, the whole-in-one aspect of things: 'the completed object is translucent, being shot through from all side by an infinite number of present scrutinies which intersect in its depths leaving nothing hidden' (Merleau-Ponty 1962: 68–69). The 'thickness' of translucence is not a geometrical dimension, as refined in the perspective painting techniques of the Renaissance to facilitate a more exact, artificial construction of the world. What is gathered in the intersecting voluminous spacing of translucency is the dynamic unfolding of the fabric of the world. This is conveyed in the uncontained, infinitely dispersed radiation of the visible, whose freedom in self-arrangement can be described as 'internal animation'.

Merleau-Ponty describes translucence as the shimmering clarity of a phenomenological vision anchored in the material world, but a simulation of translucent appearance is an image calculated by a disembodied model. Here translucency has a separate, non-phenomenological existence in a virtual form that is more readily aligned conceptually with Bergson's understanding of the dynamics of perception. Like Merleau-Ponty, Bergson does not regard perceptual experience as a function of a physical–optical relation between a subject and a transcendentally illuminated object-world. Instead, the appearance of the material universe is derived through our perception. In Bergson's account, material objects have independent functions and real actions, but a living body participates in creating perceptions through the momentary delimitation and isolation of a light that would otherwise pass by and remain unrevealed. The world of perception manifests its spontaneity insofar as: 'Images detach from themselves that which we have arrested on its way, that which we are capable of influencing' (Bergson 1988: 37). In this schema, a perception is a phenomenon of the same order as a virtual image. It is an effect of light that has been impeded and arrested momentarily, reflected without otherwise affecting the totality and freedom of action of matter. Reflections can appear as isolated moments of intentionality (contracted by and limited to our interest), as when images 'appear to turn towards our body the side, emphasized by the light upon it, which interests our body' (Bergson 1988: 36). In this way images can be perceived by us as living matters, or exist and act independently without being related to an individual, illuminating consciousness.

Bergson sets out in his vitalist philosophy to dismantle the notion of an immutable universe, which he associates with an intellectual viewpoint that renders matter inert by defining it in terms of properties that accentuate its materiality (Bergson 1911: 202). By way of contrast, he describes consciousness as a translucence in which the eye is elementally in things, universalizing a pure, non-human vision in an a-centred universe of images. Bergson's mobile, iridescent consciousness is a translucence that dematerializes solidified matter and animates the universe of images and objects. The chaotic interaction of virtual influences is the source of movement in both these things.

Both Merleau-Ponty and Bergson turn to the properties of translucent media to think their philosophies of perception through. Both also invoke the dynamics of multiple mirroring when elaborating on a global translucence. On closer consideration that association needs further elaboration. Mirrors are opaque structures that reflect light without altering its clarity. Reflection alone does not account for the qualified clarity of translucency. This raises another issue: the unique characteristics of translucency that distinguish it from transparency.

Translucency is an incomplete transparency, or partial opacity. It is a liminal quality, existing on the threshold between clarity and obscurity. The 'inner light' characteristic of translucency has a thickness that is related to material consistency, not spatial depth. Optically, a translucent substance is one that is capable of transmitting light, but also causes sufficient diffusion of that light to prevent the perception of clear and distinct images through it. Instead of being entirely permeable to light, as one sees things through a clear glass window, a translucent substance is suffused throughout with a shadowless, diaphanous lucidity. The passage and containment of light creates, simultaneously, opacities in our field of vision.[4] We can see only partly, not fully, through translucent matter. Light is reflected within the material before being either absorbed or transmitted. The internal scattering of light gives rise to a soft appearance, rather than a luminous opening.

In the stained glass windows of Gothic cathedrals, translucency was used to create the impression of the unveiling of veiled truths. The iridescent beauty of partially opaque panels at once shrouded and revealed an ineffable, divine light (Von Simson 1962: 120–22). Elsewhere the ambivalence between opaque surface and transparent opening has been employed to create a concept of a multi-natured fluid space. Translucent paper screens, a characteristic feature of Japanese architecture, were used in this way long before the concept was adopted by Western architecture in the early twentieth century. Presenting a glowing surface when closed, the screens allow direct access to nature when open (Kaltenbach 2004: 7).

Artists and architects manipulate the mutable characteristics of translucent materials to create a ‘tactile’ sensibility, or a sensual play between surfaces that admit light and the smooth, soft appearance of inner substance. Involving a sense of matter as much as light, translucency gives luminous contours to the material passages of inner-space. These passages are not rendered invisible or obliterated, as they are in optical transparency. Light blurs as it is incorporated and moved about within the blurring substance. Illumination takes on a sensuous character, not the clarity seen in the passage of a metaphysical light through material entities. If light figures as a connection between spirit and matter in virtually every culture, in translucency, it remains ambiguous whether light passes through or is moved by matter. While unobstructed openness is a defining characteristic of transparent relations, there are interruptions of clarity in the opaque/transparent glow of translucency, where matter has the power to admit, contain and transmit light.

A Computer Model of Translucent Media

In 2001 Henrik Wann Jensen and his colleagues at the University of California, San Diego, published a groundbreaking technique which made it possible to emulate the subtle characteristic traits of perceived translucency, such as colour bleeding within materials and diffusion of light across shadow boundaries (Jensen et al. 2001). A model that works for shiny, reflective materials such as metals assumes that light makes contact with and leaves the surface at the same position. In order to work for translucent materials the model must assume that light rays alter their position in their transmission through intervening materials, leaving the surface at a different point. These include liquid, solid and gaseous substances whose internal structure and composition scatter light, thus contributing to their visual complexity.

Optically, a significant amount of light is transported below the surface in translucent substances. Computer-models of translucent materials look completely wrong without the inclusion of this characteristic, known as subsurface scattering. The technique Jensen’s team proposed made the inclusion of this characteristic practical. It worked by approximating the subsurface scattering of light diffusing through translucent materials, without having to laboriously trace the individual photons.[5]

Figure 1. Three glasses of milk. From left to right: skim milk, whole milk, and diffuse milk. The skim and whole milk have been rendered using a model that takes subsurface light transport into account. The diffuse milk has been rendered using a model that defines how light is reflected at an opaque surface, which results in a hard appearance, making the milk look more like white paint rather than like milk (Jensen 2006). Courtesy of Henrik Wann Jensen.

Jensen describes his photon mapping technique as the recovery of the optical properties of matter. From this description, are we meant to understand that the likeness distilled in Jensen's model refers to a refractory substance known only by its empirically defined contours? Surely we grasp the appearance of an implied thickness and softness in a more substantive way—by responding to the image in physical terms, under the direction of the model's revision of that arrangement? Rather than posing an abstract identity, the life-like simulation of a substantive form of translucency hinges on the elaboration of an image in such a way that viewers are corporeally attuned to its material character. Jensen's team knows from experience that their task involves using a digital medium to render a materially determined 'inner light' in a visually interpretable way.

They know for example, that it is not solely the proportion of light and dark in an image, but their spatial relationships that make an object look translucent. They know that translucency affects the spatial structure of images; blurring detail, etc. Most importantly, they know that spatial organization alone does not tell us whether an object is translucent or not. Our vision is attuned to other factors unrelated to spatial layout, which influence perceived translucency (Fleming et al. 2004).

Jensen's team tests their algorithm's approximation of translucency by comparing the model's appearance with a physical model-box containing equivalent volumes and surfaces in a substantial form.[6] The visual similarity is taken as proof of the algorithm's ability to synthesize an image of an object whose translucent appearance is indistinguishable to sight from a physical translucent object. We read the object's material character from how translucent it appears in the context of its surroundings. Milk, for example, is a translucent substance that Jensen's model can replicate. Synthesized in such a way that we can identify the familiar visual surface-texture of physical translucency, a substance looks milk-like rather that looking like white paint (Jensen 2006).

Semioticians ascribed an indexical role to photography, understood as the representation of idealized physical entities. Here indexicality refers to a physically enacted connection between an object and its traces in a photographed image. Computer modelling reinvents the age-old trick of seeing by mimetic illusion. The type of index that enters into the computation of translucent appearance is the 'index of refraction', along with other parameters necessary to derive a computer model for a particular optical property. It is possible to devise models for handling all kinds of translucent substances, including the model already referred to, that can compute the parameters of milk-like translucence. Having the capacity to be fed descriptions of the fat and protein content of various milk products, it can handle the translucence of skim, regular, full fat, etc.

The experience we have of this model is regulated by an already worked-out make-up that is judged by the extent to which it achieves the intended effect; that is, a seamless visual approximation of familiar objects. Appearance modelling is based on the twin premise that images appear realistic when the model can capture, incorporate and reconstruct the essential optical-physical arrangement of the empirical world, modelled in accordance with psychophysical measurements of human powers of vision. In actuality, the model is an optical description that is designed for viewers to 'fill in' (guided by a prior carnal knowledge of milk's translucency) rather than a purely optical description.

As a circumscribed visual rendering, the image is only a partial representation. An algorithm for simulating milk-like translucency is not indicative of the mastery of phenomenal complexity. It is indicative of the mastery of the model. A model creates a unique perspective that tantalises and seduces. For example, we might experience milk in the Coca-Cola model way, as a product positioned in the company's global marketing strategy. In 2001 Coca Cola proposed a new line of dairy drinks for children under the working title 'Project Mother' (Brown 2001; Stevenson 2002). 'Milk' was not conceived of primarily as a drink made of milk. It was a beverage that was designed to capture the breakfast market because its ingredients would be judged sufficiently nutritious to win maternal approval. In other words, Project Mother wagered that appearing to be nutritious would be more seductive than being the real thing.

A computer model of a light-scattering substance is a psychophysical approximation that obviously doesn't affect our senses in the way a glass of milk does. We do not encounter the semblance as we would an 'authentic' glass of milk, whose material character is expressed in its countless corporeal manifestations; its coldness if it has been poured from a container in the fridge, forming a skin if it is hot, leaving a white moustache on our upper lip, tasting sour because it has gone off, giving us succour as did our mother, making us sick if we are lactose-intolerant.

Just as Alfred Hitchcock is able to render milk's characteristic translucency in a suspect way in the film *Suspicion* (1941), turning its glowing interior into something equally viewable as a poisoned brew,[7] the computer model formulates its own unseen parameters of sensibility. It allows us to see exactly (enough to distinguish between skim and whole milk) in adherence with its abstracted optical-physical reality. This is the 'inherently false' reality of a formal arrangement that cannot be realized physically. We cannot experience the material nature of milk based on how exactly the model enables us to understand its milky look.[8] Jensen's model is a distillation of translucent appearance, generated by the actions of an automated, virtual light. The paths of virtual photons are calculated to lose and change position between entering and leaving the simulated material, thereby reflecting its internal structure and material makeup. In the interstices, light ceases to be a radiant beam of energy and becomes something more akin to an animated, ambient light, indistinguishable from and informative of its digital-milk environment. The characteristic optical behaviour occurs spontaneously in photon mapping but its nature is pre-scripted. The degree of luminous 'density' and 'bleeding' is calculated in advance by an invisible structuring medium that determines the image's translucent appearance. In the modelling process, the invisible ordering of a materially given, luminous sensuality is recast as a sensuality of automated light flows. Jensen activates the flow to approximate a particular visual effect. His technique of image synthesis contains the chaos of a physical universe within its complex mapping of light's movement by matter.

Despite the model's artificially imposed order it is not disorienting to a viewer. Translucent appearance is instantaneously perceived, albeit in terms of new structure. The simulation amounts to a formal re-arrangement of the visible based on the indices of 'subsurface scattering'; that is, a structure determined by codified empirical indices of optical characteristics. Thus the model creates its own invisible parameters of complexity (complex variations in the translucent appearance of different materials). An ordered appearance of soft, smooth diaphanousness is spontaneously computer-generated, but is based on a quantifiable light-scattering function that must be calculated in advance. Altering the variables can produce unexpected effects, but once scripted the actual behaviours of virtual photons interacting with virtual surfaces is fixed. As well as being motivated to act in a formally specified way, the random scattering of light is a calculated variable.

Simulated Human Skin and Its Perceived Translucency

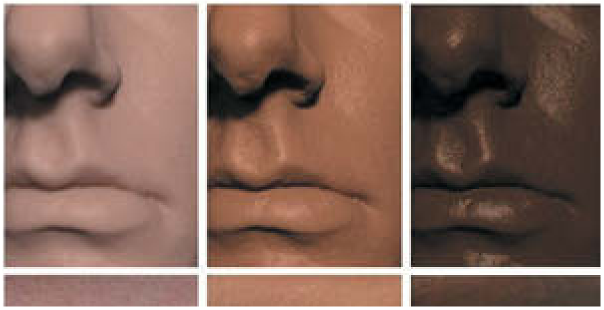

Figure 2. Different skin types simulated with model (top) compared to actual photographs of real skin samples (bottom) (Donner and Jensen 2006). Courtesy of Henrik Wann Jensen.

Appearance models describe the procedures for animating the variables that apply to the characteristic appearance of materials and media. Jensen's model for calculating subsurface scattering was quickly adopted by the 3D computer animation industry to photo-realistically render the appearance of human skin, which is a multilayered translucent substance. These multiple layers scatter light differently according to their different composition, resulting in a reddish cast to which human vision is finely attuned. More than with other materials, the slightest simulation errors are noticeable in human skin (Jimenez et al. 2010: 32). Just as the milk model can render the appearance of different types of milk (whole and skim etc.), the variables for modelling human skin can be altered to render shades of difference in its translucent appearance. The prototype for skin (skin1) was modelled, not surprisingly, as a facial close-up of a pale pink translucent cheek and fleshy, lipstick-reddened lips.[9] The modelling of various other skin-shades followed: Caucasian, Asian and African (Donner and Jensen 2006).

While the realistic appearance of simulated milk does not strike an uncanny note, the photorealism of a computer-generated actor can. The simulation of the 'inner light' occluded in human facial-skin initially exposed something of the pre-formulated 'soul' occluded in the polygonal faces of digital humans. These characters stumbled into what Masahiro Mori (1982) calls the 'uncanny valley'. Here, instead of completely identifying with a figure that appears human, audiences are repelled by traces of its robotic nature. Rather than knowing what they are looking at, viewers are disturbed by a presence they are not quite able to identify. When synthespians first appeared in 3D animations, audiences scoured their faces for traces of hidden engineering.[10] Viewers were forced to adopt an interrogative mode of perceiving while watching the moving images. Their vision was moved by practical concerns, born of an uncertainty about how they should view the photorealistic approximations of cinema screen actors they were seeing.

The simulation of human facial-skin announced a particular way of seeing the world, and with it a novel way of being (in both an existential and social sense). It announced a new form of animated presence; simulated matter with its own built-in, manipulatable, photorealistic character. It also announced new cultural image-forms—simulated photorealistic Caucasian, Asian, African characters that posed automated racial identities with their own optically defined order.

Simulation models do not replicate the natural world. They demolish a naturalized metaphysical viewpoint and replace it with systems that generate a world-order composed of quantifiable, manipulatable results. The model for subsurface scattering results in a controlled appearance of inner light that is indicative of different types of material character. An ambiguous quality is digitally recast as a precisely differentiated spectrum of 'signature' translucencies. Disclosed according to this methodical replacement of a naturalized metaphysical viewpoint, translucency is the automatic outcome of a model with adjustable parameters that renders an empirical description as believable as the appearance of photographed physical objects.

Twentieth century avant-garde photography and cinema practices confounded indexical readings of their art by privileging material process. Critically-oriented digital-based media practices have progressively confounded readings of their art in terms of reified concepts of immateriality, abstraction and materiality. We have yet to discover procedures that render the fixed behaviour of each shade of material character seen in photorealistic translucency in a questioning way. For this we need alternative ways of encountering simulated lighting effects, apart from blindly incorporating the perspective of the computer model. It takes more radical approaches to the process of approximation to shake our faith in the 'recovery' process of appearance models.[11]

For the moment experimentation with light rendering programs has been limited to extending their applications and aesthetic possibilities. Appearance models can offer an alternative perspective to naturalistic depiction. Architectural design is increasingly applying digital lighting programs to choreograph spaces that address human perception and multi-sensory experience, more in line with the aesthetics of Supermodernism. Here experimentation with computer-generated visual effects aims to evoke a sensuously rather than optically defined spatiality.

Within the computer graphics industry, refinements in light rendering techniques serve an essential role in overcoming undesirable uncanny effects in 3D computer animation. However, subsurface light transport models are costly in rendering time and are not suited to computer games and many graphics formats. Recent experimentation with alternative solutions that can be rendered quickly in games environments includes algorithms which translate the scattering effect simulated in a 3D model to screen space in a simplified form (Jiminez et al. 2010), and the proposal of even more rapid shading models (Gomez 2011). Unlike photon-mapping models of subsurface light transport, shading models provide impressionistic visual cues such as light source direction, colour gradients and blurriness, that help make an object appear translucent. With experimentation to produce ever faster ‘real-time translucency’ comes a proliferating technical typology of synthetic illumination. Although superior in terms of speed, the look achievable with real-time techniques is still inferior to the results achievable with photon-mapping techniques. Within the typology of synthetic illumination the subsurface light transport models discussed throughout this essay produce images that are formatted with the attributes of ‘true translucency’.

Here we have not only a computational model but also a model form of translucency. Ultimately, the unparalleled authenticity of ‘true translucency’, as recognized in computer graphics parlance, is a revealing expression that encapsulates the unseen substrate of digital image synthesis: an all-in-one translucent controlling medium, with an infinite capacity for absorption and diffusion of other media.

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Notes

1. A portion of this essay has appeared in 'Material-Character Animation: Experiments in Life-like Translucency,' published in *Carnal Knowledge: Towards a New Materialism Through the Arts*, edited by Estelle Barrett and Barbara Bolt (Vasseleu 2012). I originally wrote the extract material as a sequel to an earlier essay, 'What is Virtual Light?', which considered the development of the computer as a light-source (and light rendering programs specifically) in terms of a broader, cultural refiguration of light's ontological status (Vasseleu 2003). The sequel essay went unpublished until an opportunity arose to expand on the material process of computer-rendered translucency in the longer essay published in *Carnal Knowledge*. I thank Barbara Bolt and Estelle Barrett for agreeing to the republication of the extract in this volume dedicated to critical accounts of contemporary digital light-based technologies.
2. The 'myth' of transparency and its revival as a new principle of 'good modernism', exemplified by making a monument disappear in relation to its context (as in the Louvre Pyramid), as well as and other aspects of architectural transparency are discussed by at length by Anthony Vidler (Vidler 1992: 217–25).
3. Robert Slutzky's influence as a painter on the idea of phenomenal transparency in architecture is also discussed by Vidler (Vidler 2003: 6–7). Rowe and Slutzky acknowledge Gyorgy Kepes' initial description of phenomenal transparency, which they elaborated in their essay.
4. A shutter closing, functions as a thickening or blind spot that can be seen though. The closed off inner core of translucent substances functions likewise. Realised in both form and substance, the eclipse is a temporary death or moment of detachment of the subject, partially suspended from the field of vision (Fer 2000: 77–78).

5. For a full account of the process of photon mapping see Jensen's book on the subject (Jensen 2001).
6. The Department of Computer Graphics at Cornell University is home of the Cornell Box, which is a physical model housed at Cornell University, and also the ubiquitous test scene for global illumination. Since 1984 it has been used in the development and testing of algorithms for rendering light naturalistically, through physically based lighting models and perceptually based rendering procedures. The aim of such rendering methods is to produce images that are visually and measurably indistinguishable from real world images.
7. Deleuze singles out this famous scene in Alfred Hitchock's *Suspicion* (1941) as an instance in which cinema creates a 'mental image' by making relation itself the object of an image. The appearance of a thing may relate to the thing itself in a familiar, natural way, or the same appearance might leap out and strike a contradictory note (Deleuze 1986: 203). A computer model creates an appearance that may relate to the thing itself in a familiar, natural way, or not, when the rendered image calls the thing that it relates to into question because, for instance, the appearance of a glass of milk accidentally looks like a glass of white paint.
8. I am referring here to the beguiling perspective the model conjures, as discussed for example by Robert Harbison (1997: 84–98). There are other grounds for incommensurability, such as that between the model's abstracted lighting and a situated, phenomenal 'lighting' which invisibly constitutes the visible (Merleau-Ponty (1962: 311). The translucency of digital milk presents to us as a technically accessible, machine rendered likeness, which is produced by data that is unintelligible except in relation to human-machine systems.
9. The recovery of the optical properties of 'skin1' is indicative of one of the fantasy pursuits that appearance modelling can serve; in this case a familiar formal aesthetic endeavour involving a desired love object (that doesn't resemble Wall-E's gleaming white girlfriend).
10. At least one reviewer was unconvinced that Jensen's formulae could ever master the subtle intricacy with which light radiates from inside the face, that is, the so-called 'inner light' of consciousness (Weschler 2002: 120–22).
11. I take this issue up in relation to simulated translucency by assessing its life-like quality in comparison to Rachel Whiteread's tactile rendering of translucent cast resin sculptures. Whiteread works by abstraction, solidifying unseen spaces to produce uncanny perspectives that otherwise elude perception and thought. In the case of a simulation, this might include recasting the flow of virtual light to show that the material character of the world it models is returned to us strangely altered in its formal exactness (Vasseleu 2012).

CHAPTER 9

Mediations of Light: Screens as Information Surfaces

Christiane Paul

This chapter investigates the digital mediations of light enabled and supported by screens as information surfaces. As media archeologist Erkki Huhtamo, in particular, has pointed out, screens need to be examined not only as designed artefacts, but also with regard to their uses, their intermedial relations with other cultural forms, and the discourses that have framed them in different times and places. In order to investigate these aspects, one needs to first reconsider relationships between the display screen and projection, which have become more complex in the age of digital media, as well as the encoded nature of the digital image. Digital media also have introduced a shift from mostly ocularcentric paradigms—privileging vision as the basis for sense making—to a combination of vision and enacted embodiment that often employs light and shadow as enabling principles. Using these considerations as a starting point, this text explores screens in new media in their multiple roles and functionalities—as windows, mirrors, and membranes or as watchful, reactive, and transposing interfaces—to determine their role in the mediation of digital light. Light is considered in its relation to temporality and movement and as a crucial element in mediating embodied action.

Light / Screen / Projection

Plato's famous 'Allegory of the Cave' describes the existential predicament of a group of prisoners trapped in a cave: a gigantic fire at the cave's entrance separates the prisoners from the outside world while a wall in front of them provides the 'screen' for the only image of reality they know—the shadow play created by the people moving behind them, in front of the fire. Essentially, Plato's allegory is a story of enlightenment, of the ability to grasp the invisible truths underlying the apparent surface and reflections of the world surrounding us. At the same time, the allegory of the cave captures the essentials of mediation and the construction of imagery, the relationship between light and shadow, the screen and projection (in all of its meanings).

If one would update Plato's allegory for the age of cinema, one might replace the cave with a movie theatre, the fire with a projector, and the wall in front of the prisoners with a screen. In the age of digital media and 'digital light', the relationships between light, shadow, screen, and projection have become more complex: light is generated by electronic 'on and off' states, shadows can be 'read' and recoded to 'move' elements projected on a screen, and the relationship between screen and projection has shifted. Commenting on the relationship between screen display vs. projection, Steve Dietz poses the question:

> Isn't any similarity—or difference—in the *screen*, not the projection, which is invisible, essentially, when projected from the rear? Ultimately, except for the philiacs among us, the difference between 35mm front projection and TV is not about throw distance and trajectory. It is about scale and resolution. (2006)

To address qualities of the digital screen and projection, one needs to consider the role that light plays in rendering imagery visible. Whether there are distinctly different qualities between natural light and the light emitted by digital devices is beyond the scope of this text (and is addressed by other chapters in this book). In the digital age, what is visible on a screen, be it the computer screen or the wall space onto which a digital image is projected, is controlled by modulations of light in a spatially mapped array of bits or pixels. As opposed to the opto-mechanical film projector, which runs film frames through which light is projected, digital LCD (Liquid Crystal Displays) or DLP (Digital Light Processing) projectors create imagery from arrays of pixels. In the LCD projection (or screen) each pixel typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters. In DLP projectors, the image is created by microscopically small mirrors laid out in a matrix on a semiconductor chip, with each mirror representing one or more pixels in the projected image. Each mirror can be repositioned rapidly to reflect light either through the lens or onto a so-called heat sink or light dump. Mirrors are toggled between these two orientations or on and off states.

Another aspect of the digital image that is, at least indirectly, relevant to discussions of digital light is its encoded nature, which is commonly juxtaposed against the indexical one of photography and film. When Joseph Nicéphore Niépce created what is now commonly referred to as the first 'photograph' in 1826, a view from his workshop window using asphalt on a pewter plate, exposure to light was the core element in creating an image with an indexical relationship to its surroundings. One might argue that indexicality is not completely abandoned in a digital photograph. The fact that the object potentially could be completely 'simulated' in the digital medium does not turn the digital photograph into pure iconicity. While the digital photograph does not rely on light bouncing off an object to 'imprint' an image onto emulsion, it still encodes the light reflecting off a physical object. In the case of a digital image this process of encoding occurs during creation, editing, and distribution via a digital system (from computer screen to projection). German photographer Andreas Müller-Pohle's project *Digital Scores* (*Digitale Partituren*, 1995–98) nicely illustrates this encoded nature. In *Digital Scores III* Müller-Pohle translated Nicéphore Niépce's photograph into digital information. Müller-Pohle digitized the image and then translated the seven million bytes into alphanumerical code, which was distributed onto eight square panels. The information transcribed onto the panels remains undecipherable yet contains an accurate binary description of the original. *Digital Scores* both points to the fluid transition of information in the digital realm and to the different forms of encoding inherent to the digital and photographic medium. The encoding process itself, rather than the representational qualities of the image, becomes the central point of the work. The possibilities of encoding offered by the digital image play an essential role in enabling new configurations in the exploration of light in its relationship to the (projection) screen.

Ocularcentrism vs. Body Schema

Jacques Derrida suggested that the dichotomy of darkness and light is the founding metaphor of Western philosophy: 'the entire history of our philosophy is a photology, the name given to a history of, or treatise on, light' (quoted in Vasseleu 1997: 5). One could argue that presence, being, ontology, rational knowledge, enlightenment, epistemology etc., at least on some level, are all tied to notions of light and vision. As linguists and theorists such as Martin Jay have pointed out, the English language semantically connects vision and the eye with the Cartesian cogito and rational knowledge in the statement ‘I see’.

The link between vision and interpretation of the world is central to the concept of ocularcentrism, which Martin Jay popularized in his book *Downcast Eyes: The Denigration of Vision in Twentieth Century* (1993). Jay argues that there is no ‘vision’ or sight prior to cultural mediation, since everything we see is shaped through our cultural and historical context. Nevertheless ocularcentrism—which poses an objective world independent of the observer and privileges sight as the basis of rational knowledge—has been the preeminent visual model of modernity, as Jay would suggest. The twentieth century has seen an ‘anti-ocular turn’ and mounting critique of ocularcentrism in continental, particularly French, philosophy and scholarship, which Jay counters by calling for a plurality of ‘scopic regimes’. According to anti-ocularcentrism the privileging of vision as the prime model of perception results in an ‘objectification’ of our environment, which exists disconnected from us as a territory to be conquered and dominated.

Cathryn Vasseleu, in her book *Textures of Light: Vision and Touch in Irigaray, Levinas and Merleau-Ponty* (1997), critiques ocularcentrism from a different angle by reading the writings of Irigaray, Merleau-Ponty, and Levinas as undermining the dominant characterizations of vision and light in Western philosophy. Phenomenology, and Merleau-Ponty’s writings in particular, have gained enormous relevance in the field of digital media, since they provide a more appropriate philosophical and theoretical framework for approaching the forms of embodied interaction enabled by digital technologies.

In his chapter on ‘The Spatiality of One’s Own Body and Motility’ in *Phenomenology of Perception* ([1945] 1962), Merleau-Ponty makes a crucial distinction. On the one hand there is the body image (*schéma corporel*) as the visual apprehension of the body—the object or content of intentional (noetic) consciousness. On the other hand there is the body schema as a flexible, systemic form of distributed agency that extends from within the boundaries of the human body to the whole space of embodied mobility. This is essentially is a prenoetic function. As Shaun Gallagher points out, Merleau-Ponty’s distinction between body image and body schema illustrates the limitations of the phenomenological method, which, by definition, could not have access to the prenoetic role of the body schema (Hansen 2006: 40).

In his book *Bodies in Code*, Mark Hansen (2006) uses Merleau-Ponty’s theoretical framework, in particular, to analyze the pioneering works of media artist Myron Krueger, who countered the ocularcentric paradigm of immersion prevalent in virtual reality with the embodied enaction found in mixed reality environments. In his groundbreaking project *Videoplace* (1974–75), Krueger achieved synchronicity between the user's embodied action and the computer system's response, allowing users to focus on their embodied agency in 'playing' the system as an instrument rather than understanding the system's role as interaction partner. As Krueger himself puts it: 'In the ultimate interface, input should come from our voices and bodies and output should be directed at all our senses. Since we will also interact with each other through computers. The ultimate interface should also be judged by how well it helps us to relate to each other' (quoted in Hansen 2006: 28).

While Merleau-Ponty's theories do not seem directly related to notions of digital light, they are in fact crucial to the role that light plays in projected digital environments and the way we 'interface' with screens. Digital media environments commonly use vision systems that 'read' the participant's silhouette to drive the type of embodied interaction pioneered by Krueger. Both Ernesto Klar's *Relational Lights* (2010) and Scott Snibbe's *Screen Series* (2002-2003) are examples of embodied interactions that are enabled by and question configurations of light. *Relational Lights* uses light, sound, haze, and a custom-software system to produce a three-dimensional light-space that participants manipulate with their presence and movements. Lines projected through the haze onto the floor of the gallery create light-spaces or disembodied enclosures within the haze that can be 'entered' by people. As participants move around in the projected spaces, the lines adapt to the movements of the people occupying them, enabling a relational, collective shaping and expression of space. Light literally enables the creation of the space and the software-driven processing of people's movement in it.

In a different way, Scott Snibbe's *Screen Series* also questions the qualities of space and light, temporality and movement, and reconfigures conventions of projection and perception. Consisting of the works *Shadow* (2002), *Impression*, *Depletion*, *Compliant*, *Concentration* and *Shy* (all 2003), the *Screen Series* questions the cinematic status of the screen as a mere surface for image projection and turns it into a (re)active player in the representational game. Rather than simply being represented *on* the screen, the viewer's shadow is recorded and played back *by* the screen (*Shadow*). It changes the screen's rectangular outline (*Compliant*), erases it or 'paints' across it (*Depletion*, *Impression*). *Screen Series* explores relationships between bodies, light and shadow by reconfiguring cinematic conventions and allowing participants to experience the nature of the image in new ways: while representation is still inextricably bound to the process of recording, projecting and doubling, every aspect of the representational process becomes a reconfigurable, seemingly active entity. However, Snibbe's projects are not necessarily cinematic in the original sense but ultimately a subtle manipulation of light. The (deceptive) nature of the surface and the reflection play a central role in the project, which captures complex relationships between reality and representation, our bodies and their shadows (as imprint and trace of physical presence), the self and the other. In both Klar's and Snibbe's pieces disembodied information about our bodies, or, applying Merleau-Ponty's theories, aspects of the body schema, take a concrete diagrammatic form.

Screens as Interfaces and Mediations of Digital Light

The previous outline of relationships between light and representation, and the vision-centric vs. embodied interaction with digitally projected or encoded light, can be applied towards a closer reading of the role that screens now play as mediators of light. In the digital age the role of screens has been reconfigured from that of a 'passive' surface that functions as a 'projector' of information to one that seemingly 'reads' information about its viewer or environment or even 'reacts'. The properties of light are at the core of many of these reconfigurations.

The notion of the screen as 'interface'—an in-between or surface forming a common boundary of two bodies, spaces, phases—requires taking a closer look at what exactly is being 'interfaced'. In 'What Is Interface Aesthetics, and What Could It Be (Not)?', Florian Cramer (2011) distinguishes between the following interfaces: hardware to hardware; hardware to software; software to hardware; software to software; humans to hardware; humans to software. The following exploration of screens, as surfaces on which different forms of information processing meet, will predominantly focus on interfacing between software and hardware, humans and hardware, and humans to software (= user interfaces). As Cramer has pointed out, a substantial amount of research in the area of interface focuses on interface aesthetics as an aesthetics of systems, rather than the aesthetics of interfacing as the (social) practices of interaction.

In 'Elements of Screenology: Toward an Archaeology of the Screen', Erkki Huhtamo (2004)—who has formulated 'screenology' as a specific branch within media studies focusing on screens as information surfaces—argues that screens should not only be researched as designed artefacts, but also with regard to their uses, their intermedial relations with other cultural forms, and the discourses that have enveloped them in different times and places.

Concepts of the visual and embodied interaction with digital light, in combination with interface aesthetics and intermedial relations of the screen will form the basis for the following discussion of mediations of light as they manifest in the screen as window; watchful and reactive screens; the screen as mirror; the screen as membrane; and transposing screens. This classification of screens is not meant to suggest a definitive taxonomy but rather a framework for thinking about different functionalities enabled by the interfacing of software to hardware or humans to software / hardware.

Screens as Windows

Edmond Couchot has argued that 'the electronic screen does not function like a window, it does not inscribe onto a wall, it does not carry the look of the inside towards the outside; it inserts, on the contrary, the outside in the inside, in a centripetal and violent movement, at the place of the spectator. It acts by way of an inserting effect' (Couchot 1988: 80). While Couchot's argument may largely capture the effect of the TV screen, the interfacing digital technologies of screens complicate the picture and often seem to operate precisely on the border of the inside/outside. No matter how imprecise it may be, the windows metaphor, a basic element of the concept of the desktop, may itself have induced the perception of 'looking out'.

Artist John Gerrard has created several projects that, through their use of the screen itself as a navigation interface, have underscored the role of the screen as that of a window into a simulated digital world. His projects *Watchful Portrait* (2004)—a diptych of two seemingly identical, framed images of a woman (Caroline)—and *Portrait to Smile Once a Year (Mary)* (2006) appear to be photo-realistic 'head shots' of women that upon closer inspection reveal themselves as computer-generated 3D portraits. Rather than being fictitious personae, as most computer-generated characters are, the portraits are based on actual people, referencing the indexical status of photographs. While the works allude to the medium of photography, they also subtly yet radically undermine the fixed temporality of photographs—the 'freezing' of a moment in time. Both portraits include temporal components. In *Watchful Portrait*, the eyes of the two Carolines are tracking the position of the sun and the moon, respectively, throughout the course of the day. The precise scientific information as to the movement of these elements is constantly generated by the software on the basis of latitude and longitude data in combination with date and time. The portraits are designed to follow these co-ordinates with their eyes at all times. In one portrait, Caroline opens her eyes at dawn and closes them at dusk, tracking the sun's movement throughout the day. At dusk, the other portrait of Caroline opens her eyes and tracks the moon all night. Natural light and its cycles are at the core of the project yet manifest through a software-driven expression of a portrait. In the case of Mary, temporality is stretched further: the portrait will smile once a year (at a time determined by its subject or owner), creating a precious, fleeting moment of sentient expression.

The perception of the screen as mirror is created by the fact that viewers can turn the framed screen, on which the images appear, on a central pivot point and look around and behind the depicted subject. The effect is made possible through gaming technology—usually used for the construction of virtual worlds and their inhabitants—which Gerrard appropriates for his portraits to make them 'navigable' in real time. In Gerrard's works it is the 'reading' of the screen's position that in turn determines the perspective of the world on view. The seemingly simple replacement of conventional navigation devices such as mouse, joystick, or keyboard by the screen itself becomes a powerful mechanism for seemingly detaching the screen from the scene viewed through its window.

Watchful and Reactive Screens

A radically different perception of the screen is produced in projects in which screens seemingly 'watch' their viewers or react to them. In Rafael Lozano-Hemmer's *Surface Tension* (1993), the image of a giant human eye precisely follows the viewer's movements. While the motif of turning the gaze back onto the viewer has a long tradition—Tony Oursler's projected eyeballs being an obvious precedent among more recent works—the software-driven process of Lozano-Hemmer's work builds a much closer connection to computerized surveillance mechanisms and techniques. The piece was inspired by the deployment of camera-guided 'intelligent bombs' during the First Gulf War. The encoding of light in this project is common to many digital works: the viewer's position is read through a vision system and then encoded to allow the 'digital eye' to follow it. Despite the fact that the content of the project is deeply 'ocularcentric', the embodied enaction of the observed viewer is key. It is a combination of encoded light and movement rather than an actual act of seeing that drives the system.

SVEN—Surveillance Video Entertainment Network (2006–), by Amy Alexander, Wojciech Kosma and Vincent Rabaud, with Jesse Gilbert and Nikhil Rasiwasia, approaches surveillance from another angle, highlighting its inherent connection to entertainment. Fusing the threatening aspects of being watched with the pleasurable thrill of being the focus of attention, *SVEN* uses a custom computer vision system to observe people and assess characteristics that might suggest a potential rock star. By default the project takes the form of monitors showing a closed-circuit view of the space in which the piece is installed. The vision system ‘watches’ passers-by, comparing and matching their movement and body language to that of rock stars in music videos. When a person matching the system’s profile of a rock star is detected, a real-time video processing application generates visuals and audio reminiscent of music videos, incorporating the ‘profiled’ person. These clips, along with the one showing the matching rock star, interrupt the closed-circuit feed of the space and play on the monitors. *SVEN*’s tongue-in cheek surveillance illuminates concerns about profiling and automated systems as it shifts the focus from being watched to how the watching is done. The project explicates concerns about surveillance and computer systems as it challenges the assumptions of software-based systems for classifying individuals. Once again computer vision drives what is projected via the screen, turning it into an interface between human–hardware–software through the encoding of light.

The watchful and reactive screen using facial detection software will, presumably, become increasingly part of both smart phones and urban landscapes when it comes to personalized marketing. The Manhattan-based company Immersive Labs developed software that profiles the characteristics (such as gender, age) of people on the street, in order to display ads likely to attract them on the digital billboards they are passing. SceneTap, an app for smart phones originally launched in Chicago and Austin, uses cameras with facial detection software to analyze bar scenes (http://scenetap.com/). Without identifying individuals, it assesses characteristics of the crowd, such as average age and the ratio of men to women, and, through the app, assists bar-hoppers in making decisions about where to go.

Both facial detection, which does not identify specific individuals, and facial recognition, which does, involve analyses in which light plays a crucial role. In the abstract for their 2004 article, ‘Appearance-Based Face Recognition and Light-Fields’, Ralph Gross, Iain Matthews and Simon Baker from The Robotics Institute at Carnegie Mellon University outline their research as following:

> Arguably the most important decision to be made when developing an object recognition algorithm is selecting the scene measurements or features on which to base the algorithm. In appearance-based object recognition the features are chosen to be the pixel intensity values in an image of the object. These pixel intensities correspond directly

> to the radiance of light emitted from the object along certain rays in space. The set of all such radiance values over all possible rays is known as the plenoptic function or light-field. In this paper we develop a theory of appearance-based object recognition from light-fields. This theory leads directly to an algorithm for face recognition across pose that uses as many images of the face as are available, from one upwards. (2004: 1)

The research is based upon the premise that the plenoptic function or light-field specifies the radiance of light along all rays in a scene, and that the light-field of an object therefore is the set of all possible features that could be used by an object recognition algorithm based on appearance. Since an image is simply made up of a subset of measurements from the light-field, Gross, Matthews and Baker reframe the already answered question, 'what is the set of images of an object under all possible illumination conditions?' (2004: 2), and ask the same question about the set of all light-fields of an object. The authors draw the conclusion that two objects can almost always be distinguished from their light-fields if they have different shapes (under arbitrary illumination conditions, two objects that have the same shape cannot be distinguished).

A *The New York Times* article from 2011 suggested, the average person embedded in a 'high-tech' society will encounter these analyses through the mediation of screens that will expose them to a personalized ad or a breakdown of the demographics of a bar. The seemingly watchful or reactive screen in these scenarios is a light-based distribution device of a light-based algorithmic process (facial detection)—a software–hardware–human interface involving several forms of mediation of light.

Screens as Mirrors

Yet another, more obviously 'embodied' relationship to light unfolds in the use of the screen as a mirror. The metaphor of the screen that 'reflects', distorts, or remediates the viewer has been continuously explored in digital media art. *Liquid Views* (1993) by German artists Monika Fleischmann, Wolfgang Strauss and Christian-A. Bohn, for example, recreates a virtual pool of water in the form of a screen embedded in a pedestal. Bending over the pedestal, viewers see their reflection on the monitor and their touch of the screen produces wave-shaped forms, created by an algorithm, that distort the image. *Liquid Views* both translates the embodied, corporeal experience of the reflection into the virtual realm and at the same time unveils the function of the interface as a technological device that translates the viewer's image into a virtual space of reflections. While light may still be crucial in reading the viewer's image, the specular reflection of light is completely simulated.

While most of the projects discussed here are relying on the traditional computer monitor / display, a screen displaying digitally driven information can obviously take very different materialities. Artist Danny Rozin has created a series of 'software mirrors' and 'mechanical mirrors' that play with remediations of mirrors and replace the screen with mechanically driven materialities. While this is not necessarily the intent of Rozin's projects, they effectively illustrate that the screen is just one of many possible interfaces to simulate the effect of a mirror through the encoding of light. In *Snow Mirror* (2006)—from the software mirrors series—the image of the viewer, read through a video camera, is re-created through a projection of white snow flakes that accumulate in areas of the image that are brighter. Light again is the basis for encoding the simulated 'reflection'. In *Weave Mirror* (2007), the mirror image of the viewer stepping in front of the camera is (re)created by the movements of 768 motorized and laminated C-shaped prints that form the screen: a smoky, greyscale picture of viewers comes into focus through a gradual rotation in greyscale value on each C-ring. Circuitry and wiring are visible behind the picture plane of the 'screen' and the portrait assembles itself to the sound of the motors. Reminiscent of a homespun basket, *Weave Mirror* mixes textile design and new media, evoking the connection between the punched card-controlled Jacquard loom and the history of computing.

Whether they themselves are made of digital materials or not, the screens performing the function of a mirror in the display of digital information achieve a form of embodied synchronicity between viewers and their representations. While light is still crucial in the vision system's processing of the mirrored person's image, the display of the image is not necessarily bound to the reflection of light as in the case of Rozin's *Weave Mirror*.

Screen as Membrane

Screens also frequently fulfil the function of a membrane where the display of information and input from the viewer meet. One could claim that any touch screen creates the perception of the screen as a membrane or reactive surface; in the case of the touch screen, however, the screen's function as a form of membrane is not connected to input dependent on light.

An example of a relatively early project in which the information displayed on the screen seemingly reacted to viewers input, in this case their eye movement, was

Art+Com's *Zerseher / De-Viewer* (1992). *De-Viewer* first appears to be a reproduction of a traditional oil painting, Giovanni Francesco Caroto's *Boy with a Child-Drawing in His Hand* (ca. 1515), the first documented child drawing in art history. However, the painting slowly starts to blur and disintegrate in exactly the spots where the viewer's gaze meets the work. Whatever is looked at slowly deforms under each individual observer's eyes, so that the work never repeats itself. If nobody is interacting with the painting for 30 seconds, the image is reset to its original condition.

The reactive effect is created through an eye-tracking system that is analyzing the spectator's gaze and allowing for the exact calculation of co-ordinates on the canvas, which are then sent to a graphics program that in turn distorts the picture. Commercially available eye tracking systems are frequently based on video images of the eye. The trackers capture reflections of infrared light from both the cornea and the retina and thereby employ the process of 'seeing' to turn vision upon itself and track it. While *De-Viewer* appears to be inherently 'ocularcentric' it also expands the natural limits of vision by giving it destructive material properties. The project allows for embodied action that transcends the capabilities of the sense of vision.

Transposing Screens

At least since the beginnings of closed-circuit video art, experimentation with live reconfigurations of space that challenge embodied spatial and temporal perception has become a wide area of artistic practice. Video artist Dan Graham, in particular, created a number of installations that challenged the perception of space, or assigned the audience the double role of performer / viewer by making them experience themselves with a temporal delay; see for example, *Time Delay Room* (1974) or *Opposing Mirrors and Video Monitors on Time Delay* (1974). The possibilities of digital technologies have taken these temporal and spatial explorations and transpositions of views to a new level.

Kazuhiko Hachiya's *Inter Dis-Communication Machine* (1993), for example, is a communication system that transposes visual and sensual experiences. Used by two people wearing head-mounted displays, the 'machine' projects one wearer's sight and sound perception of the environment into the other one's display, thus confusing the borders between the identities of 'you' and 'me'. The *Inter Dis-Communication Machine* allows its wearers to seemingly enter each other's body and perception without being able to influence it. In a very different way than projects employing computer vision systems, *Inter Dis-Communication Machine* deliberately breaks with the synchronicity between the user's embodied action and the computer system's response while still emphasizing the vision-centric paradigm of immersion. *Inter Dis-Communication Machine* creates an out-of-body experience disrupting its users' body schema—the boundaries of their bodies and their space of embodied mobility—in order to make them aware of the body schema's function.

As the above examples show, digital technologies have substantially expanded the ways in which light is mediated. In any form of digital 'imaging' the encoding of light can occur during a project's creation, editing, and display via a digital system (be it a screen or projection). Screens are just one manifestation of interfaces that allow for mediations of light; yet they already involve enormous complexities. In many cases screens technically are just display mechanisms for a software-driven process (and mediation of light); in other cases (as in John Gerrard's works) they become an interface for navigation.

On the basis of Huhtamo's research one could argue that the use of screens, the intermedial relations they enable, and the discourses surrounding them defy merely technical explanations of the role that they play as information surfaces and mediators of light. The role of the screen as a watchful and reactive device or as a window, mirror, or membrane is not only assigned by technicalities but by perception, which is physically and culturally shaped.

Digital technologies can be said to expand the role that light plays in our engagement with the world: light is not only a basic principle of vision—tied to the ocularcentric paradigm—but also an essential element in mediating embodied action. The 'reading' and analysis of light and shadow usually is at the basis of computer systems that support the role of a screen as reactive or watchful or mirror. The complexities of the digital mediation of light expand the functionality of the screen from that of a display mechanism for pre-processed information to a surface on which multiple forms of information processing—from vision to motion—intersect.

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CHAPTER 10

View in Half or Varying Light: Joel Zika's Neo-Baroque Aesthetics

Darren Tofts

It is an image that has been glimpsed before. Many times before. A solitary figure is poised on a threshold. On the precipice of a cliff, the edge of a cave or the vertigo of doorways within doorways in confined domestic spaces. Or more ambivalent liminal spaces that are anticipatory, between states, entrances to unfamiliar interior or exterior space. This moment of anticipation may be one of enchantment, such as Alice's fall into Wonderland down the rabbit hole or melding with it through an impossible, membranous mirror. When Dante and Virgil ascend from Hell in the *Inferno* they are in abeyance between condemnation and purification, faced with the tantalizing glimpse of a paradise they have yet to achieve. The domestic interiors of Jan Vermeer and Pieter de Hooch create recursive, manifold spaces in which open doors, archways, latticed windows and mirrors suggest deeper recesses within, whereby an opening becomes the portal to yet another space. In Bram Stoker's *Dracula* (1897) Jonathan Harker is beckoned ominously to cross the threshold into his host's castle 'freely and of your own will!' This movement across physical and metaphysical thresholds is a decisive figure in that quintessentially American genre of the Western. Arguably its most totemic expression is encountered in John Ford's *The Searchers* (1956). In its iconic opening sequence the silhouette of a woman opens a cabin door from the darkness of an unseen interior. The sweeping vista of the Texan frontier onto which she gazes is the glaring and untamed wild nature that pitilessly illuminates her for our gaze in the counter shot. Her disappointed countenance, we quickly realise, suggests yet another frustrated hope of an arrival yet to come. A similar frontier drama is encountered in Neo's revelatory moment of *déjà vu* in *The Matrix* (1999): 'A black cat went past us, and then another that looked just like it'. Neo's seeing double is a sign that the invisible seams of the panoptical Construct have momentarily frayed, its omnipresence revealed as the simulacral order of things is subtly modified in response to his presence. All of these threshold moments are forms of estrangement, defamiliarizing epiphanies in which someone sees things differently, perhaps as if for the first time.

This poetic of someone watching and being watched, the undifferentiated surveillance of ambiguous spaces, of spaces within spaces, underpins the aesthetics of Australian media artist Joel Zika. Specifically, Zika's work engages with troubling perspectives of indeterminate and often vestigial environments that are viewed in half or varying light; a subtle tonality of luminance and shade that evokes an imminent crossing of a threshold (see http://joelzika.com). Though not just any threshold, one with consequences, an ambivalent passage described by the artist as 'an entrance into nowhere' (Zika 2009: 43). Joel Zika is one of a number of contemporary Australian artists discussed by Simon Gregg in his 2011 book *New Romantics: Darkness and Light in Australian* Art. Gregg is specifically interested in the ways in which the richly nuanced binary of darkness and light is played out in contemporary Australian art. Gregg is concerned with the ways in which artists as varied as Bill Henson, Jane Burton and Kathryn Ryan have engaged with Romantic notions of the sublime in their work, or have attempted to go beyond it to explore post-Romantic tropes such as the revival of the grotesque. In Zika's work the manipulation of digital light is also treated quite differently from the pastoral sublime yearned for in the work of the other artists identified by Gregg. Zika's work—specifically the two series *At Night* (2005) and *Night and Morning* (2008)—evocatively and disturbingly suggests a resurgence of the Baroque.

Zika's work is not Baroque in any classical sense of the word, as it is understood within art history. But it revives aspects of its theatricality, artifice and taste for staged *trompe l'oeil* set pieces in order to create robust, immersive visual spaces of unnerving enchantment, mystery and estrangement. As a media artist Zika is particularly known for his ongoing interest in the history of the American sideshow attraction of the 'dark ride'. With its origins in the deeper pre-moving image history of what writer Richard Abel described as a 'cinema of attractions', such as ghost trains (Abel 1994: 16), the dark ride represents for Zika a stage in the history of media technology's implicit fascination with the unseen, the otherworldly and its manifestation through sound and light.

Contemporary media artists have demonstrated an especially keen interest in the connections between the spectral and the sideshow attraction, particularly as a point of intimate, interactive encounter. Canadian artist Catherine Richards' installation *I was scared to death; I could have died of joy* (2000), for instance, constructs an enclosed world that evocatively blends the curiosity cabinet and the freak show.

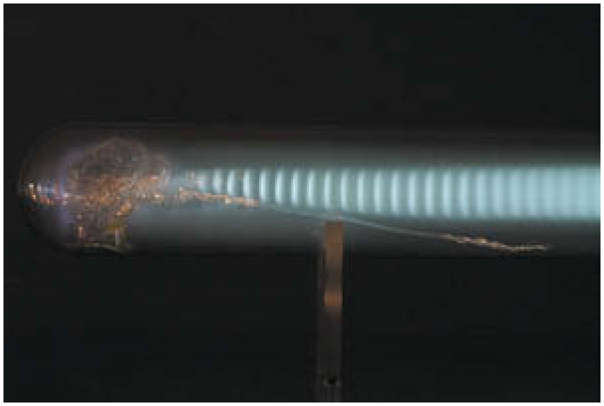

Figure 1. Catherine Richards, I was scared to death; I could have died of joy, 2000. Photo: Mitch Lenet. Courtesy of the artist.

Two glass canisters resembling nineteenth century specimen jars are set on stainless steel tables in a dimly lit room. The jars, in actuality gas-filled vacuum tubes, contain life-like glass models of a cranium and a spinal cord. As the visitor approaches them the light recedes even further until the room is completely dark. As if sensing this as a kind of bizarre curtain call in a Victorian pathology museum, each object glows in a responsive fluorescence. And it responds to your presence. Katherine Hayles has evocatively described this experience:

When an ionizing current is passed through the gas, the glass models fluoresce, creating a beautifully eerie glow … [As the ionized gas] arcs towards the visitor's hand, a connection and possibly a communication seems to be established between the interiority of the glass nervous system and the cognition of the visitor as she meditates on the experience. (2000, 10)

The play of light and shadow, brightness and darkness in this work has been described by Hayles as a kind of allegory of our experience of light itself. 'Light', she suggests, 'is the portion of the electromagnetic spectrum visible to humans' (2000: 10).[1] Her response to this foreshortened dimension of vision is to suggest, therefore, that for the most part 'we see darkly'. The act of seeing darkly is an apt figure for thinking about Zika's fascination with the complementary as well as contradictory qualities of digital light.

As attractions that simulate the crossing of thresholds, the unnerving descent into the otherworldly dark rides represent for Zika incipient, premonitory and powerful examples of immersive, virtual worlds. They are potent admixtures of light and shade, uniquely hybrid spaces that combine the mechanics of familiar trolley

Figure 2. Joel Zika, Arcade # 1, 2006. Courtesy of the artist.

rides (such as the rollercoaster), the fabricated construction of the walk-through built-environment (haunted house) and the emergent moving image technology of the cinema. Zika points out how such attractions were indelibly associated with the rapid and pervasive urbanism of early twentieth century America: 'As people became increasingly alienated from their local environs, they sought alternative destinations in a variety of forms of escape involving physical as well as imaginary sorts of "transport"' (Zika 2009: 12). Geographically, the locations of these gothic amusement parks were often found in 'a remote, isolated space', in the woods, on the edge of town, or a patch of wasteland (Zika 2009: 13). Symbolically at a distance, as if their horrors could not be countenanced in the streets where people actually lived, this of course added to their titillation as attractions. You had to make a commitment to go to them, a commitment to cross a threshold that assuredly would set the hair tingling on the back of your neck. Zika cannily captures this psychogeography of expectation in a number of image-based and installation works. For him it represented a key aesthetic and psychological component of the cultural resonance and meaning of such spaces, since the physical journey to get there, which took you to the 'end of the line', was also a 'mythological journey into the unknown' (Zika 2009: 13).

An iconic work in this respect is *Arcade* (2006). A stylized ghoul-like visage glows eerily from an undifferentiated background surrounded by trees. The silhouette of a young girl is seen approaching this unnerving portal, her hand reaching out as if feeling her way through the dark. The chilling second panel of the work reveals the child on the verge of entering into an abstract space (an image also witnessed in *Façade* of the same year). Frozen as a kind of cipher, a filtered image of light, she is forever captured in the intransitive state of enter*ing*. She is captured as a

Figure 3. Joel Zika, Arcade #2, 2006. Courtesy of the artist.

tableau vivant beyond recall and, potentially, beyond salvation.[2] Later installation works such as *Inferno* (2007) and *Terrorium* (2009) are uncannily devoid of such an expectant human presence, revealing perhaps reflexively the indifferent and solemn spectacle of a moment that has since passed. All that remains is the glow and enveloping saturation of light.

Central to the spectral, gothic atmospheres of the dark ride was the interplay between light and shade. Indeed, the historian of early cinema Laurent Mannoni describes pre-cinematic projection as a 'deceptive art', the 'great art of light and shadow' (2006: 42). The manifestation of the otherworldly as spectra of light has been traced back many times to the age of the magic lantern. The cone of light channelling through a darkened space bore an uncanny resemblance to steam, the psyche of the machine age. But more alarmingly it is also suggestive of breath, a psychosomatic aspect of projected light that Zika evocatively captures in his work, especially the *At Night* series (2005). Zika's interest in the palette of light and shade is continuous throughout his work in different media from series comprised of still images to immersive installation environments (such as the large scale walkthrough 'amusement' *Terrorium*). I want to focus particularly on *At Night* to concentrate the ways in which Zika mobilizes the seductive malleability of digital light. A latter-day Franz Mesmer, Zika invests the valencies of digital light and shade with the animus of character, of psyche and an enveloping sense of presence. His scenes, in this sense, can be considered less as planar 'inkjet' photomedia images than the orchestrated interactions of an ensemble of *dramatis personae* (mise-en-scène is far too static, less animate a term here). This performative vibe may partly be explained in terms of the artist's actual experience of the vestigial and often decaying theme parks he visited in the United States in 2007, such as Coney Island's 'Spookarama'

Figure 4. Joel Zika, At Night #1, 2005. Courtesy of the artist.

and the 'Old Mill' at Kennywood in Pittsburgh. In this sense the dark ride as a form of neo-Baroque representation, captured acutely in the *At Night* series, is the final, decadent flourish of a medium that would be succeeded by the cinema, the residue of a once former glory that still retains the power to unnerve and disturb.

Installed as a panorama of four images, *At Night* is immediately conspicuous for its absence of the human form. This immediately and uncomfortably situates the spectator as the focal point of view of the work. The first image reveals the facet of what appears to be an art deco façade of a building partially concealed by fog and the silhouette of a tree brightly illuminated from behind by an unseen source.[3] Next to it a sharply illuminated portico or entrance (not dissimilar to those of *Inferno* and *Terrorium*) manages to outshine the strong backlight of the previous image, though its saturation is still present in the casting of the winter trees as flattened out stencils in the foreground. In the third image a vulnerable distance seems to have been placed between the viewer and the environment of the previous two. We are somewhere else and there's no one else around. An old trolley car sits becalmed, but also seems out of place. Why is it here, as if concealed among the trees? The sharp light it seems to have absorbed is so clear that it reflects its own sienna hue onto the trees that conceal it, staining them a deep blood red. As if this drama of light, reflection and tension has been too much to bear, the final image of a tree in leaf brings some relief, though its complete lack of placement in any kind of identifiable landscape is still cause for concern.

Figure 5. Joel Zika, At Night # 3, 2005. Courtesy of the artist.

Figure 6. Joel Zika, At Night # 4, 2005. Courtesy of the artist.

The drama of this sequence of four modest images lies in its ambivalence. It at once resonates with the signs and atmosphere of charged expectation, as well as the desire to be frightened. A rudimentary journey into an uneasy heart of darkness guides the eye from the approach to the threshold moment of anticipation, the culmination of the ride and the return to the world of nature that is comfortably beyond the fabricated terror that brought you here in the first place. Certainly my own experience of this work in situ came with the uneasy intimation that I seemed to be the only living thing in the scene (despite the fact that there were other people in the gallery); an uncanny sensation generated by the subtle vanishing points of light in each image that insinuated that my gaze was its solitary locus. But more viscerally there is a compelling sense of presence. Alain Robbe-Grillet famously described the experience of Samuel Beckett's dramatic works in terms of presence, the overwhelming sensation that you are '*on stage*', you are '*there*' (Robbe-Grillet 1965: 111). The same is true of *At Night*. Whether you like it or not, you are not an aloof spectator. This sensation of being there has gone by many names in visual and dramatic aesthetics, such as identification, agency and empathy. For Heidegger, as Robbe-Grillet reminds us, '*to be there*' is the human condition itself. But it is also the psychopathology of what we today understand as immersion in virtual space, from installation environments to digital images. Writing in the mid-1950s Beckett himself talked about 'the power of the text to claw' (Beckett 1962: 183), a potently tactile image that reminds us that imagined or simulated presence is ultimately concerned with affect. T. S. Eliot, writing at a time when pre-cinematic projection media were familiar and still in use, captured this somatic quality of our engagement with phantoms of light in a decisive line from 'The Love Song of J. Alfred Prufrock' (1917): 'But as if a magic lantern threw the nerves in patterns on a screen'. This is the uncomfortable, non-negotiable presence Zika invokes in his manipulation of digital light.

At Night is a sequence of images unavoidably experienced in half or varying light. The experience of 'sound-in-space', Erik Davis suggests, 'does more than just shape a sound world; it also transports the listener' (Davis 2005: 71). The same can be said of the activity of vision and the manifold, tonal nuances of light. Light is the elemental force that transports the viewer as a somatic projection into the work. In his splendid book on Led Zeppelin's 'runes' album (colloquially known as *Led Zeppelin IV*), Davis picks up on Jimmy Page's oft-quoted formula of 'light and shade' as a way of describing the band's orchestration of the elemental polarities of lyricism and hard rock, lightness and aggression, brightness and darkness, pop and cock rock. The subtle modulation of light in the *At Night* series not only transports the viewer, but also creates the vicarious sensation of being in the presence of a certain kind of energy. In his famous 1975 *Crawdaddy* interview with William S. Burroughs, Jimmy Page spoke of the rock concert as an unleashing and mobilisation of energy through sound. The guitarist is a kind of magus, though one with a conscience, channelling sound in ways that blur the thin metaphysics between good and evil, light and shade (Burroughs 1975).[4] The same can be said of artisans of digital light such as Zika. It's important to note that the phrase 'view in half or varying light' that gives this essay its title and working metaphor, is the name of the painting by Barrington Colby that lines the left hand side of the inner gatefold of *Led Zeppelin IV*. Without question an instruction, the phrase was one of many cabbalistic references associated with all aspects of the album (from its liner notes, cover art and runic title to its lyrics). Once deciphered, it was understood as a direction on how to hold the Colby illustration at right angles against a mirror. Alchemy then ensues. The doubling of the image on itself creates the unmistakeable likeness of a monstrous dog, the eponymous black dog of the album's first track. Ambivalence implies in one of its connotations the possibility of an either/or dichotomy. So what may be a hound from hell may just be a misprision, the kind of wishful thinking that prompted a generation to decipher back-masked messages or tantalizing lead-out grooves on Beatles albums for yet another 'clue for you all' to do with the untimely death of Paul McCartney.

But ambivalence is also either *and* or, the uneasy co-presence of a thing and its opposite. The ambivalence of the admonition to 'view in half or varying light' can then be re-read as half *and* varying light, good *and* evil, expectation *and* dread, aftermath *and* anticipation. Let's not forget that in an age when television didn't exist and the cinema was in its infancy, the sole objective of the dark ride was to scare the wits out of you. As Zika points out in his study of the dark ride, these meandering,

Figure 7. Joel Zika, Façade, 2006. Courtesy of the artist.

Figure 8. Joel Zika, Night and Morning, 2008. Courtesy of the artist.

clunky 'pretzel' contraptions were holistic mixed media and multi-sensory experiences. The visceral nature of movement, the force of air through the hair, sound, smell and tactility meant that for a short time out-of-time, you can experience dread. In his photomedia work Zika exploits the synaesthesia of digital light to attune the senses to other channels of information to create this sense of discomfiture.

The iconic image of a death's head in *Façade* or a fourteenth century Taddeo di Bartolo-inspired Lucifer inviting you into the depths of his bowels in *Night and Morning* are figurative encounters with familiar images of dread. Their familiarity presumes a palatable distance, a kind of narcosis and a measure of safe horror that representations have always provided (what Aristotle understood as catharsis).

But *At Night* doesn't allow such a release valve. What happened at the moment when that anonymous figure went beyond the threshold in *Façade*? Or more dramatically, when the young girl in *Arcade* took what would seem to have been a fatal step into the unknown? There is no hokey counter shot in either work that allows us to share their sense of horror. Their terror is not represented, since it is beyond representation. There is no silent witness for whom it can become an image. As with that other famous literary image of a crossed threshold into the Marabar caves in E. M. Forster's *A Passage to India* (1924), it is an aporia, an irresolvable contradiction of which the truth can never be known. All we are left with as readers, as viewers, is the menace of the unknown, the signs of absent presence. This oppressive intuition that something unspeakable *has happened* prior to our arrival haunts the *At Night* series like a malevolent miasma. In this sense the images bristle, like so much static electricity, with a profound sense of aftermath that invites an act of speculation. This is the 'forensic aesthetic' described by art critic Ralf Rugoff, the realisation that we are privy to a place where '*something happened*' (1997: 62). The legendary American hard-boiled crime photographer Weegee (aka Arthur Fellig) was always the first to arrive at such scenes, photographing the body before it had time to cool. But rather than simply documenting that which has happened, he was concerned with the aesthetics of the image, with 'the way they look'. And more pertinently, he was interested in the ways in which an individual image 'fits within a series' (Wollen 1997: 31).

Armed with the forensic aesthetic as a mode of textual analysis, *At Night* dramatically changes in terms of our familiarity with Zika's dark ride works as a whole, as a series. Our perspective shifts from an anxious, solitary presence to a speculative gaze of urgent inquiry. No longer simply *there* to experience the ambience, we feel compelled to piece together a series of clues that bespeak a narrative that remains 'largely invisible to the eye' (Rugoff 1997: 62), though a narrative tempered by what Peter Wollen has evocatively described as the 'vectors of melancholy' (1997, 23). From *cinéma vérité* style glimpses of sideshow attractions, the images now resemble a set of crime scene photographs without a body. The work of mourning has begun.

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Notes

1. This work was first installed at the Galerie d'art d'Ottawa in 2000. It was also exhibited at the 2004 Sydney Biennale. For images of this work see www.catherinerichards.ca/html/brain.htm.
2. *Arcade* is very much a site-specific work. Installed in a public exhibition space in Manchester Lane, Melbourne, the work references the infamous murder of 12 year old schoolgirl Alma Tirtschke in 1921, whose body was found in a nearby alleyway.
3. The construction of the image is suggestive of Zika's approach to the treatment of light as a malleable material that can be translated through and between media. The art deco façade is modelled on the 'Laff in the Dark' ride at Lake Compounce in Bristol, Connecticut. Zika photographed it in situ in 2007. As with most vernacular photography of this kind it is intended as a testimonial image to his actual presence at the site. The photograph then formed the source material for the compositing of a digital image capable of simulating a different kind of presence for his viewers when the work was exhibited at the Spacement Gallery in Melbourne in 2006. In both instances, someone in these images is 'there'.
4. In the introduction to the *Crawdaddy* interview Burroughs reminds his readers that the origin of all the arts is 'magical in purpose' and is concerned with the 'evocation and control of spiritual forces'. For such magic to succeed, Burroughs warns, 'it must tap the sources of magical energy, and this can be dangerous'. With the notion of responsibility to his audience in mind, Page observes, somewhat ominously, that 'we don't want to release anything we can't handle' (Burroughs, 1975).

CHAPTER 11

The Panopticon is Leaking

Jon Ippolito

This chapter traces the historical roots of light as both a metaphor for knowledge and a means of control, and questions the relevance of this legacy for the era of networked dissidents such as Anonymous and WikiLeaks. As I will argue, the analogy between light and information is hampering our understanding of politics in the Internet age, even if such outdated metaphors are proving stubbornly difficult to discard. In the Internet age, a previously dominant broadcast paradigm has lost ground to a network paradigm, and it is within this context that I'm going to propose and analyse updated metaphors suggested by recent art and activism.[1]

The concept of light has no independent meaning in contemporary physics; light is simply a particular swath of wavelengths on the electromagnetic spectrum, nestled snugly between infrared and ultraviolet radiation. So-called 'digital light' is an even more arbitrary category, since the light that shines from our laptops and smartphones starts out as voltage differentials on a hard drive. If the word 'light' is to have any scientific significance, then it is distinguished not by any of its intrinsic physical properties, but by the biological fact that humans can see it.

Of course, Euroethnic culture has inherited from Enlightenment metaphysics a deep-seated sense that light is the emblem of truth, rather than a biological contingency. As René Descartes stated, 'Whatever is revealed to me by the natural light … cannot in any way be open to doubt' ([1641] 1904: 38). Even today, despite the fundamental transformations in physics over this period, our language betrays our debt to Descartes' legacy. Web designers aim to attract a lot of 'eyeballs' to a Website, to maximize its 'visibility'. 'Watchdogs' press governments to enact 'sunshine' laws to guarantee 'transparency'. The closer we look at our dependence on the metaphor of light as truth, the more we will see a political expediency hidden beneath it.

I once ate at an Asian restaurant where I received a fortune cookie that contained a rather Orwellian message: 'There is something seeing, and there is something being seen'. Sipping my green tea, I imagined the woman who inserted this fortune into the cookie, working in a nondescript factory under the watchful eyes of an overzealous night shift supervisor. However, those human eyes are increasingly being replaced, according to the relentless logic of a globalized economy, by the more efficient digital eyes of hidden security cameras. So the fortune cookie really should have said: 'There is something seeing, but it is not being seen'. It is precisely this asymmetry that makes our unexamined metaphors of light so dangerous, and helps the powerful instil fear in the powerless.

The security camera watching the fortune cookie lady is of course a modern version of the Panopticon, Jeremy Bentham's notorious 1791 design for a maximum-security prison. Bentham's plans called for a central guard tower whose windows look out onto an annular building divided into prison cells. Impenetrable walls divide the inmates from each other and each cell is designed with a window facing back at the tower, as well as another window on the opposite wall facing the outside world. The function of this second window is not to give inmates a room with a view, but to backlight them against the light of day, making them all the more visible to the inspectors in the central tower.

The inspectors employ Venetian blinds to ensure that, at any given moment, inmates cannot tell whether they are being watched. While Bentham had in mind a limited application of his design to prison architecture, the metaphor of the Panopticon has been appropriated widely by scholars and has come to represent structures of power more broadly. Michel Foucault famously called the Panopticon 'the diagram of a mechanism of power reduced to its ideal form', analysing its influence in the nineteenth and twentieth centuries on the architecture of hospitals, workshops and schools. Foucault keenly realised the applicability and effects that the Panopticon model could have in any situation where 'one is dealing with a multiplicity of individuals on whom a task or a particular form of behaviour must be imposed' (Foucault 1977: 205).

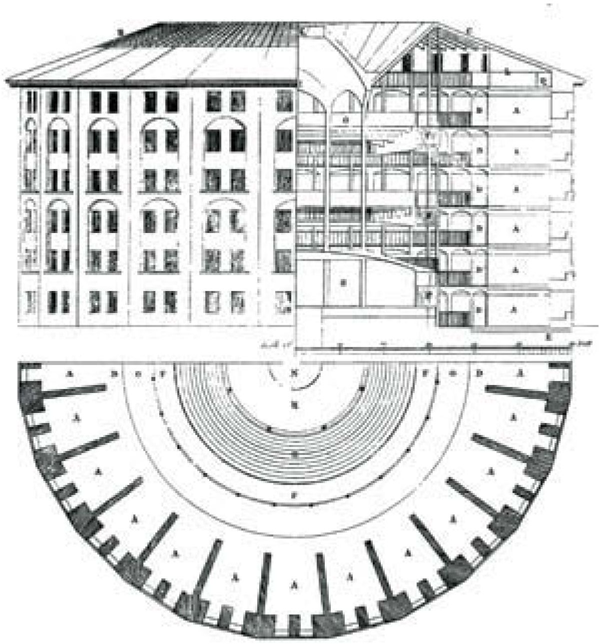

Figure 1. 'Plan of the Panopticon', 1843 (originally 1791). From The Works of Jeremy Bentham. Vol. IV, 172–3. Image courtesy Wikimedia Commons, accessed 2 March, 2014. http://en.wikipedia.org/wiki/File:Panopticon.jpg.

Figure 1 shows a layout of Bentham's Panopticon; however it could easily serve as an infographic of the IT department's recommendations for the $10 million media centre built on my university's campus in 2013. These recommendations included a newly proposed 'information security policy' that would require faculty to observe a 'clean desk' policy, provide an inventory of everything on our laptops, and to ask permission to take them home at night. The insouciance with which we yoke the incompatible words 'new media' and 'centre' into the same phrase shows how persistent panoptic attitudes remain.

Of course, 'digital' light is not a single sun in the sky shining down to provide chiaroscuro for Renaissance painters or backlighting for Panopticon wardens; it is a dispersed array of handycams, Webcams, phonecams, dronecams and software agents like face-recognition bots. Yet in spite of digital light being more dispersed it is also less trustworthy, as evidenced by the ease of manipulating a digital image through Photoshop. If Descartes were alive today, he would have to write: 'Whatever is revealed to me by *unnatural* light … cannot in any way be trusted'.

If that is true, then why is digital light still ascribed the power to control that Descartes originally attributed to natural light? As we move out of a broadcast paradigm and into a network paradigm, those metaphors of vision and its attendant radial model of information gathering and dissemination are increasingly irrelevant for a world lit not by a single light source in the heavens, but by a billion strands of interlinked fibre optics and Wifi networks. The metaphor of light endures because it slides conveniently into a metaphysics of asymmetry, which happens to be a very convenient metaphysics for government officials, university administrators, CEOs, or anyone who wants to remain in the position of power that he or she occupies.

The year 2007 saw the launch of what would become the most far-reaching example to date of the powerful using surveillance to maintain control. This secret initiative tapped into an extraordinary swath of live and stored Internet communication, from email to live audio and videochat, to cloud data stored by companies like Google and Apple. It collected private information of Internet and phone users across the world, including leaders of allied countries, and quickly became the primary source of raw intelligence used for the United States' National Security Agency. In 2013 NSA contractor and whistleblower Edward Snowden revealed this clandestine program to the world, prompting headlines about this 'shadowy' spyplot completely 'hidden from public view'. And it was not just journalists who resorted to the metaphor of knowledge as light; the program's very codename, PRISM, suggests the ability to filter the 'white noise' of signals from data 'clouds' into precise frequencies that can be individually observed and analysed.[2]

Perhaps presciently, January 2012 saw the 'empyre' discussion list[3] attempt to update the nineteenth century concept of the Panopticon for the twenty-first century. The original Panopticon, as its name implies, depended on light as a means of gathering information. But the means by which light illuminates a perspectival space is different from the way that electromagnetic signals—even if travelling through fibre optic cables—spread knowledge through networks. Perspectival light is a broadcast medium; it radiates. An illuminated object reflects light outward in all directions from its position. Conversely, a central eye, by swivelling in different directions, can monitor incoming light from every quarter. A guardian of the Panopticon could do a quick count of the entire prison population simply by panning his glance 360 degrees across the rows of cells in the peripheric ring. However there is a natural limit to such an illuminated landscape: the horizon. Potential threats from barbarian invaders would come from the horizon, necessitating lookout towers that could see such enemies before they reached their target. Conversely, the horizon is also a point of possible escape; thus the Panopticon functioned to control the sight lines through which inmates would attempt to flee.

Now that the backlit horizon of the Panopticon has been replaced with a backlit screen, we can no longer always see an invader before it is upon us. Paul Virilio has noted that in previous eras military control hinged on keeping the target always in sight, but in the future the means of control may not depend on visual contact. Reconnaissance can be replaced by a global Search, strikes by Search and Delete, invasion by Search and Replace, colonization by Search and Replicate. As the forces of 'offence' abandon the Panopticon in favour of networked attack, so the defence must abandon the medieval tower. In Panoptic space, the height of the lookout tower enables a more comprehensive control of information. In cyberspace, however, control is maintained not at a high level but at a low one. The lowest level of computer code is the most powerful, which is why data-miners reap profits by tapping into TCP/IP streams and hackers dig deep into code to inject rogue SQL and other malware.

Information no longer radiates from a point outwards in all directions, but rather it follows diverse and sometimes multiple pathways to its destinations. If an inmate managed to escape from an ordinary prison, the authorities might suspect a conspiracy and would therefore interrogate the next-door neighbours in the cellblock. It was precisely to prevent such collaboration that Bentham designed walls between adjacent cells in a way that meant contiguous prisoners could not see each other. However today in cyberspace, the tendency of information to suffuse the local neighbourhood is replaced by a tendency for information to proceed through one or more discrete vectors. Governments and corporations now interrogate nodes instead of neighbours, hoping to trace the routes that information takes in the Internet age. This is why Egyptians organizing online protests in 2011 hid their activities using the Tor 'onion router', which was designed to bounce network traffic through untraceable pathways. Unfortunately, not all netizens are as careful to hide their tracks. Bentham's guards locked inmates behind iron bars, while wardens of today's virtual enclosures have designed fishbowls that victims inhabit voluntarily; they're called Facebook accounts.

Architect Malkit Shoshan christened the twenty-first century Panopticon spawned by the Internet the 'Netopticon'. A more accurate coinage would have been PanNetwork, since light is only an incidental medium for electronic networks. By clinging to an optical etymology, the term Netopticon betrays the difficulty we have in discarding the metaphor of light as information. In a Netopticon, networks serve as simply another conduit for light to bring information from the powerless to the powerful; advertisers mine Facebook for example, and the FBI mines Twitter. In a truly distributed network, however, information is not a commodity for privileged nodes to broadcast or trade privately; information is a property of the system. That's why in its recent spying on phone calls the US government chose to store metadata—which reveals the connections among events—in addition to or in place of recording the actual calls. It's also why the government's claim that this practice is more sanitized doesn't ring true. Consider this example cited by Princeton computer scientist Edward Felten on behalf of the American Civil Liberties Union:

> A young woman calls her gynecologist; then immediately calls her mother; then a man who, during the past few months, she had

> repeatedly spoken to on the telephone after 11pm; followed by a call to a family planning center that also offers abortions. A likely storyline emerges that would not be as evident by examining the record of a single telephone call. (Washington's Blog 2014)

This is also why light is such an inadequate metaphor for information in a network.[4] There is no single vantage point from which all these events are visible. The most information on the planet sits where light cannot reach it, in the rhizomes and mycelia under the soil, in the nervous systems and brains of mice and men, in what neurologists call the 'connectome'. As Joline Blais argues, the Enlightenment was about the trees—in Diderot's words, 'encompassing each and every branch of human knowledge.' In the twenty-first century, it is about the roots (Blais 2011).

So what metaphor would be appropriate to describe networked information? Marshall McLuhan claimed in *The Global Village* (1989) that electronic networks are based on an acoustic, rather than an optical, world-view in that they permit overlapping, mutually compatible signals without a clear origin. Indeed, Bentham's first plan for the Panopticon had included an acoustic surveillance system with pipes leading from the cells to the central tower.[5] The problem was that the prisoners could also hear what the inspectors were doing. Perhaps Bentham's leaky network could offer a prototype for a more liberatory Internet. The strategy could be to refuse the metaphysical belief that information is light bestowed by a higher power, and to hack some leaks into the Panopticon. The following examples illustrate possible strategies to level the playing field, suggesting updated metaphors that respond to the situations we encounter in the Internet age.

Strategy 1. Go Underground

The disorganized mob of bored geeks known as Anonymous have terrorized YouTube, the Australian government and the Mubarak regime, and have been named by CNN as a potential successor to WikiLeaks. Yet unlike political leaders who cherish the limelight, the primary weapon wielded by these guerrillas—apart from knowing enough JavaScript to be dangerous—is their studious application of technologies that render their identities invisible. They've poked leaks into security firms and governments, while remaining too dispersed across the 'Dark Web' to be pinned down themselves.

The social architecture of Anonymous is not a watchtower that rises above its targets. Anonymous' campaigns are not planned by a central committee but suggested by individuals and taken up or neglected by spontaneous volunteers. Some

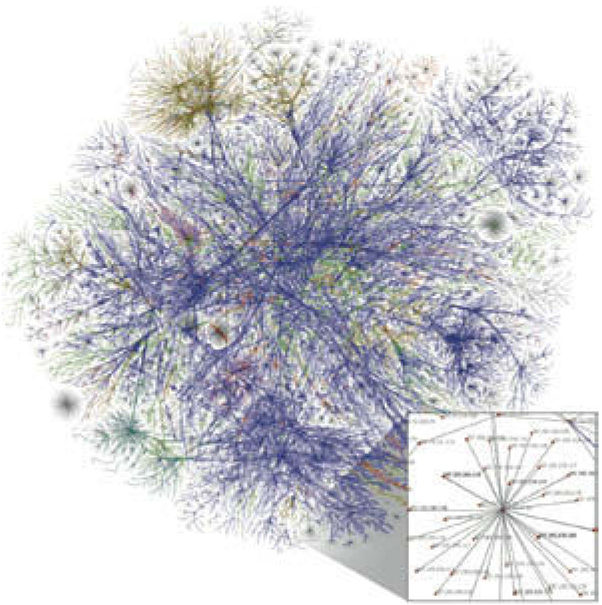

Figure 2. Partial map of the Internet based on the 15 January, 2005 data found on opte.org. Each node represents an IP address, with longer lines indicating longer delays in transmission between the nodes. Courtesy of Wikimedia Commons, accessed 2 March, 2014. http://en.wikipedia.org/wiki/File:Internet_map_1024_-_transparent.png.

of its members have chosen as their emblem the cicada (Lipinski 2012), an insect that emerges from the soil every few years to make a ruckus and then buries itself underground again. A more fitting mascot might be the mycelium, the fungal root structure that can live thousands of years and extend nearly ten square kilometres.[6] (It's no coincidence that maps of the Internet's own 'series of tubes' plumbed by researchers like Bill Cheswick bear a striking resemblance to the mycelium's rhizomatic branches, as figure 2 illustrates.[7]) Despite their shadowy reputation neither mycelia nor Anonymous are loners. Fungal roots stretch from tree to tree, passing nutrients and environmental information to an entire ecosystem of symbiotic flora. The hackers of Anonymous likewise operate autonomously yet coalesce around popular causes promoted online in forums like 4chan.

Strategy 2. Blind Them With Light

In 1993 Jennifer Ringley of JenniCam had chosen the opposite strategy to hack the Panopticon: By setting up a Webcam and leaving it on 24/7 for seven years, she flooded the Web with unedited images of her everyday moments.[8] While Ringley did not censor any of the 'footage' conveyed by her always-on Webcam, voyeurs keen on catching Ringley in a state of undress or in an intimate moment with a sexual partner were thwarted by the sheer volume of scenic data captured by the stationary lens. In this case, complete visual access proved an effective if ironic barrier to prying eyes, forcing would-be Peeping Toms to confront quotidian moments in a real girl's life, from brushing hair to sleeping to staring at a computer screen.

One year before Ringley retired her Webcam, Hasan Elahi became Ringley's successor, employing a more political strategy in response to US government insinuations that he was a terrorist. Rather than conceal his private information from Big Brother, Elahi decided to leak everything about his life publicly, via a Website that obsessively documents every plane he takes, every hamburger he eats, every toilet he pees in. Unfortunately, while these floodlights on quotidian behaviour may have been radical in their day, the subsequent launch of Facebook and Twitter showed that most netizens are happy to broadcast intimate details of their lives without political or aesthetic motivation, to the commercial benefit of data-miners.

Figure 3. Tracking data recorded by the author's iPhone during a layover in the Philadelphia International Airport on 19 January, 2011. The data was 'unearthed' using the free forensic tool provided by researchers Alasdair Allan and Pete Warden (Fenton 2011).

The British surveillance agency GCHQ's secret harvest of Webcam images of millions of Yahoo users not suspected of wrongdoing between 2008 and 2010 provides a less deliberate, but equally delicious instance of Elahi's visual noise drowning out the signal. Predictably enough, the project title, Optic Nerve, embodied yet another panoptic metaphor. The neural allusion in this codename aptly reflects the networked aspect of the project, which enabled spooks to sniff out and capture Webcam data packets as they routed through the Internet. The project's ambition to emulate the 'optical' capabilities of a human spy might be forgiven since the word *spy* means 'to look at'; yet the facial recognition software deployed by Optic Nerve failed to anticipate the large quantities of Webcam flesh that wasn't part of someone's face.[9]

Strategy 3. Light Up Your Path

Mobile technologies are like a Panopticon on wheels, which is why Richard Stallman won't even carry a cell phone. German Green Party politician Malte Spitz had to take Deutsche Telekom to court to learn that his carrier had recorded his GPS position 35,000 times in a six-month period. Google Street View even captured a privacy advocate stepping out of his office at the Electronic Frontier Foundation to sneak a cigarette. Whereas the Panopticon surveilled its subjects from a central watchtower, devices like tablets, smartphones, and fitness bracelets track their subjects

Figure 4. John Bell, Octris (op 1 capriccio for bells and space), 2010, audiovisual virtual reality installation.

as they move through a dispersed global network of ski slopes, subways, and airports (see fig. 3).

In an evocative response, Ze Frank invited people to use Google Street View to follow a remembered route they used to walk in childhood and then note down their emotional reactions. Frank's intervention is more targeted than the 'flood everything' model of Ringley and Elahi, though of course his participants are just giving Google more information on themselves. Nevertheless Frank's 'if you can't beat 'em join 'em' strategy suggests that data mined by impersonal corporations can be repurposed to new ends—in this case, to remind citizens of the hometown roots from which a globalized economy has detached them.

Strategy 4. Light Up a Decoy

Heath Bunting's anamorphic photos designed to fool security cameras and fake-identity services like Tracenoiser aim to chaff the network, distracting would-be data-miners with fake information. While Ringley and Elahi also injected additional information about themselves into the network, theirs was accurate; the ersatz homepages created by Tracenoiser are a pack of lies, each a different, algorithmically created misrepresentation of its subject. But those who fly close to the sun have to take care not to get burned. The Security Camera Players were a group of actors who acted out scenes for the benefit of security guards in front of cameras in public spaces, until one of their lead actors was himself compromised by a hidden camera even he didn't see.

Strategy 5. Tunnel from Light to Dark

John Bell's *Octris* (see fig. 4) is a Virtual Reality version of Tetris that uses musical chords as cues for which falling puzzle pieces fit where.[10] While originally designed with blind spatial engineer Nick Giudice as its audience, the work also trains sighted players to listen for acoustic matches by slowly dimming the light as they level-up the game. Instead of judging visually that an L-shaped puzzle piece should be manoeuvred into an L-shaped hole, players who don *Octris*' goggles and earphones must learn to move a piece by turning their head until the pitch associated with that piece finds other pieces whose notes complete a musical chord. To win the final level these viewers-turned-listeners must complete a line of the puzzle in complete darkness—a capability the game has prepared players for by slowly weaning them from visual cues onto auditory ones. It's tough to complete that final level—just as it's tough to relinquish our optical metaphors for information. *Octris* shows us that we can do both.

Strategy 6. Light Up the Watchtower

WikiLeaks may be the most infamous contemporary conduit of leaked information, but Steve Mann turned the tables on a store clerk in a much more personal way back in 1997. Wearing his own custom-made sunglasses with a built-in hidden video camera, Mann asked a store clerk if she was bothered by the nearby surveillance cameras. In response to her platitude 'if you have nothing to hide, they shouldn't bother you', Mann took out his own camera—at which point she protested his invasion of her privacy. Thanks to his secret recording, these two contradictory moments are caught on the same video.

Mann's SafetyNet is perhaps the most progressive hack of the Panopticon to date. In his model, concealed Wearcams netcast continuous video from the wearer not to the entire world, but to a geographically dispersed band of compatriots who could 'sousveille' the wearer and intervene in the case of police brutality or personal injury. In giving one's friends, rather than an official police force, the responsibility of looking after a person, SafetyNet is less a strategy of turning a floodlight on Big Brother than handing flashlights to one's Little Brothers.

Strategy 7. Dangle Something Shiny

Like those deep-sea anglerfish, Natalie Jeremijenko's project *How Stuff Is Made* offers baits that lure corporate mal-doers to step into the light of their own accord. This wiki produced by Jeremijenko's students offers revelations about contemporary products that their manufacturers may not want public—such as the fact that shrimp farmers earn pennies per hour, American flags are made in China, and that the woman who stuffed my fortune into its cookie was quite possibly a Hispanic worker in Philadelphia.

To set the trap, Jeremijenko's students email the companies represented on the site and invite them to correct any factual errors. Marketing mavens can hardly

Figure 5. A 2001 US public service advertisement that reminded people to adjust their clocks. Image courtesy Wikimedia Commons, accessed 2 March, 2014. http://en.wikipedia.org/wiki/File:Daylightsavings.svg.

resist the temptation of whitewashing a wiki to suit their PR needs, as studies of corporate influence in Wikipedia confirm. In this case, the edits made to this wiki are visible in the page's history, and Jeremijenko built the site with plans to highlight such changes in order to draw attention to corporate cover-ups.

Strategy 8. Point Out Cracks in the Light Bulb

The presumption that light conveys information about time is one of humanity's longest-endured metaphysical equations, a carryover from an era in which all human activity was governed by circadian rhythms—that is, the sun's traversal across a particular neighbourhood's slice of the globe. As humanity's reach spread, time zones were invented to patch the increasingly unreliable equation between light and time. In the nineteenth century, the telegraph and railroad expanded the need for a consistent nonlocal time; time zones solved the contradiction between the global time of networks and the local time of sunlight by insisting that 'it's 10am your time but 7pm my time'. As technologies progressed, so did the circumstances in which the imposition of time zones on a continuous sphere proved to be completely illogical. Circadian rhythms are different for different seasons, which is why Daylight Saving Time was introduced as a corrective in the early 1900s, screwing with humanity's collective sleep cycle twice a year (and necessitating the kind of public awareness campaigns seen in figure 5). Circadian rhythms also vary by geography, which is why many nations chose not to obey Daylight Saving Time, and some closer to the poles such as Argentina, Iceland, and Russia have essentially switched to it permanently (see fig. 6). As humanity expands its orbit beyond Earth, setting time by sunrise and sunset ceases to be meaningful at all; satellites pass through many time zones in a day, and the clock effectively stood still for Apollo astronauts en route to and from the moon.

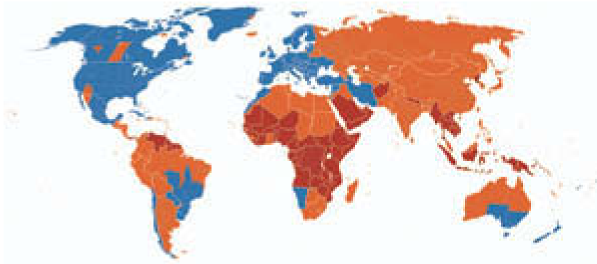

Figure 6. Countries that adhere to Daylight Saving Time (blue: DST is used; orange: DST is no longer used; red: DST has never been used). Image courtesy Wikimedia Commons, accessed 2 March, 2014. http://en.wikipedia.org/wiki/File:DaylightSaving-World-Subdivisions.png.

For the 'always on' Internet, time zones are also an anachronism. In recent years, annual and regional discrepancies with time zones have played havoc with information technologies of all kinds. Apple's iOS operating system failed to account accurately for Daylight Saving Time shifts in 2010, 2011, and 2013, causing alarms to wake European iPhone owners too late and Australian iPhone owners too early. In most cases these glitches were more inconvenient than life-threatening; however, in 2010 the US Food and Drug Administration warned that such arbitrary time shifts pose a grave danger due to the increasing dependence upon wearable medical devices for the timing of injections and similar treatments (FDA 2010). As an exercise in continuity, time zones also produce one of the most discontinuous artifices imaginable, the International Dateline—effectively a self-declared time machine in which stepping a metre east or west propels you forward or backwards 24 hours in time.[11] This awkward incongruity demonstrates the extent to which we are willing to give up bedrock assumptions about time in order to cling to cherished metaphors of light.[12]

Often among the first eager to explore metaphysical glitches, artists have exploited the anachronistic collision of time zones with global communication to creative ends. Ken Friedman's 1975 Fluxus performance *In One Year and Out the Other* instructed performers, 'On New Year's Eve, make a telephone call from one time zone to another so that you are conducting a conversation between people located in two years'.[13] In a similar paradigm updated to the Internet age, Curator Steve Dietz included in his 2006 exhibition *Edge Conditions* an installation by artists Jon Thomson and Alison Craighead consisting of a simple Webcam of the sky in Oceania shown in San Jose, artfully underscoring the contradictions inherent in applying the paradigm of light to the Internet under the title *Light From Tomorrow*.[14] Artist Shawn

Brixey's *Epicycle* likewise aims to expose the contradiction in linking Internet time to daylight, as Richard Rinehart explains:

> In this proposed new media work, Brixey would place cameras in each of the Earth's twenty-four time zones, pointed at the horizon. In a central room, he would then display the live video feed on twenty-four monitors circling the viewer. The viewer would then be presented with a view of nature that is not possible in nature—a view in which the sun is always rising (on at least one of the screens around him in a perpetual sunrise/sunset). *Epicycle* uses technology in an attempt to marry two types of time: the ancient circadian rhythms of biology and geology and the newer global time where the sun never sets on the Net. (Rinehart and Ippolito 2014: 51–52)

Optical metaphors can be tough to shake once ingrained in a language, as I'm reminded every time my blind neighbour concludes a visit with 'I'll see you later'. Yet we ignore their asymmetric metaphysics at our peril. An undue focus on the minarets where power shines brightly can blind us to the mycelia nourishing the gardens below—their potential to reinforce power or subvert it. Activists and artists of the Internet age offer networked approaches for turning back the Panoptic gaze. In an era of networks, we should be paying more attention to what we can't see than what we can.

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Notes

1. Some of the concepts in this talk were originally introduced in Ippolito (1999: 26–27).
2. *Wikipedia* has a good summary of PRISM's history and scope. 'PRISM (surveillance program)', *Wikipedia*, http://en.wikipedia.org/wiki/PRISM_%28surveillance_program%29 (accessed 15 February, 2014).
3. 'empyre' is an email mailing list frequented by new media artists and scholars, originally started by Melinda Rackham in Australia in 2002. http://www.subtle.net/empyre (accessed 15 February, 2014).

4. From the standpoint of quantum physics, even light is capable of entanglement, an experimental result that calls into question whether light is a broadcast medium at all.
5. Given our language's bias toward the optical, it's hard to avoid etymological oxymorons like 'acoustic surveillance'—'surveillance' meaning literally 'overseeing'.
6. Paul Stamets (2005: 45, fig. 60) argues convincingly that a mycelium in Oregon is the largest-known organism on (or more precisely, under) the Earth.
7. Bill Cheswick traces the routes of single information packets as they course along the frequently travelled backbones of Sprint and AT&T as well as the 'back roads' of regional phone systems.
8. The Wikipedia page on Jennifer Ringley, in one of the site's more memorable phrases, notes that 'CNET hailed JenniCam as one of the greatest defunct websites in history', citing the Internet Archive.
9. The disappointed tone of GCHQ analysts reveals how out of touch they are with the social norms of contemporary netizens: 'It would appear that a surprising number of people use webcam conversations to show intimate parts of their body to the other person' (Ackerman and Ball 2014).
10. For more information, see John Bell.
11. This essay is based on a talk originally given over Skype from a location in Maine to the conference on the opposite side of the globe in Melbourne. The date in Maine happened to be the day before my birthday. Melbourne was fifteen hours ahead of Maine, and hence 7pm in Maine was 10am the next day in Melbourne. Thanks to the International Dateline, therefore, conference-goers in Melbourne were able to celebrate even though I was not, putting me in the awkward position of being 48 and 49 years old at the same time.
12. For very different reasons, Einstein made a similar choice to privilege light over time, and Special Relativity was the result.
13. First performed on New Year's Eve 1975–1976, calling from Springfield, Ohio forward to Nam June Paik, Christo and Jeanne-Claude, Dick Higgins, and George Maciunas in New York, then back to Tom Garver and Natasha Nicholson in California. Celebrated annually since then by telephone, telefax, and email. With Melbourne, Australia going into the New Year before most of the world, messages have gone back to the old year since 2008' (Friedman 2013). It is yet another coincidence that Melbourne was the site of my teleconference mentioned in note number 11.
14. I'm grateful to Craig Dietrich for reminding me about this piece.

Notes on Contributors

Sean Cubitt is Professor of Film and Television at Goldsmiths, University of London; Professorial Fellow of the University of Melbourne and Honorary Professor of the University of Dundee. His publications include *Timeshift: On Video Culture*, *Videography: Video Media as Art and Culture*, *Digital Aesthetics*, *Simulation and Social Theory*, *The Cinema Effect* and *EcoMedia*. His new book, *The Practice of Light*, will be published in 2014. He is the series editor for Leonardo Books at MIT Press. Current research is on the history and philosophy of visual technologies, on media art history and on ecocriticism and mediation.

Terry Flaxton began working with sound in 1970, film in 1971 and analogue video in 1976 creating numerous installations, television, art, drama and documentaries. He was commissioned for Channel 4's *Ghosts in the Machine*, exhibited his work on *Alive from Off-Center* on PBS and *Avance Sur Image* on French Television and created a 5 part series on video art for Channel 4. He recently exhibited in Xi'an, China and at the Cathedral of St John the Divine in New York. As a cinematographer Terry shot for Apple during the making of Ridley Scott's 1984 commercial; shot one of the first video to cinema releases in 1987; worked with analogue HD in the early '90's; and shot four feature films. In 2007 he won an AHRC Creative Research Fellowship then in 2010 an AHRC Knowledge Exchange Fellowship at the University of Bristol. He is now Professor of Lens Based Arts at the University of the West of England.

Jon Ippolito is an Associate Professor of New Media at the University of Maine, who specializes in doing the right thing in the wrong ways. Ippolito invents ways to build and sustain networks, a fact that often makes him unpopular with media monopolists, bureaucrats, and other apologists for hierarchic culture. Ippolito works with the Variable Media Network to devise new preservation paradigms to rescue digital culture from obsolescence, with the Open Art Network to promote open architectures for media art, and with the Interarchive working group to find net-native ways to connect online scholarship. He's exhibited collaborative artworks at the

Walker Art Gallery, ZKM, and Harvard; curated shows for the Guggenheim on virtual reality and Nam June Paik; and written for the *Washington Post*, *Artforum*, and *Leonardo*. Ippolito's collaborative architectures such as The Pool and ThoughtMesh have nabbed *Wired* headlines, while his book *At the Edge of Art*, co-authored with Joline Blais, offers an expansive definition for art of the 21st century. See www.three.org/ippolito

Stephen Jones (born 1951, lives in Sydney, Australia) is an Australian video artist, curator, video engineer and conservator of long standing. He worked with Bush Video (1974–75), the Paddington Video Access Centre (1976–78), with Nam June Paik during his exhibition at the Art Gallery of New South Wales in Sydney (1976), as well as providing technical support for many major exhibitions including the *Biennale of Sydney* and *Australian Perspecta* from 1976 to 1985. From 1983 to 1992 he was the video-maker for the electronic music band Severed Heads. Between 1989 and 1996 he worked as an engineer for several major video post-production and computer graphic production facilities. In 1996 he returned to making art and in 1998 received a New Media Arts Fellowship from the Australia Council for the Arts. He provides technical support for artists, developing sensor-controlled systems for interactive video/DVD installations and physical immersion installations, as well as developing theoretical perspectives on interactivity, artificial intelligence and artificial life. Since 2002 he has been researching the history of art and technology in Australia. This work has lead to his book, *Synthetics: Aspects of Art and Technology in Australia, 1956–1975* (MIT Press, 2011).

Carolyn L. Kane is the author of *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code* (University of Chicago Press, 2014). Currently a postdoctoral fellow at Brown University (2014–2015), she received her Ph.D. from New York University in 2011. Her research fields include the history and philosophy of new media, electronic color, and digital aesthetics.

Scott McQuire is an academic and writer with a strong interest in interdisciplinary research linking social theory, new media, art, and urbanism. He is the author of *Crossing the Digital Threshold* (1997), *Visions of Modernity: Representation, Memory, Time and Space in the Age of the Camera* (1998), *Maximum Vision* (1999), and most recently *The Media City*: *Media, Architecture and Urban Space* (2008) which won the Urban Communication Foundation's 2009 Jane Jacobs Publication Award. He is also co-author with Peter Lyssiotis of the artist's book *The Look of Love* (1998), co-editor with Nikos Papastergiadis of *Empires Ruins + Networks: The Transcultural Agenda in Art* (2005) and with Meredith Martin and Sabine Niederer of the *Urban Screens Reader* (2009). Scott is Associate Professor and Reader in the School of Culture and Communication at the University of Melbourne.

Daniel Palmer is Associate Dean of Graduate Research and Senior Lecturer in the Art History & Theory Program at MADA (Monash Art, Design & Architecture). He has a long-standing involvement with the Centre for Contemporary Photography in Melbourne, as a former curator and current board member. His publications include the books *Twelve Australian Photo Artists* (2009), co-authored with Blair French, and the edited volume *Photogenic: Essays/Photography/CCP 2000–2004* (2005). His scholarly writings on photography have appeared in journals such as *Photographies*, *Philosophy of Photography*, *Angelaki* and *Reading Room*, and he also contributes to art magazines including *Art & Australia* and *Frieze*.

Christiane Paul is Associate Professor at the School of Media Studies, The New School, and Adjunct Curator of New Media Arts at the Whitney Museum of American Art. She has written extensively on new media arts and lectured internationally on art and technology. Her recent books are: *Context Providers – Conditions of Meaning in Media Arts* (Intellect, 2011; Chinese edition, Beijing Beepub Media & Culture Publishing Co., 2012), co-edited with Margot Lovejoy and Victoria Vesna; *New Media in the White Cube and Beyond* (UC Press, 2008); and *Digital Art* (Thames and Hudson 2003; expanded new edition 2008). As Adjunct Curator of New Media Arts at the Whitney Museum of American Art, she curated several exhibitions—including Cory Arcangel: Pro Tools, Profiling (2007), Data Dynamics (2001) and the net art selection for the 2002 Whitney Biennial—as well as artport, the Whitney Museum's website devoted to Internet art. Other recent curatorial work includes The Public Private (Kellen Gallery, The New School, Feb 7–Apr 17, 2013); Eduardo Kac: Biotopes, Lagoglyphs and Transgenic Works (Rio de Janeiro, Brazil, 2010); Biennale Quadrilaterale (Rijeka, Croatia, 2009-10); Feedforward – The Angel of History (co-curated with Steve Dietz; Laboral Center for Art and Industrial Creation, Gijon, Spain, Oct 2009); INDAF Digital Art Festival (Incheon, Korea, Aug 2009); and Scalable Relations (Beall Center for Art and Technology, Irvine, CA; as well as galleries at UCSD, UCLA and UCSB, 2008–09). Dr. Paul has previously taught in the MFA computer arts department at the School of Visual Arts in New York (1999-2008); the Digital+Media Department of the Rhode Island School of Design (2005-08); the San

Francisco Art Institute and the Center of New Media at the University of California at Berkeley (2008).

Alvy Ray Smith cofounded two successful startups: Pixar (sold to Disney) and Altamira (sold to Microsoft). He was present at the beginning of computer graphics at Lucasfilm, the New York Institute of Technology, and the Xerox Palo Alto Research Center. He was the first Graphics Fellow at Microsoft. He has received two technical Academy Awards, for the alpha channel concept and for digital paint systems. He invented, directed, originated, or was otherwise instrumental in the following developments: first full-color paint program, HSV (aka HSB) color model, alpha channel, the Genesis Demo in *Star Trek II: The Wrath of Khan*, *The Adventures of André & Wally B.*, first Academy-Award winning computer-generated short *Tin Toy*, first computer-generated film *Toy Story*, Academy-Award winning Disney animation production system CAPS, and the Visible Human Project of the National Library of Medicine. He was a star witness in a trial that successfully invalidated five patents that threatened Adobe Photoshop. Dr. Smith has a PhD from Stanford University and an honorary doctorate from New Mexico State University. He is a member of the National Academy of Engineering and a Fellow of the American Association for the Advancement of Science. He has published often in theoretical computer science and computer graphics, and holds four patents. He retired in 2000 to devote time to the emerging art form of digital photography and to scholarly genealogy, to which he has contributed two award-winning books and half a dozen learned journal papers. He is Trustee Emeritus of the New England Historic Genealogical Society, Boston, and a Fellow of the American Society of Genealogists. He has won many awards, speaks widely, and is now writing a book, *A Biography of the Pixe*l, a laymen's guide to modern media. For more see alvyray.com

Darren Tofts is Professor of Media and Communications, Swinburne University of Technology. He is the author (with artist Murray McKeich) of *Memory Trade. A Prehistory of Cyberculture* (Sydney: Interface Books, 1998), *Parallax. Essays on Art, Culture and Technology* (Sydney: Interface Books 1999) and *Interzone: Media Arts in Australia* (Thames and Hudson: Sydney, 2005). With Annemarie Jonson and Alessio Cavallaro he edited *Prefiguring Cyberculture: An Intellectual History* (Power Publications/MIT Press, 2003) and with Lisa Gye edited *Illogic of Sense: The Gregory L. Ulmer Remix* (Colorado: Alt-X Press, 2009). His most recent book is *Alephbet: Essays on ghost writing, nutshells and infinite space* (Prague: Litteraria Pragensia, 2013).

Cathryn Vasseleu teaches animation at the University of Technology, Sydney. She is author of *Textures of Light: Vision and Touch in Irigaray, Levinas and Merleau-Ponty* (Routledge, 1998), editor of Jan Švankmajer's *Touching and Imagining: An Introduction to Tactile Art* (I. B. Tauris, 2014), and writer/director of animated experimental films including *De Anima* (1991).

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