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Chapter 37

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WHAT IS DIGITAL CINEMA?

Cinema, the art of the index

MOST DISCUSSIONS OF CINEMA in the computer age have focused on the possibilities of interactive narrative. It is not hard to understand why: since the majority of viewers and critics equate cinema with storytelling, computer media is understood as something which will let cinema tell its stories in a new way. Yet as exciting as the ideas of a viewer participating in a story, choosing different paths through the narrative space and interacting with characters may be, they only address one aspect of cinema which is neither unique nor, as many will argue, essential to it: narrative.

The challenge which computer media poses to cinema extends far beyond the issue of narrative. Computer media redefines the very identity of cinema. In a symposium which took place in Hollywood in the spring of 1996, one of the participants provocatively referred to movies as 'flatties' and to human actors as 'organics' and 'soft fuzzies.'[1] As these terms accurately suggest, what used to be cinema's defining characteristics have become just the default options, with many others available. When one can 'enter' a virtual three-dimensional space, to view flat images projected on the screen is hardly the only option. When, given enough time and money, almost everything can be simulated in a computer, to film physical reality is just one possibility.

This 'crisis' of cinema's identity also affects the terms and the categories used to theorize cinema's past. The French film theorist Christian Metz wrote in the 1970s that 'Most films shot today, good or bad, original or not, "commercial" or not, have as a common characteristic that they tell a story; in this measure they all belong to one and the same genre, which is, rather, a sort of "super-genre" ["*sur-genre*"].'[2] In identifying fictional films as a 'super-genre' of twentieth-century cinema, Metz did not bother to mention another characteristic of this genre because at that time it was too obvious: fictional films are *live action* films, i.e. they largely consist of unmodified photographic recordings of real events which took place in real physical space. Today, in the age of photorealistic 3D computer animation and digital compositing, invoking this characteristic becomes crucial in defining the specificity of twentieth-century cinema. From the perspective of a future historian of visual culture, the differences between classical Hollywood films, European art films and avant-garde films (apart from abstract ones) may appear to have less significance than this common feature: that they relied on lens-based recordings of reality. This chapter is concerned with the effect of computerization on cinema as defined by its 'super genre' as fictional live action film.[3]

During cinema's history, a whole repertoire of techniques (lighting, art direction, the use of different film stocks and lenses, etc.) was developed to modify the basic record obtained by a film apparatus. And yet behind even the most stylized cinematic images we can discern the bluntness, the sterility, the banality of early nineteenth-century photographs. No matter how complex its stylistic innovations, the cinema has found its base in these deposits of reality, these samples obtained by a methodical and prosaic process. Cinema emerged out of the same impulse which engendered naturalism, court stenography and wax museums. Cinema is the art of the index; it is an attempt to make art out of a footprint.

Even for the director Andrei Tarkovsky, film-painter par excellence, cinema's identity lay in its ability to record reality. Once, during a public discussion in Moscow sometime in the 1970s, he was asked whether he was interested in making abstract films. He replied that there can be no such thing. Cinema's most basic gesture is to open the shutter and to start the film rolling, recording whatever happens to be in front of the lens. For Tarkovsky, an abstract cinema is thus impossible.

But what happens to cinema's indexical identity if it is now possible to generate photorealistic scenes entirely in a computer using 3D computer animation; to modify individual frames or whole scenes with the help of a digital paint program; to cut bend, stretch and stitch digitized film images into something which has perfec photographic credibility, although it was never actually filmed?

This article will address the meaning of these changes in the film-making process from the point of view of the larger cultural history of the moving image. Seen in this context, the manual construction of images in digital cinema represents a return to nineteenth-century pre-cinematic practices, when images were hand-painted and hand-animated. At the turn of the twentieth century, cinema was to delegate these manual techniques to animation and define itself as a recording medium. As cinema enters the digital age, these techniques are again becoming the commonplace in the film-making process. Consequently, cinema can no longer be clearly distinguished from animation. It is no longer an indexical media technology but, rather, a sub genre of painting.

This argument will be developed in two stages. I will first follow a historica trajectory from nineteenth-century techniques for creating moving images to twen tieth-century cinema and animation. Next I will arrive at a definition of digita cinema by abstracting the common features and interface metaphors of a variety o computer software and hardware which are currently replacing traditional film technology. Seen together, these features and metaphors suggest a distinct logic o a digital moving image. This logic subordinates the photographic and the cinematic to the painterly and the graphic, destroying cinema's identity as a media art.

A brief archaeology of moving pictures

As testified by its original names (kinetoscope, cinematograph, moving pictures), cinema was understood, from its birth, as the art of motion, the art which finally succeeded in creating a convincing illusion of dynamic reality. If we approach cinema in this way (rather than the art of audio-visual narrative, or the art of a projected image, or the art of collective spectatorship, etc.), we can see it superseding previous techniques for creating and displaying moving images.

These earlier techniques shared a number of common characteristics. First, they all relied on hand-painted or hand-drawn images. The magic lantern slides were painted at least until the 1850s; so were the images used in the Phenakistiscope, the Thaumatrope, the Zootrope, the Praxinoscope, the Choreutoscope and numerous other nineteenth-century pro-cinematic devices. Even Muybridge's celebrated Zoopraxiscope lectures of the 1880s featured not actual photographs but colored drawings painted after the photographs.[4]

Not only were the images created manually, they were also manually animated. In Robertson's Phantasmagoria, which premiered in 1799, magic lantern operators moved behind the screen in order to make projected images appear to advance and withdraw.[5] More often, an exhibitor used only his hands, rather than his whole body, to put the images into motion. One animation technique involved using mechanical slides consisting of a number of layers. An exhibitor would slide the layers to animate the image.[6] Another technique was slowly to move a long slide containing separate images in front of a magic lantern lens. Nineteenth century optical toys enjoyed in private homes also required manual action to create movement – twirling the strings of the Thaumatrope, rotating the Zootrope's cylinder, turning the Viviscope's handle.

It was not until the last decade of the nineteenth century that the automatic generation of images and their automatic projection were finally combined. A mechanical eye became coupled with a mechanical heart; photography met the motor. As a result, cinema – a very particular regime of the visible – was born. Irregularity, non-uniformity, the accident and other traces of the human body, which previously inevitably accompanied moving image exhibitions, were replaced by the uniformity of machine vision.[7] A machine which, like a conveyer belt, was now spitting out images, all sharing the same appearance, all the same size, all moving at the same speed, like a line of marching soldiers.

Cinema also eliminated the discrete character of both space and movement in moving images. Before cinema, the moving element was visually separated from the static background as with a mechanical slide show or Reynaud's Praxinoscope Theater (1892).[8] The movement itself was limited in range and affected only a clearly defined figure rather than the whole image. Thus, typical actions would include a bouncing ball, a raised hand or eyes, a butterfly moving back and forth over the heads of fascinated children – simple vectors charted across still fields.

Cinema's most immediate predecessors share something else. As the nineteenth-century obsession with movement intensified, devices which could animate more than just a few images became increasingly popular. All of them – the Zootrope, the Phonoscope, the Tachyscope, the Kinetoscope – were based on loops, sequences of images featuring complete actions which can be played repeatedly. The Thaumatrope (1825), in which a disk with two different images painted on each face was rapidly rotated by twirling a string attached to it, was in its essence a loop in its most minimal form: two elements replacing one another in succession. In the Zootrope (1867) and its numerous variations, approximately a dozen images were arranged around the perimeter of a circle.[9] The Mutoscope, popular in America throughout the 1890s, increased the duration of the loop by placing a larger number of images radially on an axle.[10] Even Edison's Kinetoscope (1892–6), the first modern cinematic machine to employ film, continued to arrange images in a loop.[11] Fifty feet of film translated to an approximately twenty-second-long presentation – a genre whose potential development was cut short when cinema adopted a much longer narrative form.

From animation to cinema

Once the cinema was stabilized as a technology, it cut all references to its origins in artifice. Everything which characterized moving pictures before the twentieth century – the manual construction of images, loop actions, the discrete nature of space and movement – all of this was delegated to cinema's bastard relative, its supplement, its shadow – animation. Twentieth-century animation became a depository for nineteenth-century moving image techniques left behind by cinema.

The opposition between the styles of animation and cinema defined the culture of the moving image in the twentieth century. Animation foregrounds its artificial character, openly admitting that its images are mere representations. Its visual language is more aligned to the graphic than to the photographic. It is discrete and self-consciously discontinuous: crudely rendered characters moving against a stationary and detailed background; sparsely and irregularly sampled motion (in contrast to the uniform sampling of motion by a film camera – recall Jean-Luc Godard's definition of cinema as 'truth 24 frames per second'), and finally space constructed from separate image layers.

In contrast, cinema works hard to erase any traces of its own production process, including any indication that the images which we see could have been constructed rather than recorded. It denies that the reality it shows often does not exist outside of the film image, the image which was arrived at by photographing an already impossible space, itself put together with the use of models, mirrors, and matte paintings, and which was then combined with other images through optical printing. It pretends to be a simple recording of an already existing reality – both to a viewer and to itself.[12] Cinema's public image stressed the aura of reality 'captured' on film, thus implying that cinema was about photographing what existed before the camera, rather than 'creating the "never-was"' of special effects.[13] Rear projection and blue screen photography, matte paintings and glass shots, mirrors and miniatures, push development, optical effects and other techniques which allowed film-makers to construct and alter the moving images, and thus could reveal that cinema was not really different from animation, were pushed to cinema's periphery by its practitioners, historians and critics.[14]

In the 1990s, with the shift to computer media, these marginalized techniques moved to the center.

Cinema redefined

A visible sign of this shift is the new role which computer-generated special effects have come to play in Hollywood industry in the 1990s. Many blockbusters have been driven by special effects, feeding on their popularity. Hollywood has even created a new mini-genre of 'The Making of . . .' videos and books which reveal how special effects are created.

I will use special effects from 1990s Hollywood films to illustrate some of the possibilities of digital film-making. Until recently, only Hollywood studios had the money to pay for digital tools and for the labor involved in producing digital effects. However, the shift to digital media affects not just Hollywood, but film-making as a whole. As traditional film technology is universally being replaced by digital technology, the logic of the film-making process is being redefined. What I describe below are the new principles of digital film-making which are equally valid for individual or collective film productions, regardless of whether they are using the most expensive professional hardware and software or its amateur equivalents.

Consider, then, the following principles of digital filmmaking:

1. Rather than filming physical reality, it is now possible to generate film-like scenes directly in a computer with the help of 3D computer animation. Therefore, live action footage is displaced from its role as the only possible material from which the finished film is constructed.
2. Once live action footage is digitized (or directly recorded in a digital format), it loses its privileged indexical relationship to pro-filmic reality. The computer does not distinguish between an image obtained through the photographic lens, an image created in a paint program or an image synthesized in a 3D graphics package, since they are made from the same material – pixels. And pixels, regardless of their origin, can be easily altered, substituted one for another, and so on. Live action footage is reduced to be just another graphic, no different from images created manually.[15]
3. If live action footage was left intact in traditional film-making, now it functions as raw material for further compositing, animating and morphing. As a result, while retaining visual realism unique to the photographic process, film obtains the plasticity which was previously only possible in painting or animation. To use the suggestive title of a popular morphing software, digital film-makers work with 'elastic reality.' For example, the opening shot of *Forest Gump* (Robert Zemeckis, Paramount Pictures, 1994; special effects by Industrial Light and Magic) tracks an unusually long and extremely intricate flight of a feather. To create the shot, the real feather was filmed against a blue background in different positions; this material was then animated and

composited against shots of a landscape.[16] The result: a new kind of realism, which can be described as 'something which is intended to look exactly as if it could have happened, although it really could not.'

4 Previously, editing and special effects were strictly separate activities. An editor worked on ordering sequences of images together; any intervention within an image was handled by special effects specialists. The computer collapses this distinction. The manipulation of individual images via a paint program or algorithmic image processing becomes as easy as arranging sequences of images in time. Both simply involve 'cut and paste.' As this basic computer command exemplifies, modification of digital images (or other digitized data) is not sensitive to distinctions of time and space or of differences of scale. So, re-ordering sequences of images in time, compositing them together in space, modifying parts of an individual image, and changing individual pixels become the same operation, conceptually and practically.

Given the preceding principles, we can define digital film in this way:

digital film = live action material + painting + image processing + compositing + 2D computer animation + 3D computer animation

Live action material can either be recorded on film or video or directly in a digital format.[17] Painting, image processing and computer animation refer to the processes of modifying already existent images as well as creating new ones. In fact, the very distinction between creation and modification, so clear in film-based media (shooting versus darkroom processes in photography, production versus post-production in cinema) no longer applies to digital cinema, since each image, regardless of its origin, goes through a number of programs before making it to the final film.[18]

Let us summarize these principles. Live action footage is now only raw material to be manipulated by hand: animated, combined with 3D computer-generated scenes and painted over. The final images are constructed manually from different elements; and all the elements are either created entirely from scratch or modified by hand. Now we can finally answer the question 'What is digital cinema?' *Digital cinema is a particular case of animation which uses live action footage as one of its many elements.*

This can be reread in view of the history of the moving image sketched earlier. Manual construction and animation of images gave birth to cinema and slipped into the margins . . . only to reappear as the foundation of digital cinema. The history of the moving image thus makes a full circle. *Born from animation, cinema pushed animation to its boundary, only to become one particular case of animation in the end.*

The relationship between 'normal' film-making and special effects is similarly reversed. Special effects, which involved human intervention into machine recorded footage and which were therefore delegated to cinema's periphery throughout its history, become the norm of digital film-making.

The same logic applies for the relationship between production and post-production. Cinema traditionally involved arranging physical reality to be filmed though the use of sets, models, art direction, cinematography, etc. Occasional manipulation of recorded film (for instance, through optical printing) was negligible compared to the extensive manipulation of reality in front of a camera. In digital film-making, shot footage is no longer the final point but just raw material to be manipulated in a computer where the real construction of a scene will take place. In short, the production becomes just the first stage of post-production.

The following example illustrates this new relationship between different stages of the film-making process. Traditional on-set filming for *Stars Wars: Episode I – The Phantom Menace* (George Lucas, 1999) was done in just sixty-five days. The post-production, however, stretched over two years, since 95 percent of the film (approximately 2,000 shots out of the total 2,200) was constructed on a computer.[19]

Here are two more examples further to illustrate the shift from re-arranging reality to re-arranging its images. From the analog era: for a scene in *Zabriskie Point* (1970), Michaelangelo Antonioni, trying to achieve a particularly saturated color, ordered a field of grass to be painted. From the digital era: to create the launch sequence in *Apollo 13* (Universal Studios, 1995; special effects by Digital Domain), the crew shot footage at the original location of the launch at Cape Canaveral. The artists at Digital Domain scanned the film and altered it on computer workstations, removing recent building construction, adding grass to the launch pad and painting the skies to make them more dramatic. This altered film was then mapped onto 3D planes to create a virtual set which was animated to match a 180-degree dolly movement of a camera following a rising rocket.[20]

The last example brings us to another conceptualization of digital cinema – as painting. In his book-length study of digital photography, William J. Mitchell focuses our attention on what he calls the inherent mutability of a digital image: 'The essential characteristic of digital information is that it can be manipulated easily and very rapidly by computer. It is simply a matter of substituting new digits for old. . . . Computational tools for transforming, combining, altering, and analyzing images are as essential to the digital artist as brushes and pigments to a painter.'[21] As Mitchell points out, this inherent mutability erases the difference between a photograph and a painting. Since a film is a series of photographs, it is appropriate to extend Mitchell's argument to digital film. With an artist being able easily to manipulate digitized footage either as a whole or frame by frame, a film in a general sense becomes a series of paintings.[22]

Hand-painting digitized film frames, made possible by a computer, is probably the most dramatic example of the new status of cinema. No longer strictly locked in the photographic, it opens itself towards the painterly. It is also the most obvious example of the return of cinema to its nineteenth-century origins – in this case, to hand-crafted images of magic lantern slides, the Phenakistiscope, the Zootrope.

We usually think of computerization as automation, but here the result is the reverse: what was previously automatically recorded by a camera now has to be painted one frame at a time. But not just a dozen images, as in the nineteenth century, but thousands and thousands. We can draw another parallel with the practice, common in the early days of silent cinema, of manually tinting film frames in different colors according to a scene's mood.[23] Today, some of the most visually sophisticated digital effects are often achieved using the same simple method: painstakingly altering by hand thousands of frames. The frames are painted over either to create mattes ('hand-drawn matte extraction') or to directly change the images, as, for instance, in *Forest Gump*, where President Kennedy was made to speak new sentences by altering the shape of his lips, one frame at a time.[24] In principle, given enough time and money, one can create what will be the ultimate digital film: ninety minutes, i.e., 129,600 frames, completely painted by hand from scratch, but indistinguishable in appearance from live photography.

The concept of digital cinema as painting can be also developed in a different way. I would like to compare the shift from analog to digital film-making to the shift from fresco and tempera to oil painting in the early Renaissance. A painter making fresco has limited time before the paint dries; and once it is dried, no further changes to the image are possible. Similarly, a traditional film-maker has limited means to modify images once they are recorded on film. In the case of medieval tempera painting, this can be compared to the practice of special effects during the analog period of cinema. A painter working with tempera could modify and rework the image, but the process was quite painstaking and slow. Medieval and early Renaissance masters would spend up to six months on a painting a few inches tall The switch to oils greatly liberated painters by allowing them to quickly create much larger compositions (think, for instance, of the works by Veronese and Titian) as well as to modify them as long as necessary. This change in painting technology led the Renaissance painters to create new kinds of compositions, new pictorial space and even narratives. Similarly, by allowing a film-maker to treat a film image as an oil painting, digital technology redefines what can be done with cinema.

If digital compositing and digital painting can be thought of as an extension o the cell animation techniques (since composited images are stacked in depth paralle to each other, as cells on an animation stand), the newer method of computer-based post-production makes film-making a subset of animation in a different way. In thi method the live action, photographic stills and/or graphic elements are positioned in a 3D virtual space. This gives the director the ability freely to move the virtua camera through this space, dolling and panning. Thus cinematography is subordinated to 3D computer animation. We may think of this method as an extension o multiplane animation camera. However, if the camera mounted over a multiplan stand could only move perpendicularly to the images, now it can move in an arbitrary trajectory. The example of a commercial film which relies on this newe method which one day may become the standard of film-making (because it give the director most flexibility) is Disney's *Aladdin*; the example of an independen work which fully explores the new aesthetic possibilities of this method withou subordinating it to the traditional cinematic realism is *The Forest* by Tamas Waliczk (1994).

The reader who followed my analysis of the new possibilities of digital cinem may wonder why I have stressed the parallels between digital cinema and the pre-cinematic techniques of the nineteenth century but did not mention twentieth century avant-garde film-making. Did not the avant-garde film-makers alread explore many of these new possibilities? To take the notion of cinema as painting Len Lye, one of the pioneers of abstract animation, was painting directly on film a early as 1935; he was followed by Norman McLaren and Stan Brackage, the latte extensively covering shot footage with dots, scratches, splattered paint, smears an lines in an attempt to turn his films into equivalents of abstract expressionist painting More generally, one of the major impulses in all of avant-garde film-making, from

Leger to Godard, was to combine the cinematic, the painterly and the graphic – by using live action footage and animation within one film or even a single frame, by altering this footage in a variety of ways, or by juxtaposing printed texts and filmed images.

When the avant-garde film-makers collaged multiple images within a single frame, or painted and scratched film, or revolted against the indexical identity of cinema in other ways, they were working against 'normal' film-making procedures and the intended uses of film technology. (Film stock was not designed to be painted on.) Thus they operated on the periphery of commercial cinema not only aesthetically but also technically.

One general effect of the digital revolution is that avant-garde aesthetic strategies became embedded in the commands and interface metaphors of computer software.[25] In short, *the avant-garde became materialized in a computer*. Digital cinema technology is a case in point. The avant-garde strategy of collage re-emerged as a 'cut and paste' command, the most basic operation one can perform on digital data. The idea of painting on film became embedded in paint functions of film editing software. The avant-garde move to combine animation, printed texts and live action footage is repeated in the convergence of animation, title generation, paint, compositing and editing systems into single all-in-one packages. Finally, another move to combine a number of film images together within one frame (for instance, in Leger's 1924 *Ballet Méchanique* or in *A Man with a Movie Camera*) also become legitimized by technology, since all editing software, including Photoshop, Premiere, After Effects, Flame and Cineon, by default assumes that a digital image consists of a number of separate image layers. All in all, what used to be exceptions for traditional cinema became the normal, intended techniques of digital film-making, embedded in technology design itself.[26]

From kino-eye to kino-brush

In the twentieth century, cinema has played two roles at once. As a media technology, cinema's role was to capture and to store visible reality. The difficulty of modifying images once they were recorded was exactly what gave cinema its value as a document, assuring its authenticity. The same rigidity of the film image has defined the limits of cinema as I defined it earlier, i.e. the super-genre of live action narrative. Although it includes within itself a variety of styles – the result of the efforts of many directors, designers and cinematographers – these styles share a strong family resemblance. They are all children of the recording process which uses lens, regular sampling of time and photographic media. They are all children of a machine vision.

The mutability of digital data impairs the value of cinema recordings as documents of reality. In retrospect, we can see that twentieth-century cinema's regime of visual realism, the result of automatically recording visual reality, was only an exception, an isolated accident in the history of visual representation which has always involved, and now again involves the manual construction of images. Cinema becomes a particular branch of painting – painting in time. No longer a kino-eye, but a kino-brush.[27]

The privileged role played by the manual construction of images in digital cinema is one example of a larger trend: the return of pre-cinematic moving images techniques. Marginalized by the twentieth-century institution of live action narrative cinema which relegated them to the realms of animation and special effects, these techniques re-emerge as the foundation of digital film-making. What was supplemental to cinema becomes its norm; what was at its boundaries comes into the center. Computer media returns to us the repressed of the cinema.

As the examples discussed in this article suggest, the directions which were closed off at the turn of the century when cinema came to dominate the modern moving image culture are now again beginning to be explored. Moving image culture is being redefined once again; the cinematic realism is being displaced from being its dominant mode to become only one option among many.

Notes

1 Scott Billups, presentation during 'Casting from Forest Lawn (future of performers)' panel at 'The Artists Rights Digital Technology Symposium '96,' Los Angeles, Directors Guild of America, February 16 1996. Billups was a major figure in bringing Hollywood and Silicon Valley together by way of the American Film Institute's Apple Laboratory and Advanced Technologies Programs in the late 1980s and early 1990s. See Paula Perisi, 'The New Hollywood Silicon Stars,' *Wired* 3.12 (December, 1995), 142–5; 202–10.

2 Christian Metz, 'The Fiction Film and its Spectator: A Metapsychological Study,' in *Apparatus*, edited by Theresa Hak Kyung Cha (New York: Tanam Press, 1980), 402.

3 Cinema as defined by its 'super-genre' of fictional live action film belongs to media arts which, in contrast to traditional arts, rely on recordings of reality as their basis. Another term which is not as popular as 'media arts' but perhaps is more precise is 'recording arts.' For the use of this term, see James Monaco, *How to Read a Film*, revised edition (New York and Oxford: Oxford University Press, 1981), 7.

4 Charles Musser, *The Emergence of Cinema: The American Screen to 1907* (Berkeley and Los Angeles: University of California Press, 1990), 49–50.

5 Musser, *The Emergence of Cinema*, 25.

6 C.W. Ceram, *Archeology of the Cinema* (New York: Harcourt, Brace & World, 1965), 44–5.

7 The birth of cinema in the 1890s is accompanied by an interesting transformation: while the body as the generator of moving pictures disappears, it simultaneously becomes their new subject. Indeed, one of the key themes of early films produced by Edison is a human body in motion: a man sneezing, a famous bodybuilder Sandow flexing his muscles, an athlete performing a somersault, a woman dancing. Films of boxing matches play a key role in the commercial development of Kinetoscope. See Musser, *The Emergence of Cinema*, 72–9; David Robinson, *From Peep Show to Palace: the Birth of American Film* (New York: Columbia University Press, 1996), 44–8.

8 Robinson, *From Peep Show to Palace*, 12.

9 This arrangement was previously used in magic lantern projections; it is described in the second edition of Athanasius Kircher's *Ars magna* (1671). See Musser, *The Emergence of Cinema*, 21–2.

10 Ceram, *Archeology of the Cinema*, 140.

11 Musser, *The Emergence of Cinema*, 78.

12 The extent of this lie is made clear by the films of Andy Warhol from the first part of the 1960s – perhaps the only real attempt to create cinema without a language.

13 I have borrowed this definition of special effects from David Samuelson, *Motion Picture Camera Techniques* (London: Focal Press, 1978).

14 The following examples illustrate this disavowal of special effects; other examples can be easily found. The first example is from popular discourse on cinema. A section entitled 'Making the movies' in Kenneth W. Leish, *Cinema* (New York: Newsweek Books, 1974) contains short stories from the history of the movie industry. The heroes of these stories are actors, directors, and producers; special effects artists are mentioned only once. The second example is from an academic source: the authors of the authoritative *Aesthetics of Film* (1983) state that 'the goal of our book is to summarize from a synthetic and didactic perspective the diverse theoretical attempts at examining these empirical notions [terms from the lexicon of film technicians], including ideas like frame vs. shot, terms from production crews' vocabularies, the notion of identification produced by critical vocabulary, etc.' The fact that the text never mentions special effects techniques reflects the general lack of any historical or theoretical interest in the topic by film scholars. Bordwell and Thompson's *Film Art: An Introduction*, which is used as a standard textbook in undergraduate film classes, is a little better as it devotes three out of its five hundred pages to special effects. Finally, a relevant piece of statistics: a library of University of California, San Diego contains 4,273 titles catalogued under the subject 'motion pictures' and only 16 titles under 'special effects cinematography.' For the few important works addressing the larger cultural significance of special effects by film theoreticians, see Vivian Sobchack and Scott Bukatman (see below). Norman Klein is currently working on a history of special effects environments.

Kenneth W. Leish, *Cinema* (New York: Newsweek Books, 1974); Jacques Aumont, Alain Bergala, Michel Marie, and Marc Vernet, *Aesthetics of Film*, trans. Richard Neupert (Austin: University of Texas Press, 1992), p. 7; David Bordwell and Kristin Thompson, *Film Art: An Introduction*, 4th edn (New York: McGraw-Hill, 1993); Vivian Sobchack, *Screening Space: The American Science Fiction Film*, 2nd edn (New York: Ungar, 1987); Scott Bukatman, 'The Artificial Infinite,' in *Visual Display*, eds Lynne Cooke and Peter Wollen (Seattle: Bay Press, 1995).

15 For a discussion of the subsumption of the photographic to the graphic, see Peter Lunenfeld, 'Art Post-History: Digital Photography and Electronic Semiotics,' *Photography After Photography*, eds V. Amelunxen, Stefan Iglhaut, Florian Rötzer, 58–66. München: Verlag der Kunst, 1995.

16 For a complete list of people at ILM who worked on this film, see *SIGGRAPH '94 Visual Proceedings* (New York: ACM SIGGRAPH, 1994), 19.

17 In this respect 1995 can be called the last year of digital media. At the 1995 National Association of Broadcasters convention Avid showed a working model of a digital video camera which records not on a video cassette but directly onto a hard drive. Once digital cameras become widely used, we will no longer have any reason to talk about digital media since the process of digitization will be eliminated.

18 Here is another, even more radical definition: digital film $= f(x, y, t)$. This definition would be greeted with joy by the proponents of abstract animation. Since a

computer breaks down every frame into pixels, a complete film can be defined as a function which, given horizontal, vertical, and time location of each pixel, returns its color. This is actually how a computer represents a film, a representation which has a surprising affinity with a certain well-known avant-garde vision of cinema! For a computer, a film is an abstract arrangement of colors changing in time, rather than something structured by 'shots,' 'narrative,' 'actors,' and so on.

19 Paula Parisi, 'Grand illusion,' *Wired* 7.05 (May 1999), 137.

20 See Barbara Robertson, 'Digital Magic: Apollo 13,' *Computer Graphics World* (August 1995), 20.

21 Mitchell, *The Reconfigured Eye*, Cambridge, Mass.: MIT Press, 7.

22 The full advantage of mapping time into 2-D space, already present in Edison's first cinema apparatus, is now realized: one can modify events in time by literally painting on a sequence of frames, treating them as a single image.

23 See Robinson, *From Peep Show to Palace*, 165.

24 See 'Industrial Light & Magic alters history with MATADOR,' promotion material by Parallax Software, SIGGRAPH 95 Conference, Los Angeles, August 1995.

25 See my 'Avant-Garde as Software,' in *Ostranenie*, edited by Stephen Kovats (Frankfurt and New York: Campus Verlag, 1999). (http://www.manovich.net)

26 For the experiments in painting on film by Lye, McLaren, and Brackage, see Robert Russett and Cecile Starr, *Experimental Animation* (New York: Van Nostrand Reinhold, 1976), 65–71, 117–28; P. Adams Smith, *Visionary Film*, 2nd edn (Oxford: Oxford University Press), 230, 136–227.

27 Dziga Vertov coined the term 'kino-eye' in the 1920s to describe the cinematic apparatus's ability 'to record and organize the individual characteristics of life's phenomena into a whole, an essence, a conclusion.' For Vertov, it was the presentation of film 'facts,' based as they were on materialist evidence, that defined the very nature of the cinema. See *Kino-Eye: The Writings of Dziga Vertov*, ed. Annette Michelson, trans. Kevin O'Brien (Berkeley: University of California Press, 1984). The quotation above is from 'Artistic Drama and Kino-Eye' (originally published in 1924), 47–9.