Carleton University

PARTICLES AND WAVES: COMPUTATIONAL FLUID DYNAMICS AND FILM THEORY

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by

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ABSTRACT

This thesis contends with definitions of digital media which have been constructed in opposition to film. These definitions extend from the assumption that film as a technology and practice can be simply and clearly defined. My main contention is that there are specific ontological functions which we ascribe to film that continue in the cinema even as photochemical technology becomes supplanted by digital technology. To argue this, I use the example of Computational Fluid Dynamics, a procedural technique in digital animation that can be found in many films made over the past decade. Through its scientifically based relationship to natural movement and stochastic emergence, Computational Fluid Dynamics demonstrates ontological possibilities for digital cinema consonant with the filmic precedent.

INTRODUCTION

At the 2011 conference on the *Impact of Technology on the Theory and Historiography of Film* held in Montreal, participants remarked that the proceedings were taking on a rather elegiac tone in light of anxieties felt regarding the rise of digital technology in the cinema. Though computers have had a role in the cinema for long enough now that younger conference attendees could not remember a cinema without them, recent changes in projection have signalled cause for alarm. 2011 was the milestone year for digital cinema projection. Modern digital cinema began in 1999 when Texas Instruments first unveiled its Digital Light Processing (DLP) projector with the premiere of *Star Wars Episode I: The Phantom Menace* (Lucas 1999). In 2005 the studio-negotiated Digital Cinema Initiative (DCI) set down standards for content delivery and exhibition, thus officially institutionalising the technology. Finally, at the end of 2011 an official majority of international theatres were using Digital Cinema (comprised mostly of DLP projectors) with an effective total conversion predicted for 2015.[1]

Projection systems are not the only form of digital technology affecting the cinema, but their widespread use is as a rather significant nail in the coffin of what we consider film culture. DLP technology is fundamentally different from film projection. Instead of passing light through celluloid, DLP reflects light off of microscopic mirrors which control luminance by truing away from the screen. The content which we used to call "a film" can be recorded using a number of processes and is now delivered as encrypted data from a server. The rhythmic mechanical machine that fed images through an assembly-line-like journey from reality to screen will soon be a nostalgic artefact. With projection now digital and more movies being shot with digital

[1] David Hancock, "Thanks for the Memories: It's the end of an era as 35mm film declines," *Film Journal International*, December, 2011, http://www.filmjournal.com/filmjournal/content_display/news-and-features/features/technology/e3i9d8bb28649c6da4d1d61f39d3e90700a (accessed 1 March 2012).

cameras all the time, no more specific technological remnant of the cinematograph's photochemical process remains.

Much of the film studies discipline has already made changes to meet this new reality. University film studies faculties are now being divided up between cultural studies and media studies. The study of Hitchcock grows ever closer to the study of Shakespeare, while the discussion of contemporary issues in cinema are now included in new research fields that include various forms of visual culture and new media. Enduring Film Studies departments can seem oblivious in the face of these changes. It puts one in mind of Arnold Genthe's famous photograph of *Sacramento Street* during the 1906 San Francisco Earthquake. In the photo people in the foreground have set up chairs to observe the great fire that is rising in the background. So preoccupied are the people with the act of witnessing the disaster, they do not realize that they are part of it. They do not know that someone behind them is enframing their image with the disaster and that indeed their neighbourhood will soon be engulfed.

It could be said that cinema has always involved a history of constant technological change. Nonetheless, the introduction of digital technology is especially significant. No one denies that digital technology will continue to have a substantial and probably increasing influence on cinema. But what this means for the theory of cinema is a point of contention. The arguments usually gravitate toward one of two poles: either we are witnessing the loss of an important way of connecting with our world or cinema is continuing on a more-or-less un-troubled course.

In recent years, theories regarding film's relationship to movement, time, perspective, trace, and more generally reality, have all been employed in an attempt to account for digital technology's impact on cinema. For those who believe that cinema is capable of representing a concrete and accessible reality, the ontology of film, as conceived by thinkers like Bazin, is perhaps what is most at stake in a digital age. Additionally, Charles Sanders Peirce's semiotic category of indexicality, introduced as a concept in film studies by Peter Wollen, is often involved in work on the issue.

Digital media are constructed in opposition to conceptions of filmic ontology inspired by Bazin and Peirce. The constitutive traits most commonly ascribed to digital media in contrast to film are discreet approximation and mutability. These concepts were first applied to digital images by William J. Mitchell and then later expanded upon by Lev Manovich.[2] Discreet approximation refers to the process of reducing information to a specific value. As a simplified example, the hexadecimal value for a specific shade of red in html is "FF1111." The colour in a digital image must be recorded as a value such as this. The resolution or accuracy of the colour is dependent on how many different options there are to choose from. Any digital image is reducible to a collection of such transcodable data values. Mutability goes hand-in-hand with discreet approximation. Mutability refers to the fact that any image stored as data can be changed by altering that data. For example one could change the shade of red to "FF1122" and there would be no trace of the alteration. These very basic definitive elements of digital media and distinctions between it and film are problematic for some film theorists though.

In his essay titled "What's the Point of an Index? Or, Faking Photographs," Tom Gunning argues that some of the current discourses of digital media have simply displaced the old problems of film theory. By arguing that the extra mediation introduced by digital technology has invalidated film's direct indexical relationship to that which it represents, we assume a priori

[2] See William J. Mitchell, *The Reconfigured Eye* (MIT Press, 1994) and Lev Manovich, *The Language of New Media* (MIT Press, 2001).

that such a relationship had defined cinema in the first place.[3] Digital images are mutable; everyone acknowledges they can be changed at their very core. But, Gunning observes, photographic images are also alterable at their core, as in the case of spirit photography. The existence of the practice of faking must be predicated on the prior concept of a truth claim.[4]

In a similar vein to Gunning, Philip Rosen takes a critical look at the discourse of digital media in his book *Change Mummified.* Rosen looks at the "technical" definitions of film put forward via ideas like indexicality. Regarding these definitions of what digital media is not, Rosen reaches the conclusion that they are "ultimately sociocultural and representational ideals."[5] Rosen is also highly critical of the way digital media become associated with future-ness and conflated with postmodernity. Very much like Gunning, Rosen states that the definitive elements of this "digital utopia" come purely from its opposition to definitions of film as a medium.[6]

So how do we conceptualise digital technology in its own right without resorting to the displaced ideals of film theory? One difficulty answering this question stems from the extent to which digital technology does not have a specific set of limiting elements in the way that other media do. We can look at how lenses, successive frames, film stock and projection define what film is, but digital media entail a far broader, more abstract and less specific technology. If we are seeking to understand digital technology as it relates to cinema, relying too heavily on old film theory concepts can be problematic. The best thing we can do is to look specifically at the digital techniques that are being developed and institutionalized in cinemas today. Furthermore,

[3] Tom Gunning, "What's the Point of an Index? Or, Faking Photographs," *Nordicom Review* (2004), 39.

[4] Ibid., 42.

[5] Philip Rosen, *Change Mummified: Cinema, Historicity, Theory* (U of Minnesota Press, 2001), 302.

[6] Ibid., 318.

we can ask what things audiences are responding to and how are they being institutionally implemented. This is the best way we can begin to approach digital technology in its own right.

With this in mind, the following pages of this thesis will be looking at a specific technique for creating animated digital images using physics. This will provide an important example from which to address digital media theory. The importance of physics-based animation has been acknowledged by the Motion Picture Academy, which gives out awards for science and technology every year in addition to their well known Oscars ceremony. In 2007 the majority of the awards given out involved the digital animation made possible by computational physics. In computational physics, an object or fluid is programmed to have the behaviour of its equivalent in real life and it is basically allowed to behave as it wants in a given set of conditions.[7] Computational physics is a type of "procedural animation," meaning that it is generated automatically rather than being done by hand. The movement created by computational physics is not animated through frame-by-frame manipulation; rather it is the result of complex algorithms that simulate physical behaviour. Once the conditions and parameters are set, an animator presses "go" and the object or fluid animates itself. The computational physics models examined in the following pages fall under the heading of computational fluid dynamics or CFD, which includes the simulation of phenomenon like water, fire and smoke.

Perhaps the most salient example of CFD technique from the last twenty years is the "big wave" in disaster films, such as *The Day After Tomorrow* (Emmerich 2004) or *The Perfect Storm* (Peterson 2000). The special effects teams that worked on these films employed CFD to create large cataclysmic waves which were noted in the press for their uncanny appearance. Todd

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[7] Academy of Motion Picture Arts and Sciences, "2007 Scientific & Technical Awards Winners," http://www.oscars.org/awards/scitech/winners/2007.html (accessed 12 January 2012).

McCarthy remarked in *Variety Magazine* that "The frequent aerial views of water surging through the streets" in *The Day After Tomorrow* were "eerie and dramatically convincing..." [8] Stephen Hunter at *The Washington Post* described the same scene as a "beguiling vision" and said he was affected by the "poignancy of the image." [9] Reactions to *The Perfect Storm* were largely similar, though reviewers noted that while the images of waves were compelling they were somehow uncannily unreal. Stephanie Zacharek at *Salon.com* remarked that the images "shook [her], and the feeling lingered," going on to note that the "spectacular special effects threaten to swallow characters whole." [10] These dramatic descriptions illustrate that special effects created using CFD were especially salient to the viewing public. This was clearly also apparent to the film's promoters as both of the film's trailers focus strongly on images which utilize CFD.[11]

This practice of animating movement for special effects may seem to have only a niche application, but increasingly CFD is being used for more banal background effects both in animation and live-action cinema. Filling in the background of a given shot with a realistic computer-generated ocean can be more cost-effective than shooting on location. In a digital animation textbook such as Rick Parent's *Computer Animation: Algorithms and Techniques*, CFD is the subject of one of eight chapters which collectively amount to what could be called an animator's toolbox. Two of the book's chapters fall under the heading of computational physics.

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[8] Todd McCarthy, "The Day After Tomorrow," *Variety*, 26 May 2004, http://www.variety.com/review/VE1117923968?refcatid=31 (accessed 1 March 2012).
[9] Michael O'Sullivan, "A Perfect Storm of Clichés," *Washington Post*, 27 May 2004, http://www.washingtonpost.com/wp-dyn/articles/A60382-2004May27.html (accessed 1 March 2012).
[10] Stephanie Zacharek, "The Perfect Storm," *Salon.com*, 30 June 2000, http://www.salon.com/2000/06/30/storm/ (accessed 1 March 2012).
[11] Theatrical trailer of *The Perfect Storm* (Peterson 2000), available at http://movies.nytimes.com/movie/186759/The-Perfect-Storm/overview (accessed 1 March 2012) and Theatrical Trailer of *The Day After Tomorrow* (Emmerich 2004), available at http://movies.nytimes.com/movie/281154/The-Day-After-Tomorrow/overview (accessed 1 March 2012).

CFD and computational physics in general are clearly becoming a widespread practice in computer animation.

There are two key interdependent elements to CFD: the algorithmic knowledge of how a fluid behaves and the stochastic processes which enable the simulation of the possible movements of a complex system. Though we may have a pretty good understanding of how matter behaves from the subatomic level all the way up to the scale of a giant wave, the calculation of all of those particles in every detail is far too great a task for any computer to handle. What scientists do instead is approximate the aggregate behaviour of the more detailed levels. They do this by implanting randomized elements into the algorithms which describe behaviour on a larger scale. In other words, we know that millions of particles are bumping into each other and consequently are influencing each other's paths in a fluid, but rather than calculating each particle's path, we assume their behaviour on a whole to be random. This is what is referred to as a stochastic process: a non-deterministic process which contains certain random elements in place of complexity.

The birth of the modern stochastic process coincided with the institutionalisation of the computer as a new type of scientific tool around the end of World War II. In order to calculate the complex paths of neutrons in nuclear fission a stochastic process dubbed the "Monte Carlo method" by its inventors was employed. This tool represents a conceptual turn in the history of science. Whereas science was once limited to experimentation and observation, the Monte Carlo method points to a new avenue for learning about the world: simulation. The project of simulation assumes that we can make observations and test hypothesise without dealing directly with material reality. Though the subjects of simulation cannot be said to exist, their connection to reality and ability to inform out understanding of our world is undeniable. Many of the things we "know" about the physical world today are based on invisible or even un-observable phenomenon.

Like computer simulation, film was also imagined as a scientific tool that was capable of seeing the invisible. If one were to look at the first uses of movement in film, the kinship between CFD and film becomes quite apparent. Étienne-Jules Marey sought to understand movement through chronophotography. Movement was pure data for Marey. He did not seek to document movement in a specific time and place; instead he approached movement as a general reproducible scientific principal. This is, in essence, the same approach to movement as CFD, in that they are both concerned with motion as a fact of nature. It is further worth noting that Marey actually conducted experiments in fluid dynamics and captured the results on film late in his career.[12]

CFD compels our attention today because of its powerful ramifications for current debate on cinema's digital future. CFD raises perennial questions of film ontology because it exercises a fascination like that of the first motion pictures. According to some accounts, early cinema primarily inspired a fascination with natural movement. Dai Vaughan, in his collection of essays on documentary, highlights the role of natural motion in the Lumière films. Citing Georges Sadoul, he writes that early audiences were most fascinated by things like smoke and dust.[13] He also tells the well known story of how Georges Méliès was more interested in the leaves rustling in the background than the baby being fed in the Lumière film *Répas De Bebe* (1895). If cinema's great attraction was its uncanny ability to make realistic motion in realistic pictures,

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[12] Musée d'Orsay. "Movements of Air Etienne-Jules Marey (1830-1904) Photographer of Fluids," 2004, http://www.musee-orsay.fr/en/events/exhibitions/in-the-musee-dorsay/exhibitions-in-the-musee-dorsay/article/mouvements-de-lair-etienne-jules-marey-1830-1904-photographe-des-fluides-4216.html?cHash=dacd31b3b3 (accessed 12 Janaury 2012).

[13] Dai Vaughan, *For Documentary* (U of California, 1999), 4.

surely the reproduction of the random and complex movement of nature was its greatest feat. This would seem to be something both the scientist Marey and the un-initiated audiences of the cinematograph recognized.

The waves of CFD have an even closer relative in the crashing waves of Brit Acers' *Rough Seas at Dover* (1896). In Acers' film the chaotic aesthetic of the waves illustrates the camera's ability to capture the unpredictable contingencies of the real world. When we set up a camera in the world and start to record, anything might happen. Embracing that contingency is to some the essence of a good film or even a moral film. Dudley Andrew, drawing on the work of Andre Bazin, describes the cinema as a flashlight in the dark, searching the world and discovering the things which the light happens to illuminate.[14] For him good cinema is all about encountering unpredictable things in the world. Andrew takes particular issue with digitally produced imagery on these grounds. He criticizes Jean Pierre Jeunet's *Amélie* (2001) for its meticulous control of every type of contingency. Every flaw, every mistake, is corrected in post production so that anything not already expected or planned cannot enter the frame. He highlights the irony that though Amélie celebrates an errant fly on the screen in *Jules et Jim* (1962), no such contingency would ever be allowed into Jeunet's film.[15] It is quite appropriate that another Truffaut film, *Les Quatre Cents Coups* (1959), ends with Antoine Doinel running towards the sea. A film which is so often celebrated for opening itself up to un-controlled reality concludes at the sea: a setting where chance is constantly playing itself out, just as it is in Brit Acer's film.

The sea provides a perfect example of divergence within a system of laws. This is the

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[14] Dudley Andrew, *What Cinema Is!* (Wiley-Blackwell, 2010), 2.

[15] Ibid., 19.

essence of a stochastic process. Though no one could ever predict the shape of every wave on a beach, we know how they are generally formed and how they will generally behave on different days. They represent an element of chance in a naturally stable world. Waves have been crashing on the beach in much the same way since long before humanity, yet they are subject to infinite variation at every moment.

Of course one could also look at the ways in which CFD does not embrace possibility or encounter but instead introduces it only to control it. Chief graphic scientist for Rhythm and Hues Jerry Tessendorf has stated that the reality he tries to portray with a given CFD process is the one in the director's mind.[16] The first films to feature this technology were large studio productions. For instance *Star Trek II: Wrath of Kahn* (Meyer 1982) was the first film to feature the graphic rendering of a stochastic process, and mega-productions like *Waterworld* (Reynolds 1995) were the first to feature CFD. Given our tendency in film studies to see control in studio productions and spontaneity and exploration in more peripheral art cinema, one is tempted to argue that the stochastic is being unleashed in CFD only so that it can be better controlled. Siegfried Kracauer uses the example of a snowstorm when describing the degree of control exacted by studios in the Weimar era. Whereas a Swedish production at that time would want to capture an actual snowstorm, a German studio would produce a fake one on a giant studio set in order to control every element of contingency.[17] The snowstorm is a suitable example for our purposes, given that such a thing in a studio picture today would quite probably be simulated using a stochastic process.

The fake studio snowstorm, of course, contains some pro-filmic movement. Even if the

[16] Jerry Tessendorf, "TEDx Conejo: Art and Science in Visual Effects," TEDx, 2004, http://www.youtube.com/watch?v=XW2LtGtCbk0 (accessed 12 January 2012).

[17] Siegfried Kracauer, *Theory of Film: The Redemption of Physical Reality* (Princeton University Press, 1997), 74.

snow is artificial and the wind comes from industrial fans, the swirling of the snow shows random movement that could never be fully controlled. The snow is not real snow but it is materially real. The fake snow's movement has some sort of marvelous attraction to it. Residing within the image of the fake snow is a tension between formal control and chaotic unpredictability. Kracauer sees a dichotomy of formalism and realism, of imposed control or of spontaneity. In the fake snowstorm as well as in CFD there is an example of a similar kind of tension between the formal and the real.

Film theorist Mary Ann Doane would perhaps describe this tension in terms of contingency and systemisation. In her book *The Emergence of Cinematic Time* she describes early cinema as exhibiting the thermodynamic law of entropy where energy will always dissipate into chaos over time.[18] She observes that chaos emerges in the films of Méliès and the Lumières with the passage of time.[19] She describes the development of film form as a process of containing contingency in a "representational system while maintaining both (contingency's) threat and its allure." [20] Doane is offering a new dichotomy; instead of contrasting the formalism of Méliès with the realism of the Lumières, she is contrasting the raw possibility of reality captured on film with the formal organisation of film.

It could be argued that this same dichotomy is at work within the process of CFD, where control is balanced against unpredictability. Control dictates the form of a fluid but the stochastic elements are what give the fluid an uncanny presence on the screen. Filmmakers are faced today with the opportunity for unprecedented control through digital production, the type of thing

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[18] Mary Ann Doane, *The Emergence of Cinematic Time: Modernity, Contingency, the Archive* (Harvard University Press, 2002), 117.

[19] Ibid., 136.

[20] Ibid., 138.

Weimar studio directors could only dream of. Yet, CFD would seem to suggest that technology is providing opportunities to let go of some control, to leave some things to chance.

Though a few works on digital media have addressed the notion of "algorithmic" animation, none have addressed the concept of procedural animation based on physics and stochastic processes.[21] The idea of animation that is automatic is generally consistent with familiar dichotomies of digital media and film. CFD, with its mimicry of the scientific properties of matter and its unique articulation of the unpredictability of reality, creates problems for almost all currently held positions.

Lev Manovich set a substantial trend in his book *The Language of New Media* when he stated that the digital, with its numerical representation, modularity, automation, transcodability and variability, is not capable of having the same relationship to reality as film. He dismisses digital cinema's current preoccupation with "illusionism" and concludes that future cinema will return to the days of the relative abstractness of the magic lantern show and animation.[22] CFD, however, in some respects has a stronger kinship with early cinema than with the hand-drawn magic lantern. Through its algorithmic and stochastic simulation of the natural world, CFD articulates just the sort of automatic and technological relationship to reality that film has. Regarding the CFD-generated image, in some ways we can say that, yes, it is real, yet in others we know that it is not. The idea of numerical (or discreet) approximation which Manovich focuses on is an important one, but CFD embraces the numerical. The processing of data is a constitutive element of CFD's claim to representing reality.

Though theorists like Manovich express futuristic optimism that digital media will

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[21] For example see: Manovich, "Complexity and Abstraction," and Rodowick, *The Virtual Life of Film*, 104.

[22] Manovich, *The Language of New Media*, 250.

surpass film, the conceptual distinction that he makes between film and digital media is consonant with the work of film scholars who advocate for aspects of film threatened by digital technology. Though he takes nothing for granted in reaching his conclusions, D.N. Rodowick echoes Manovich's concepts of numerical approximation, mutability and transcoding. Rodowick states that a photograph "transcribes" while a digital image "transcodes". For Rodowick transcoding means a "fundamental separation of inputs and outputs." [23] From this standpoint, the digital photograph does not have the same special relationship to reality that film does. According to Rodowick, in the transcoding of the data of a digital image, "the special link of physical causality is broken as well as the temporal continuity of transformation." [24] Because Rodowick's argument is focused on how the photographic process is special, he dismisses digital technology as incapable of connecting to reality in a meaningful way. CFD problematizes this position because it is an anomaly: a digital system that offers a connection to reality despite its numerical nature. The transformation of data through a stochastic process could perhaps be the early development of what Rodowick and Cavell refer to as an "automatism" of film in a digital medium. CFD has a logic of temporal transformation much like film, but instead of a transformation between past and present it is a transformation between remote and present, or theoretical and present.

CFD evokes the nature of chance in reality by mediating it through numerical data. In reviewing disaster films with CFD waves and storms a trope emerges which seems to prompt the viewer to consider the concept of a digitally mediated yet accessible reality. Blockbuster disaster films such as *Twister* (De Bont 1996), *The Day After Tomorrow* (Emmerich 2004) and *The Perfect Storm* (Peterson 2000) all feature catalysimic disasters represented through diegetic

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[23] David Norman Rodowick, *The Virtual Life of Film* (Harvard University Press, 2007), 117.

[24] Ibid.

computer screens and visualizations. All these films include sequences where a weather center is analysing data and simulation projections. Each articulates a different relationship to simulation, but each seems to be trying to reflect on the nature of virtual knowledge, contingency and simulation's relationship to the natural world and reality.

The Perfect Storm depicts weather conditions converging in an extremely unlikely way to form a storm of unprecedented magnitude; an extremely remote possibility becomes actual. *The Day After Tomorrow* confronts its audience with the possibility of future cataclysmic changes residing virtually within the present. *Twister's* narrative follows scientists attempting to gather motion information about storms, the climax of which is a computer display of points moving in a tornado. Though the film features no CFD, it can be related to the first widely distributed public image of stochastic simulation visualization, *Study of a Numerically Modeled Severe Storm* released by the National Centre for Supercomputing Applications in 1990.

In these films the viewer is asked to conceive of different ways of imagining reality through chance. The climax of these films, a CFD storm or wave, represents an articulation of this theme through movement. Unlike films which ask us to consider our relationship to things which are remote because they existed in the past, CFD asks us to consider our relationship to remote things in the present or future. One useful way the concepts of reality and chance can be approached is through process philosophy, first articulated by philosophers such as Alfred North Whitehead, Charles Sander Peirce and Henri Bergson, and later applied to cinema by Gilles Deleuze.

Deleuze used the cinema to illustrate an ontology which was predicated on process philosophy. In his essay *Deleuze-Bergson: an Ontology of the Virtual*, Constantin Boundas describes Deleuze's ontology through the concepts of movement and "coexistent multiplicities."

[25] Movement here refers to the constant process of change and becoming. Multiplicity refers to the idea that any "actual" instant we observe a substance is merely an anecdote of a process that carries with it the "virtual" existence of all the other possibilities unseen. According to Boundas this virtual existence is not actual but it is real.[26] This concept of movement and indeterminate form suits the conceptual underpinnings of CFD quite well. When the artist runs a simulation, there is no way of knowing what motion will happen. The image of CFD-generated movement that we see on screen in the theatre is one of a great number of possibilities for motion, each of which exists virtually in the stochastic algorithm which gave birth to the movement.

CFD requires a processual ontology in order to account for its relationship to time and reality, but it is an ontology nonetheless. Attempting to understand CFD through a dichotomy of abstraction and trace (or index) tells us very little about the way we access reality through digital technology in cinema. It would seem instead to suit a much more complex conception of reality: a reality of change and becoming, a reality beyond the immediate and concrete. Contrasting this form of representation with existing film theory poses the potential for resolving some very unique characteristics of computer generated motion. This may in fact prove to be the beginnings of an ontology of the digital.

As hardware continues to increase exponentially in computational power and as CFD engines become available in open-sources programs such as Blender, it is reasonable to conclude that computational physics will become an increasingly common practice in cinema and become an increasingly important subject of study. The following chapters will discuss specific examples of CFD and their relevance to a theory of digital media.

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[25] Constantin V. Boundas, "Deleuze-Bergson: an Ontology of the Virtual," in *Deleuze: A Critical Reader*, ed. Paul Patton (Wiley-Blackwell, 1996), 83.

[26] Ibid., 86.

Chapter 1 of this thesis will examine the history and conceptual premises of CFD. Stochastic algorithms and computer visualization in science will be specifically addressed before examining their role in cinema special effects. This chapter will examine the way the specific numerical relationship between stochastic simulations and their visualization problematizes many current definitions of digital media.

Chapter 2 will further explore the way visual culture studies and film theory have thus far constructed digital and numerical media as abstract and precise, in contrast to the photograph which is constructed as a source of infinite resolution and ambiguity. Chapter 2 will demonstrate the way stochastic processes transcend this dichotomy to create numerically based images which can be profoundly ambiguous.

Chapter 3 will address CFD's peculiar relationship to time. This relationship to time will be considered in light of process philosophy and the work of Deleuze. It will also be considered in light of contemporary scientific issues which require a more expanded approach to time and contingency than the one traditionally offered by film. Though film and CFD have different ontologies, their uses in the cinema are intimately linked in that both film and CFD are automatic processes which address the matter of reality and our ways of knowing it.

CHAPTER 1

VISUALIZING THE INDETERMINATE

What can be controlled is never completely real; what is real can never be completely controlled.
- Physicist Ilya Prigogine quoting Vladimir Nabokov

This chapter will explore the concepts and discourses which are relevant to an understanding of computational fluid dynamics. There are two key discourses in which to place the history of CFD. The first is visualization, both its changing role in the computer age as well as its tradition in western culture. The second is the rise of computation and stochastic processes as they relate to the nuclear age and a resulting philosophical change in the sciences. Both of these subjects provide critical discourses in which to place CFD, but more importantly they provide us with a conceptual framework for understanding CFD's significance to cinema.

The Stochastic in Science

Our understanding of the properties of water is closely linked to technologies of visualization in the history of science. Over the final two decades of the 19th century Arthur Worthington conducted experiments on the properties of fluids. His work involved observing the impact of droplets of fluid on solid surfaces. He arranged a flash of light to coincide with the impact of the droplet so that the image of the fluid in motion was temporarily imprinted in his vision.[1] He would then sketch the image of the droplet from the imprint in his vision. This technique allowed Worthington to see something which had been previously impossible to observe due to the speed with which it transpired. Worthington documented many of these

[1] Martin Kemp, *Seen/ Unseen: Art, Science, and intuition from Leonardo to the Hubble Telescope* (Oxford University Press, 2006), 306.

events with different liquids and he observed in summary that the dispersion of liquid after impact was perfectly symmetrical.[2]

This observation was, of course, completely false. In 1894 he was finally able to use photography to conduct his research; the photographs that he produced demonstrated that in fact the liquid did not disperse symmetrically at all. Worthington was forced to admit the flaws in his previous work. Lorraine J. Daston and Peter Galison use Worthington as an example in their book *Objectivity*. They highlight the way that Worthington had ignored the evidence of asymmetrical behaviour as he abstracted the shapes of the liquid to what he felt was the essential, reductive core of the phenomenon.[3] The photograph captures everything; it does not evaluate and remove the elements that a human observer might see as non-essential. Through this new technology Worthington's assumption about the behaviour of fluids was disproved. Worthington had assumed that a uniform liquid impacting with a uniform surface would result in uniform movement. What he discovered is that no one could predict the complex set of forces influencing each other within the fluid. There was simply no order. While the fluid's behaviour could be captured in a photograph, it could not be understood completely according to reductive principals. The photograph brought Worthington closer to understanding the behaviour of liquids, yet further from being able to predict their specific behaviour.

From the earliest stages of mechanical measurement, studies of fluid dynamics have revealed a tension between simplified, predictable, calculable unities and the unpredictable contingencies of each incidence of natural movement. Worthington appreciated this in the early days of his work, stating that calculating fluid dynamics "taxes the highest mathematical powers

[2] Peter Galison and Lorraine J. Daston, *Objectivity* (MIT Press, 2007), 12.

[3] Ibid., 15.

to elucidate."[4] He imagined that the complexity amounted to some greater order though, assuming the result of complexity to be "orderly and inevitable." [5] As it turned out, the behaviour of a complex system follows no such order. The threshold between complexity and predictable behaviour would continue to emerge in many physical sciences as ideas like quantum mechanics emerged in the 1920s. In a sense, scientists were discovering what was already well known. Any instance of natural motion is far from a metaphysical stability; it is a constant playing out of unpredictability. Being able to able to contend with these contingencies and still make meaningful predictions clearly became a problem for Worthington in 1894. A mere thirteen years later, though, stochastic calculations began to emerge as a way of conceptualising this problem and dealing with incalculable complexity.

"Brownian motion" is a classic example of an idea which directly engaged the unpredictable nature of fluid behaviour. Brownian motion can be used to describe the drifting of a particle through a fluid. Imagine releasing a coloured dye into a glass of water and picture the beautiful and unpredictable path it traces as it moves through the water and gradually dissipates. No equation could ever predict a specific instance of this path; there are simply too many factors to contend with. With so many particles interacting with each other and each one influencing the other, the sum total of their movement is too complex. Minor magnitudes of force that were present when the particle was introduced quickly become untraceable as their complexity is magnified. Certain factors and properties can be accounted for, but others always escape us.

In 1907 Paul Langevin developed a way to calculate the possible path of a particle through a fluid. This Stochastic technique was based in part on what is referred to as a "random

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[4] Ibid., 12.

[5] Kemp, *Seen/ Unseen,* 306.

walk." [6] Basically, at every stage in the motion of the particle a random direction is chosen. The path in aggregate draws an unlikely line which may continue in a direction for sometime or may completely change at any point. The graphic representation of such a path is compellingly arbitrary because the orientation of the entire structure was dictated by all of the previous random turns (Fig. 1). The shape in its entirety is unlikely in every way. A key premise of Brownian motion is that it calculates a single instance of motion. A calculation of Brownian motion does not resolve the specific outcome of a specific circumstance because the various forces would simply be too complex to calculate. Instead, Brownian motion can be calculated as an instance of possible motion. These early stochastic processes offer the outline of the conditions of a problem and illustrate the possibilities that reside within those conditions.

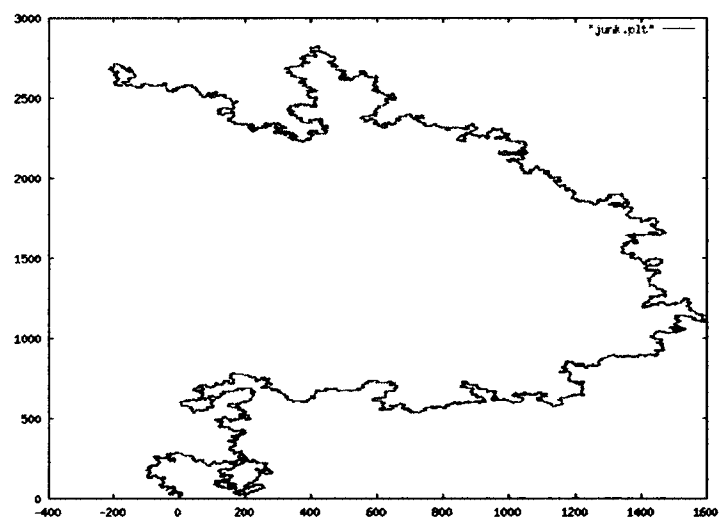

Fig 1. Example of Two-Dimensional Brownian Motion, Probability at Cornell University, http://www.math.cornell.edu/~probability/ (accessed 1 March 2012).

The fact that early stochastic calculations coincide with a shift in technology is worth examining. Worthington's understanding of fluid dynamics was clearly altered by the technology

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[6] Franz J. Vesely, *Computational Physics: An Introduction* (Springer, 2001), 48.

of the photograph. Brownian motion itself reflects a sort of photographic imagination of events. The motion of the particle in Langevin's calculation is merely a collection of instances. Each time the direction of the particle is calculated it is an instance of motion. One could not conceive of this random change in direction without breaking up the duration of the particle's movement into instances. This bizarre sort of reclamation of Zeno's paradox is quite apt because it deals with a hypothetical set of positions in space. When does the particle change direction if it is always changing direction? How does one calculate a duration of constant change except to calculate the end? Thus, the random walk of Brownian motion is made up of instances, just like a film. Both are an image of the duration of motion made possible by a dissection into instances. Both attempt to make sense of a very difficult and elusive temporal process. Further developments concerning this profound conceptual link between technology and the use of stochastic processes will be discussed later in this thesis.

Physics Become Virtual

One of the first uses of computational physics was undertaken by researchers from the Los Alamos research facility. The first general purpose computer, the ENIAC (Electronic Numerical Integrator And Computer), was constructed under the supervision of Physicist John Mauchly and Engineer Presper Eckert for the United States Military's Ballistics Research Laboratory. Though it had been conceived of during the Second World War, ENIAC was not finished until 1945. The ENIAC was proposed by Mauchly and Eckert as a way of calculating the ballistic trajectories of weapons under various circumstances. Given that up until then calculating ballistics had been a labour intensive process involving menial calculations done by scores of workers, the construction of a costly experimental electronic computer could actually offer a resource efficient solution.[7] Though the ENIAC was built for ballistics, it was a versatile platform; it was a general purpose computer, meaning that it could be physically programmed to do different operations. Quite immediately, the ENIAC proved to be a powerful tool for experimentation.

The first test conducted on the ENIAC had nothing to do with calculating ballistics at all. John von Neumann, a mathematician famous for his work on quantum mechanics, fluid dynamics, economics and many other fields involving mathematical complexity, arranged for the first test of the ENIAC to be a simulation of a thermonuclear reaction. This test, designed by physicist Nicholas Metropolis and Stan Frankle, provides an example of an early scientific computer simulation. The purview of the computational sciences is to conduct research that cannot be conducted by practical means. Computational science sits somewhere in-between pure math and experimentation. Conditions are set and a process is run in order to discover an outcome. Instead of a scientist observing a phenomenon in nature or creating an experiment in reality to test a principle, computational experiments are conducted virtually. Though completely theoretical, computational models can test theories numerically and invisibly. Atomic science lends itself to such work because it is not always practical to test reactions in the real world.

Von Neumann and Metropolis went on to work with Enrico Fermi and Stanislaw Ulam to conduct tests of neutron diffusion in a fission reaction on the ENIAC. This test followed the paths of neutron as they collided and entered different materials.[8] Fission occurs under certain circumstances when enough neutrons collide with nuclei, producing more neutrons in order to start a chain reaction of collisions. This is a complex system indeed, because atomic particles will collide and affect each other's paths and momentum. The calculation of each neutron's path

[7]Nicholas Metropolis, "The Beginning of the Monte Carlo Method," *Los Alamos Science* (1987), 126.

[8] Ibid., 127.

as it influences and is influenced by other particles is extremely complex. The efficient solution to calculating the problem was to introduce random elements as a sort of stand-in for complexity. The distribution of the neutrons and the locations of collisions were calculated randomly rather than attempting to account for the specific path of every neutron. Random numbers were sourced using von Neumann's "middle square" method for achieving random values. This method of utilising random numbers was referred to as the "Monte Carlo method," referring to the random nature of games of chance played at a casino.[9] This was the first stochastic process calculated using a computer.

Stochastic processes like the Monte Carlo method have become a foundational component of CFD. The scientists at Los Alamos may have been dealing with atomic structures and doing calculations on a machine whose operations were measured in the hundreds per second (whereas the home computer today is measured in the billions) but the principals are essentially the same. A computer is used as a sort of "loaded die – that is, a random number generator that produces a sequence of numbers with certain desired statistical properties."[10] It is a form of science which embraces the fluctuating and transient nature of reality. A stochastic process produces an anecdote, that is, it produces one possible outcome and alludes to the other outcomes which did not occur. Stochastic processes are not probabilistic in that they do not reveal the likelihood of an occurrence; instead they reveal the possibility of occurrences. Stochastic processes are conceptually significant because they exhibit an appreciation for the unknown not normally associated with the sciences, least of all physics.

Physics is an investigation into the nature of matter. It has classically been understood as

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[9] Ibid.

[10] Vesely, *Computational Physics*, 49.

a part of natural philosophy. The meaning of the word "nature" as we understand it today is essentially the same as *physis* was to the Greeks when the term was coined.[11] On one hand nature is the content of the natural world: plants, animals and geological formations of the earth. On the other hand, nature is also the way things are: the natural state of something. In Homer's *Odyssey* Odysseus is shown the physis of the phallic plant moly by Hermes as a means of defeating the spell of Circe. The plant is a part of nature and it also has proprieties which are intrinsic and meaningful.[12] This is the earliest recorded use of the word, and it demonstrates the dual overlapping meaning of physis. Simply put, it is the meaning of matter.

The concept of physis presupposes some sort of stability of meaning. The idea of an acknowledged indeterminacy is somewhat heretical to the very idea of physis. This is the reality of knowledge in modern science though. Quantum physics illustrates this on a very remote sub-atomic scale. The idea of indeterminacy is crystallized rather acutely when it addresses the physics of matter on an everyday scale the way CFD does. CFD represents the immediate material manifestation of the conceptual realities of modern science. CFD is a form of representation for a science which no longer relies on stable deterministic forms.

The choice of a stochastic process indicates the limits or conditions of what a scientist hopes to learn. The calculations imagine matter in time, rather than in a static position. The things being studied in the examples involving Brownian motion and the Monte Carlo method are phenomena of change and movement. This is of course the case with CFD as well, which imagines a fluid moving and flowing in duration rather than sitting statically in abstraction. These calculations are about fluctuation, change, movement, duration and possibility.

[11] Francis P. Dinneen and E.F.K. Koerner, *North American Contributions to the History of Linguistics* (John Benjamin's Publishing, 1990), 2.

[12] Jenny Strauss Clay, *The Wrath of Athena: Gods and Men in the Odyssey* (Rowman & Littlefield, 1983), 158.

Visualisation

It is important to note here that neither CFD nor computational physics in general are visual themselves. Visual examples of fluid dynamics are abundant in our world and can be observed from something as mundane as pouring a cup of coffee to something as world-changing as a tsunami (our understanding of the properties at work in these phenomenon is virtual and algorithmic though). The product of a computer simulation of fluid behaviour is data content, that can be visualised in any number of ways. Certain aspects of the data can be highlighted, other aspects can be omitted. Indeed the data itself can be skewed to the point of meaninglessness if one so wishes. The visualization of this information is thus subject to a logic of its own, a logic of representation. A discussion of CFD in the cinema must take into account both the process itself and the conventions of its visualization.

Computer visualization has its own particular discursive claims to truth. Work has been done over the past few decades to understand this discourse of digital verisimilitude. Much like the photograph, the computer can only be defined as an overdetermined intersection of technology, culture, theory and practices. In other words, there are things which we can say a computer consists of, but more importantly there are many things which we construct the computer to be. The visualization of CFD has its own specific discourse, but in order to understand it, one must first understand the broader context of the history of computer visualization.

All forms of representation are dictated by some sort of conventional logic. Art historian Ernst Gombrich used the word "schemata" to describe the forms of representation which are dictated by technique and academy. Gombrich argued that an objective representation of reality in art is in a sense impossible. One painting cannot be said to be more realistic than another.

According to Gombrich,

> All representations are grounded on schemata which the artist learns to use. But we may now see more clearly why he (sic) is so dependent on tradition. The injunction to 'copy appearances' is really meaningless unless the artist is first given something which is to be made like something else.[13]

In a similar vein to Gombrich, Martin Kemp conducts a review of the conventions of representation in both science and art in his book *Seen | Unseen.* Kemp's review stretches from the renaissance to the present, focusing on the overlap between science and visual art. Kemp includes in this review automatic, mechanical and computational techniques. Kemp's conclusion is that in any given time and place there seems to be a consistency of style, a logic for representing reality.[14] Kemp expresses concern regarding the use of conventions of representation when they become too deeply engrained. He questions what opportunities we miss to "extend our consciousness into new realms of visualization" when we only have one way to think about the world.[15]

Perhaps one of the most deeply engrained conventions of representation since the renaissance has been that of perspective. This is a major concern for both Gombrich and Kemp. Gombrich tells the story of Yoshio Markino, a Japanese artist who traveled to the west, learning perspective and eventually returning home to Japan. When Markino draws a box in perspective and shows his father, his father says the box is crooked.[16] This anecdote is meant to illustrate the nature of schemata. To the western viewer the box was more real, more accurate, but to a

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[13] Ernst Gombrich, *Art and Illusion* (Princeton University Press, 2000), 263.

[14] Kemp, *Seen/ Unseen*, 314.

[15] Ibid., 55.

[16] Gombrich, *Art and Illusion*, 227.

different culture the appearance of perspective was a code which was not immediately intelligible. Perspective is thus merely a culturally specific schema for representing reality.

Perspective of course dictates the logic of three-dimensional computer visualization. When viewing a fully rendered digital visualization with every embellishment looked after in great detail, it can be easy to forget that the elements of this composition are carefully mapped out upon a virtual Cartesian grid and that each object consists of polygons or particles placed with their position and properties recorded as numerical data. The logic of three-dimensional computer visualization, as with the camera, camera lucida and camera obscura before it, is indebted to the tradition of renaissance perspective. These technologies are predicated on schemata. Though perspective has become, in a sense, universalised since the time of the Gombrich's Markino anecdote, it is still very much a topic of discussion in the era of computer generated images. These critiques of computer visualization assumes that even the most basic techniques of representation are culturally grounded and can be deconstructed.

A "Numerical Storm"

The first visualization of a computer simulation released to the public was a reconstruction of a well documented natural phenomenon. [17] In 1989 the Department of Atmospheric Science and the National Center for Supercomputing Applications (NCSA) collaborated on a project which used a Cray supercomputer to model a tornado-producing storm that had killed seven people in Oklahoma and Texas in the spring of 1964.[18] The project assembled information about air temperature, air pressure, moisture and wind velocity into a

[17] John Vince and Rae Earnshaw, *Visualization and Modelling* (Morgan Kaufman, 1997), 2.

[18] Vince, *Visualization and Modelling*, 2.

simulation which produced a model of a storm system analogous to the one that had actually occurred under those historically recorded conditions. The raw data output of the simulation was then translated into a three-dimensional visualization using Wavefront's Advanced Visualizer.[19] The resulting visualization was eventually distributed to the public as a video clip with narration titled *Study of a Numerically Modeled Severe Storm.* This digital storm has become a strong rhetorical point for those who wish to critique the discursive claims of computer visualization. Visualizations such as the *Numerically Modeled Storm Severe Storm* pose several issues. These images can have a strong value as visible evidence based on both technological and cultural discourses. They are also subject to artistic invention and visual rhetoric though. This simultaneity of truth claim and inflection is a source of anxiety, much in the same way it is for documentary film.

The *Numerically Modeled Storm* clip begins with a black and white amateur camcorder clip of an actual tornado forming. It then proceeds to show a three-dimensional visualization of a large grey mass hovering just on top of a black and grey grid pattern which stretches until it dissolves into a black "sky" on the horizon. The angle of the virtual camera is high, looking down upon the grey mass. This mass is of course the storm; it is surrounded by a shaded box on the grid pattern with the width and length of the storm labelled in kilometers (Fig. 2). A compass heading is also visible on the grid. Notably, both the camcorder footage and the visualization have time counting out in the corner of the screen. The video goes on to display other views of the storm in the same grid setting. These images render the mass transparent. Some images display a series of coloured particles which are picked up by the storm, carried to its top and

[19] M. Pauline Baker and Colleen Bushell, "After the Storm: Considerations for Information Visualization," *National Centre Supercomputing Applications University of Illinois*, http://vis.iu.edu/Publications/Storm.pdf (accessed 12 January 2012), 1.

transported horizontally. Orange lines are visible in some images which represent the paths of these particles.

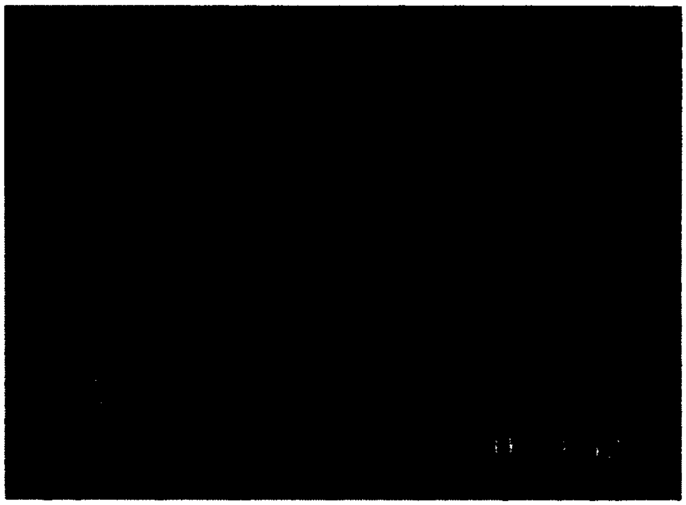

Fig. 2.Still from *Study of a Numerically Modeled Severe Storm.* NCSA and The Department of Atmospheric Science, 1990, http://www.fondation-langlois.org/html/e/media.php?NumObjet=13230 (accessed 1 March 2012).

Despite its success in capturing the imagination of the public, this visualization has been criticised by many since its very first versions were rendered in 1989. Perhaps one of the most surprising critics is Mark Bajuk, who was employed by the NCSA and actually worked on the project. Bajuk notes that the original visualization (not the one available in archive) took place over a textured surface that resembled a ploughed field rather than a grid. He notes that the field was criticized because the numerical model was conducted over flat ground and a cloud formation over such uneven ground would have formed differently. The textured surface was simply added for a realistic effect; in fact it is terribly inaccurate. As Bajuk states, given the size of the cloud (twice the height of Mount Everest) the furrows of the textured surface would be perhaps several hundred feet deep. This oversight led the public to conclude that what they were in fact seeing was a tornado and not a tornado-producing storm system which is many times larger.[20] Bajuk is a staunch critic of all of the embellishments made in computer visualization in the name of realism.[21] He would prefer to see an image which is as close to raw data as possible. The problem of scale is a strong rhetorical point for Bajuk because it throws into question the ability for a visualization of nature to speak for itself. If early audiences thought they were seeing a tornado and not a storm, meaning would seem to be constructed entirely by framing rather than the translation of data.

Bajuk's criticism is consistent with one leveled by Edward Tufte at the storm visualization. Amoung many things, Tufte takes issue with the lack of scale in the image. Tufte relates this criticism to another early visualization the *Magellan Space Probe flyover of the surface of Venus* (1992). The Magellan space probe had gathered measurements of the surface of the planet using radar and a NASA team turned that raw data into a 3D visualization where a camera flies over dramatic peaks and valleys of an orange planet with a black sky. The problem with this visualization, as Tufte notes, is that the visualization team changed the ratio of width to height in the data, making the topographic features far more dramatic than they actually would appear to a human eye on the surface of the planet. Tufte refers to this as an "extravagant dequantification" of information.[22] Though *Numerically Modeled Severe Storm* does not skew data to this extent, the issues are essentially the same. The use of traditional schemata of realism without appreciation for the nature of the source data causes these visualizations to be problematic.

Why did this happen though? Why are images which should be direct translations of raw

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[20] Mark Bajuk, "Aesthetics and Nature," in *Understanding Images: Finding Meaning in Digital Imagery*, ed. Francis T. Marchese (Telos, 1995), 254.

[21] Ibid., 244.

[22] Edward Tufte, *Visual Explanations* (Graphics Press, 2005), 22.

data becoming so contorted? Martin Kemp cites the "voracious public need for pictures of new discoveries within a culture which ceaselessly demands cascades of visual novelty" as one possible motivation for the character of visualization.[23] Perhaps, like the "cinema of attractions" of early cinema, the content of early computer images is reflecting a desire for what this new medium can show. Kemp also notes the pressure such publicly funded scientific institutions feel to produce compelling visual content. Hey likens it to a renaissance or baroque system of artistic patronage.[24] Whatever the aims of a given organisation may be, the product of their work must please their sponsors. Organizations like NASA or NCSA must communicate their validity and need for funding to the public and the government.

The purpose of visualization is perhaps less to render information intelligible to the public than it is to persuade the public. Rae Earnshaw and John Vince have noted the important role these visualizations play in shaping public policy. Rather than attempting to legitimise the value of their own content, some visualizations are designed with the specific intention of articulating a persuasive viewpoint on a state of affairs with the intention of effecting political change. They note the EPA's use of visualizations in their 1990 Clean Air Act campaign.[25] These images showed pollution from one state crossing the border over to another. The goal of these images was to persuade people who value states rights that federal legislation is needed to combat pollution. Earnshaw and Vince note how very successful this visualization was in swaying public opinion.

Discussing *Numerically Modeled Severe Storm* or the *Magellan Probe Scan* in these terms makes computer visualization the specific subject of rhetoric. One could argue this is the

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[23] Kemp, *Seen/ Unseen* (Oxford University Press, 2006), 62.

[24] Ibid., 63.

[25] Vince, *Visualization and Modelling*, 5.

essence of Edward Tufte's approach to all visualization. Given that all visualizations require an element of Aristotelian invention or creativity, one should discuss the value of their rhetorical appeals rather than their status as evidence or documentation. Tufte considers the purpose of both art and scientific visualization to be, "to show the results of intense seeing." [26] Seeing involves collecting data but also evaluating it, since its significance is rarely self-evident. The author of a visual representation thus has a responsibility to process and evaluate information. There is a rhetorical dimension to all visualization. It is the goals of the author and the rhetorical strategies they employ which determine the quality of the visualization in Tufte's eyes.

The cardinal sin which scientific computer visualization can commit, then, is to appear as a simulacrum of human vision. Here the discussion returns to the subject of perspective as a schema of representation. If perspective is a classical logic for rendering something as it appears, it poses issues to those who wish to imagine computer visualization as a place where transparent arguments are being made. If the content of a visualization is designed to appear as it would to the eye, it is making a tacit claim to existence and therefore unmediated proof. Tufte takes issue with what he refers to as the "school of Caravaggio" background of the *Numerically Modeled Severe Storm* and the grid which "exaggerates renaissance perspective recession." [27] The computer visualization makes use of perspective as a classical schema for representing reality. The storm, positioned within the exacting structure of a grid, is constructed as a piece of reality plucked from the world and suspended in a computer. This hides the translation of data which is so important to critics of these visualization practices.

This discourse is relevant to a discussion of digital images in the cinema. Though much

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[26] Edward Tufte, *Beautiful Evidence* (Graphic Press, 2006), 105.

[27] Tufte, *Visual Explanations,* 21.

of the computer-generated special effects and animation found in the cinema do not have a claim to scientific measurement like the *Magellan Probe Scan* or *Numerically Modeled Severe Storm*, processes like CFD complicate the issue. CFD works in exactly the same stochastically simulated way as the *Numerically Simulated Severe Storm.* The storm in the NCSA visualization was not a direct recording of the storm which killed seven people in 1964. At the same time it cannot be said that there is no connection between the visualization and that storm because they were both creations of the same atmospheric conditions. The storm in the visualization only ever existed in a computer, but it represents the type of storm that could arise in the atmospheric setting of the Oklahoma skies in 1964. In the same way, water which is created through CFD and placed in a camera-recorded setting cannot be called *the* water of a specific time and place but it can be called *some* water.

This conceptual distinction complicates the rules of visualization as they are conceived by the likes of Tufte and others. Like other schemata of representation, the stochastic is based on certain assumptions, a certain way of seeing the world. But, unlike many schemata, there is an important conceptual link between representation and a conceptual understanding of reality. There is a technical/ ontological linkage. When the visualization shares in the numerical quality of the object which it represents, a certain claim to virtual truth can be made. The virtual truth of motion and shape in stochastic processes is in fact observable in one of the earliest examples of computer generated imagery in cinema.

Early Examples of Computational Stochastic Processes in Cinema

The transition between visualization in science and early computer-generated images in the cinema is more seamless than one might expect. Indeed the first use of computer generated imagery in a feature film was itself diegetically a visualization of a computer model. In *Star Trek II: The Wrath of Kahn* (Meyer 1982) Captain Kirk (William Shatner) and Spock (Leonard Nimoy) consult a computer for archival material on a "genesis device" which appears as computer-generated three-dimensional images on a video screen (Fig. 3). The entire clip is framed by the edge of a futuristic looking viewing screen. The clip they watch contains video of a scientist describing a device which brings life to lifeless planets. The clip then continues to show a very abstract computer visualization consisting of coloured lines in a black field rotating in three dimensions which appear to form a DNA-like structure. The next part of the clip shows the rendering of an explosion on the surface of a dead planet, followed by geographical features and water emerging from its surface. During this sequence the camera flies along the surface at a great speed in a fashion not unlike the *Magellan Probe Scan* visualization. The diegetic narrating scientist refers to this sequence as a "simulation." Much like the computer generated images in *Tron* (1982) which was released the same year, the digital images in *Star Trek II* refer to something diegetically real yet represented through a computer framing device. Digital images were not yet being used as a replacement for photographic images. Instead these films introduce the idea of a numerical ontological link between a computer world and reality.

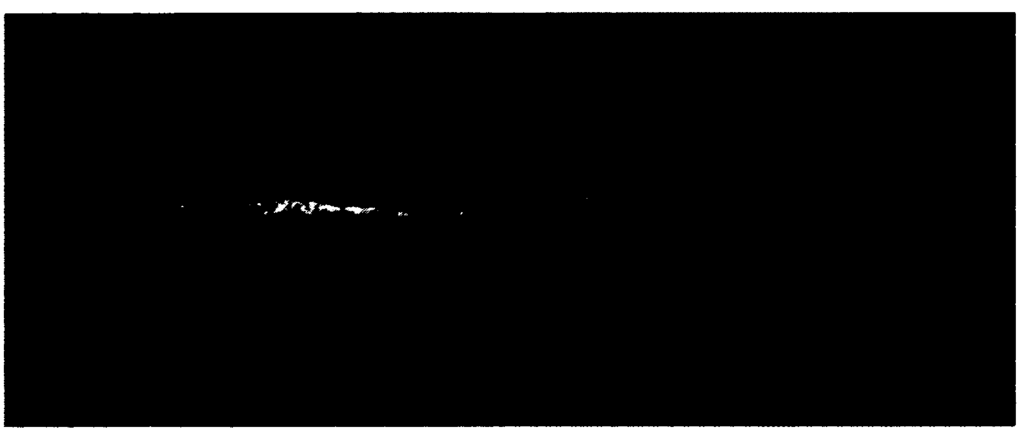

Fig 3. Still from *Star Trek II: Wrath of Kahn* (Meyer 1982). An example of fractal topography from the *Genesis Device* sequence.

The sixty-second sequence in *Star Trek II* was produced by LucasFilm's Computer Division, which would later become Pixar Animation Studio. The sequence was notable for both the explosive fire effect and the realistic geographic features on the planet. The fire effect was created using a particle system innovated by William T. Reeves. This proved to be a very influential practice for creating volumetric bodies like fire and smoke in digital animation. The particle system Reeves employed did involve a procedural element of generation but it was not stochastic in nature. The growth of the geographic features was designed by Loren Carpenter who utilized fractals to generate a topography of mountain ranges, valleys and lakes. This technique actually did involve stochastic elements.[28] Fractals are self-similar generative procedural algorithms developed by mathematician Benoit Mandelbrot in the sixties. Fractals were a popular topic in computation for a time because they were considered beautiful and had affinities with structures in nature despite the fact they were created automatically by a computer. Mandelbrot describes fractal algorithms as being "pregnant with beauty." [29]

Carpenter's dead planet geography was not based specifically on how mountains are formed, but it was consistent with the theme of creation in that the shape of the topography extended from randomness and variation. Generative algorithms like fractals are, however, able to mimic certain simple types of growth found in nature. An "L-system" is a set of rules that governs the growth of certain plants. For example, an L-system can be written that makes random decisions on where tree branches grow within certain constraints. The result of such a

[28] William T. Reeves, "Approximate and probabilistic algorithms for shading and rendering structured particle systems," *SIGGRAPH 12th Annual Conference on Computer Graphics* (July *1985).*

[29] Benoît B. Mandelbrot, *The Fractal Geometry of Nature* (W.H. Freeman, 1983), 14.

process is a tree which looks realistic due to the arbitrary yet logical distribution of branches.[30] Generative algorithms can also make use of the logic of Brownian motion, which can be used to accurately simulate the growth of certain crystals.[31] Loren Carpenter did further stochastically generative work on the computer animated short *The Adventures of André and Wally B* (Smith 1984). [32] Though the short focuses on characters made of featureless polygons, it is set in a three-dimensional world of realistic plant life. Carpenter in fact employed L-systems to build and distribute the plants in the forest in this short.[33]

Though the genesis device sequence in *Star Trek II* resembles NASA visualizations such as the *Magellan Probe Scan*, these examples conceptually borrow more heavily on the concepts of model simulations observable in the *Numerically Modeled Storm* visualization. Both Reeves and Carpenter utilizes a procedural logic that creates things automatically within the virtual computer environment. The quality that these techniques create is difficult to describe yet undeniably compelling. Carpenter's mountains in the genesis device sequence are a particularly good example. Though it is contestable how realistic they look, the quality of variation, of the shape of the peaks and the irregularity of their distribution, speaks with a legible arbitrariness. It seems visibly clear that a human mind did not conceive of such shapes and a human hand could author them. Their shape is beyond the horizon of human imagination.

These early examples of cinematic digital images are not primarily concerned with traditional schemata of realism. Carpenter's trees or mountains do not look like photographs of

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[30] Rick Parent, *Computer Animation: Algorithms and Techniques* (Morgan Kaufmann, 2007), 540.

[31] Kemp, *Seen/ Unseen*, 223.

[32] Reeves, "Approximate and probabilistic algorithms for shading and rendering structured particle systems," 314.

[33] Valliere Richard Auzenne, *The Visualization Quest: A History of Computer Animation* (Fairleigh Dickinson University Press, 1994), 84.

objects. Their appearance and shape speaks more to the numerical and generative quality of their creation than it does to their resemblance to objects in photographs. The visualization of the trees and mountains is intimately related to the data which generated them, and the generative character of this data is itself related to reality. This type of representation sees natural objects as the products of complexity, randomness, variation and emergence. These objects are not captured and represented; instead they are virtually enacted.

Twister

The issues *Numerically Modeled Severe Storm* raised can be identified in one of the most consummate spectacle-driven digital special effects films of the 1990s, *Twister.* Examples of vision, visualization, data, nature and randomness are all prominent in this film. *Twister* follows a group of scientist storm chasers who are trying to digitally document the development of a tornado. Coupled with this is a subtext involving Dr. Harding's (Helen Hunt) past experience with devastating storms which leads her to a Melvillian struggle against a demonic natural phenomenon.

Screens and recording devices abound in the film. The team is followed by a camera crew in some scenes and the scientists have camcorders themselves. Because the occurrence of a tornado is so difficult to predict, the portable video camera is the most common publicly circulated source of images of tornados. An example of this can of course be found at the beginning of the *Numerically Modeled Severe Storm* video. In both of these texts the camcorder is clearly being constructed as the visible evidence against which other forms of visualization will be compared. *Twister* also features weather reports with maps and illustrations, another type of more abstract representation which is common in the public sphere. The film features the obligatory sequence where a meteorologist is observing converging systems from some sort of weather centre at a removed location. An image of a radar screen is accompanied by a meteorologist describing the meaning of the colours and shapes, explaining how the systems are converging to cause a catastrophic storm. This is a trope which occurs in all of the feature films examined in this thesis. The weather map, the camcorder, and the digitally created storm are all different access points to the phenomenon of tornados. These are objects which can be experienced from many perspectives and can be seen in a number of ways.

The scientific team in the film is attempting to collect data from a tornado by dispersing hundreds of tiny motion-tracking transmitters into its vortex. This system seems to function in the same manner as an "active marker" motion-capture system used for cinema special effects. These are the systems in which a series of radiating points are distributed around a human figure to record an abstraction of a person's motion. When the scientists in the film finally succeed in obtaining their measurements there is an image of a computer screen processing the motion data. The screen shows a whirling collection of points in a three-dimensional environment (Fig. 4). This image is juxtaposed with the final and most obvious image of the tornado: the realistic digitally rendered image. These fully rendered photorealistic images utilise a more evolved version of the type of particle system created by William T. Reeves for *Star Trek II*. The film juxtaposes this completed and seamlessly realistic digital image of a tornado with the abstracted motion of the same tornado being recorded by the scientists. The film clearly wishes to draw an analogy between the two forms of visualization. The spectator is prompted to consider the nature of different access points to the tornado. The tornado can be seen through radar images, through the abstract tracing of its motion, through video cameras or through computer simulation. The film is attempting to negotiate the conceptual issues raised by computational science and visualization.

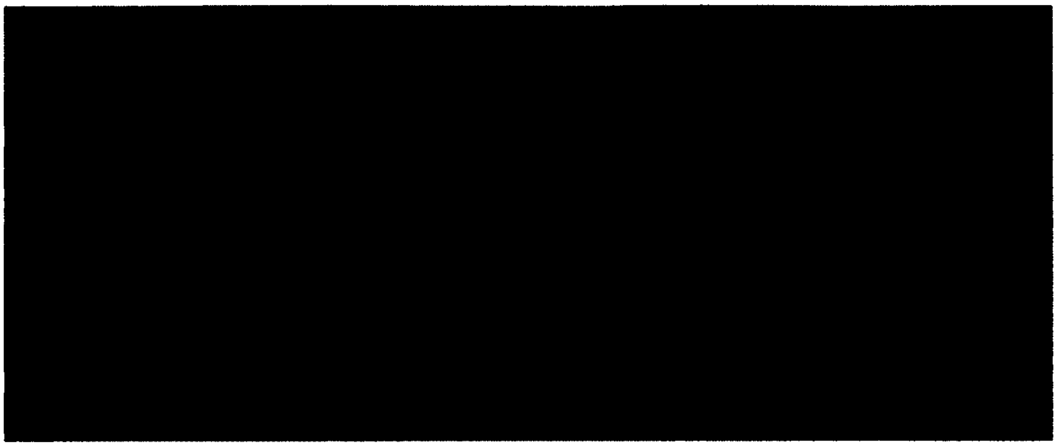

Fig. 4. Still from *Twister* (De Bont 1996). The screen displays motion points being tracked in a tornado.

As an extension of the topic of visualization, the film mediates on the nature of randomness as it relates to nature and specifically the weather. Weather is one of the classic examples of a complex system which has proven to be difficult to predict far into the future. John von Neumann, one of the architects of the Mont Carlo process and creator of the pseudo-random middle-square method, actually conducted weather simulations on the ENIAC computer.[34] Fluids, weather and many other complex systems are the types of things which require an element of the stochastic in order to be simulated.

Indeed it was a weather simulation that gave birth to the chaos theory. Mathematician Edward Lorenz was conducting a simulation to predict weather patterns and happened to run two exact simulations with extremely minor differences in input values. There should have been very little effect on the output figure but in fact it had a surprisingly substantial one. The complexity of the weather simulation had magnified the seemingly minor numeric variation in unpredictable

[34] Leo Donner and Wayne Schubert, *The Development of Atmosphere General Circulation Models: Complexity, Synthesis and Computation* (Cambridge University Press, 2010), 9.

ways. This discovery led to the theory of "strange attractors" in complex systems.[35] Interestingly this is a topic addressed by the digital-effects centered film *Jurassic Park,* which is contemporaneous with *Twister*. It is further worth noting that Stefen Fangmeier was visual effects supervisor on both of these films. Before beginning work at ILM, Fangmeier worked at the NCSA on complex systems. He in fact worked on weather simulations similar to the one portrayed in *Numerically Modeled Severe Storm.* Cleary he had a profound understanding of the conceptual challenges of working with complex systems.

Twister addresses the topics of complexity and the stochastic in its subplot involving Dr. Harding. The film begins with a depiction of Harding losing her father to a tornado. Later in the film she attempts to explain her fear and hatred of tornados saying, "You've never seen it miss this house and miss that house and come after you." Harding is asking the classic question that every individual faced with the cruel randomness of a non-anthropocentric world must ask: why? This is the question that besets Job in the Hebrew Bible as it can any victims of calamity. The unpredictable natural event, an 'act of god', is a consummate example of the unpredictable, arbitrary and meaningless nature of a non-anthropocentric world. This opaque and aporetic natural menace in contemporary disaster films is often both *composed of* and *a symbol for* randomness as a threshold of understanding or knowledge. Our scientific understanding of these elusive phenomena and our digital representation of them includes the randomness which Dr. Harding identifies. The legible lack of human authorship which could be observed in Leslie Carpenter's mountain peaks is rendered in more existential terms in the disaster film, yet both could be said to be decisively non-anthropocentric. This is a theme that will continue to emerge as this thesis continues to examine the practice of making CFD special effects.

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[35] Peter J. Westwick, "Computational Physics," in *The Oxford Guide to the History of Physics and Astronomy*, ed. John L. Heilbron (Oxford University Press, 2005), 53.

CHAPTER 2

THE BLURRED LINE BETWEEN FILM AND DIGITAL

The medium of the movies is physical reality as such.
-Erwin Panofsky, "Style and Medium in The Motion Pictures"

This chapter will contend with the current film theoretical accounts of the relationship between digital media and film theory. This will involve focusing on the fundamental changes that have been attributed to digital media and the positive, perhaps utopian, visions some theorists such as Lev Manovich, Timothy Engstrom and Evan Selinger have for the future of digital media. This vision for the future involves a sort of medium-specificity argument that advocates for digitally-based "data art" (art which visualizes information and connections) as a something that is more transparent and meaningful than film. This characterization of digital media's diversion from the path of film and the cinema is predicated on a classic dichotomy of formalism and realism. The computer, with its automatic and mathematical conceptual premise, is constructed as a medium which lends itself to abstract visualization rather than the presentation of realistic images. This image of digital media ignores the ways in which film has been used for data collection and the visualization of natural motion throughout its history. The tradition of abstractly representing natural motion in the cinema continues to the present through the use of computational fluid dynamics. This chapter will demonstrate that there is no neat conceptual dichotomy separating film from digital media. Both film and digital media utilize the aesthetic resources of natural motion in a similar fashion.

The Digital Logic of Discreet Approximation

The connection that reductive theorists like Manovich and William J Mitchell make between digital technology and numerical precision follows a rather obvious logic. When they set out to define a medium they look at *what it is made of.* In the case of digital media, *what it is made of* is data. Digital information is made of discreet values within a pre-determined range. The abacus, for example, could be considered an example of a digital medium. Digital information in a computer is reducible to binary digits which carry logic information such as "on or off" or "true or false". These bits are basically digital matter; they are the makeup of all information and processes within a conventional computer environment. The nature of the system would seem to lend itself to definite precision. There is no digitally stored information that cannot be reduced down to an exact logical definition. There is no room for ambiguity or interpretation.

In Mitchell's very influential work on photography in the digital age, *The Reconfigured Eye,* he establishes the concepts of "discreet value" and "mutability" as the definitive characteristics of digital images. Mitchell uses the raster grid as the core concept of digital imagery.[1] In order for an image to be processed into digital information it must be broken up into a grid of squares (pixels). Each pixel represents a point of information with colour and brightness values. This is how the continuous and infinite world is broken down into discreet digital bits of information. A high resolution image has many squares and a low resolution image has very few. In either case there is a threshold past which there is no more information in an image. Mitchell contrasts this with an analogue photograph, which continues to yield information as you look more closely. Though, as you look more closely at a photograph, objects become harder to recognize and shapes become less familiar.

Since a digital image is made up of discreet data, its properties are always alterable at

[1] William J. Mitchell, *The Reconfigured Eye* (MIT Press, 1994), 5.

their very core. There is no grounding physical link to reality as there is with photographic emulsion. "The stored array of integers has none of the fragility and recalcitrance of the photograph's emulsion covered surface... the essential characteristic of digital information is that it can be manipulated easily and rapidly by a computer." [2] These two overlapping concepts of discreet approximation and mutability that Mitchell focuses on in his work have proven to be very influential to most of the digital media theory that has followed since.

Mitchell's ideas are clearly evident in the later, more comprehensive work of Lev Manovich, who concerns himself with digital media in general rather than just digital photographs. Manovich's seminal and still relevant book *The Language of New Media,* establishes a conceptual framework for audio visual information that is stored and accessed digitally. He premises the concepts of numerical representation, modularity, automation, variability and transcoding all on the discreet value nature of digital information which Mitchell identified. One can do things to numbers that simply cannot be done to analog information, such as translating it into different codes or displaying it in different ways. This is what leads Manovich to conclude that as the cinema continues into a digital age "motion graphics" such as those found in magic lantern shows, the historical avant-garde and the title sequences of Saul Bass, will prove to be the true telos of cinema rather than the photographic image or "realism." [3]

Mitchell's ideas are also evident in D.N. Rodowick's comments on digital media. Mitchell focused on the "recalcitrant" nature of the physical photographic image and the way it resists alteration. Rodowick shares this view of the photographic process as physical and stable. This of course seems problematic at first, since deception has been the stock and trade of the cinema at least since the work of Georges Méliès. Rodowick gives more theoretical weight to

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[2] Ibid., 6.

[3] Manovich, *The Language of New Media*, 250.

Mitchell's ideas though. To Rodowick this stable physical link can best be understood through the "temporal continuity of transformation." [4] The process by which a photograph is formed is constitutive of the medium, therefore an image formed by a digital process cannot be said to have the same qualities as a photochemical photograph. Emulsion works only one way, while digital numbers can work in any way imaginable. Mitchell's early work on the digital image laid the groundwork for this very fundamental distinction between digital and photochemical images.

Data Art and the Future of Visualization

The conclusion that the digital image and the photographic image are fundamentally different is not necessarily a negative one. This conclusion has led many to imagine a positive use for digital images, one that perhaps even improves upon what photochemical photography can do. To Lev Manovich, Timothy Engstrom and Evan Selinger, digital media is a more appropriate way to connect to our contemporary world. Rather than seeing digital technology as something which approximates a continuous reality of infinite information, these theorists see reality as already digital. This approach assumes a societal or even an epistemological shift to have occurred with the rise of computers.

Manovich sees the contemporary individual living in a "data society" where one's relationship to the world is organized through complex global networks of information. Manovich even goes so far as to refer to this digital relationship to the world as a "data-epistemology." [5] Manovich's theory of data epistemology is based on a perceived change in the sciences caused by the development of computational techniques. Manovich establishes a

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[4] Rodowick, *The Virtual Life of Film*, 117.

[5] Lev Manovich, *The Anti-Sublime Ideal in Data Art*, 2002, http://www.meetopia.net/virus/pdf-ps_db/LManovich_data_art.pdf (accessed 12 January 2012).

historical connection between modernist art and the reductive nature of modern science as a contrast. He posits that contemporary science is no longer about reductive simplicity, instead it is now concerned with managing complexity. [6] An art which manages complexity and makes it intelligible thus suits the current conceptual horizon of science. Manovich's vision for digital art engages the issues that are relevant to the contemporary spectator much the way modernist art did for the spectator in modernity.

Manovich values the tradition of the historical avant-garde in film, particularly the work of Dziga Vertov. This is an art which explored the possibilities of what could be made intelligible in modernity. Manovich thus envisions some kind of digital media which remediates this value and articulates reality in more abstract and less deceptive ways. In his essay "The Anti-Sublime in Data Art" Manovich advocates for a new type digital art referred to as "data art." Manovich sees in data art the capability to represent and make intelligible the complexity of the spectator's experience of the contemporary world. An individual's relationship to a multi-national corporation could, for example, be mapped out graphically using digital sources of data. Data art is thus, tacitly, a remedy for the culture of late capitalism.

In keeping with his preoccupation with the historical avant-garde, Manovich constructs data art against Romantic art, specifically focusing on the concept of the sublime. While a sublime image in Romantic art renders the individual helpless before mysterious and complex powers, data art empowers the individual by rendering complexity and opacity intelligible and transparent. Transparency and opacity are key concepts for differentiating Manovich's bad object of sublime art with his vision for data art. Following the logic of Manovich's argument, the sublime can be associated with some of the more Romantic realist theories of photography and

[6] Lev Manovich, "Complexity and Abstraction," Manovich.net, www.manovich.net/DOCS/abstraction_complexity.doc (accessed 12 January 2012), 8.

film. The photograph does not reveal the data of its content, of course. Photographs are opaque in this sense. An image wrested from time carries with it its own sort of hermetic world which can never be completely intelligible. Roland Barthes' theory of punctum, for example, is diametrically opposed to Manovich's data art. For Barthes a photographic image has both punctum and studium. Some of the meaning in a photograph is stable and intelligible, while some of it is fugitive, difficult and subjective.[7] Such fugitive meaning is excluded and abandoned in data art.

Timothy Engstrom and Evan Selinger follow a very similar line of thinking as Manovich in their volume on *Rethinking Theories an Practices of Imaging*. Indeed they consider this transition toward digital imaging which Manovich sees in data art to have already taken place. Our language and ideas are what lag behind as we continue to rely on rubrics, "of the real, of proximity, of intimacy, of reference, of indexical trace, of correspondence" while our forms of representation have already moved on.[8] Due to the visual metaphors used in the work of philosophers like Lacan or Heidegger, we have developed a language which discusses deceptive images and the reality which is hidden behind them. Engstorm and Selinger believe that new digital forms of representation present the opportunity to move past this problematic approach to vision and reality. Digital imaging presents the opportunity to make images which are "exempt from the indeterminacies of nature." [9] Free from the burden of producing an image of reality as it appears, we have the capability to see the data of reality in any number of ways. An example of this would be an MRI machine (product of digital technology) as opposed to the X-Ray (fair-

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[7] Roland Barthes. *Camera Lucida: Reflections on Photography*, trans. Richard Howard (Hill and Wang, 1994), 26.

[8] Timothy Engström and Evan Selinger. *Rethinking Theories and Practices of Imaging* (Palgrave Macmillan, 2009), 27.

[9] Ibid., 36.

ground sibling of the cinematograph and phantasmagoria). Engstorm and Selinger state that, "... because digital (data) collection techniques transcend normal and embodied thresholds of sight, they also provide unprecedented opportunities for revising, manipulating and reconfiguring what wasn't there at all to being with in a naturalistically analog-sense." [10] For Engstorm and Selinger digital media is not only more accurate, precise and significant, it can also tell us more.

New examples of data art are emerging on the internet all the time. The internet is an especially easy place to create content rich visualizations because the data is already there. Live data feeds can be accessed from any number of live sources and shaped to reflect subjective connections. All that needs to be done is to have information inputted organized and visualized, a process which can be done in real time through Flash or Java based programs. One example of this is a project being conducted jointly by the BBC and the British Art and Humanities Research Council. On this website the public can access dynamic visualizations such as *Locus* which allows users to produce a "tag cloud" of news items related to a search term over a scalable length of time.[11] For example, a user can input the word "Iraq" and position a slider between 2005 and 2007 and a constellation of circles of various sizes with overlapping positions will appear. These circles represent other words which appeared with "Iraq" in the news during that period (Fig. 5). When the user moves the time slider the circles shift and change in size. The visualization is largely monochromatic. The circles are all different shades of grey, allowing them to overlap and be transparent. The circles give the impression of complexity combined with extreme precision. When a user clicks on a circle a list of news items for the selected term appears. Each circle relates to an incursion, power shift, abduction, victory or even misunderstanding. The lived experience of such events seems to be irrelevant from this

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[10] Ibid., 45.

[11] BBC Backstage, *Locus*, BBC Data Art, 2009, http://www.data-art.net/locus/ (accessed 12 January 2012).

perspective, where reality is reduced to connections and statistics.

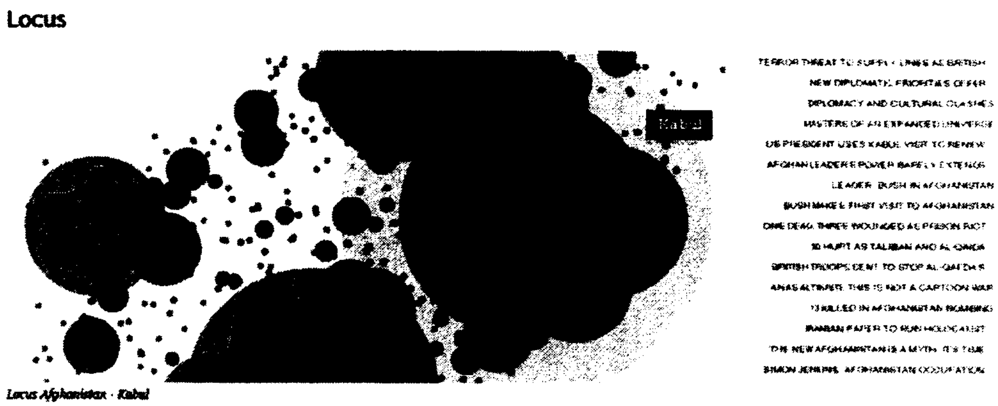

Fig. 5. *Locus* displaces a tag cloud for "Kabul" over a given period of time.

Virtuality and the Challenge of Randomness

Data art as described by Manovich assumes that digital information is precise and incapable of conveying the opaque ambiguity of analogue media. It also assumes that this numerical form of media is the best way to represent out contemporary world. These types of assumptions can be best categorised under the term "virtuality". Katherine Hayles defines virtuality as, "the cultural perception that material objects are interpenetrated by information patterns." [12] Hayles sees in virtuality a replacement of the dichotomy of presence and absence with a new dichotomy of pattern and noise. In order to establish when we are receiving significant information (a signal) a distinction must be made between information which can be processed into something meaningful and information which is meaningless. Hayles refers to this as "maximum entropy formalism."[13]

Theories of virtuality hold that digital media can speak to the spectator/ user in a relevant

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[12] Katherine N. Hayles, "The Condition of Virtuality," in *The Digital Dialectic: New Essays on New Media*, ed. Peter Lunenfeld (MIT Press, 1999), 69.

[13] Ibid., 77.

way about their experience of reality while still being at their core made up of discreet numerical information. The problem with this position, as Halyes identifies, is that it requires the medium to choose a point somewhere between signal and noise that separates meaningful information from irrelevant information. Noise is not given its fair due. Any significance that could not be defined and categorised immediately is lost.

Noise and randomness have traditionally been the bad object of digital media. Noise is constructed as error or lack. Noise is the ugly shortcoming of low bit-rate digital video. Anyone who has ever viewed a digital video which was encoded has seen what digital noise in compression looks like. There are many different codecs available now which compress digital video in a variety of ways. Some of the more common ones are mpeg 4, Divx or Xvid. To make a video smaller and more easily stored or transferred, codecs look for patterns in video and then collapse those patterns into a single piece of information. When the video is played the information is then expanded back out in accordance with the pattern that was originally established. For example, three adjacent regions of slightly different shades of black may be lumped together into a single shade to save space (Fig. 6). This is why ugly blocky shapes (artifacts) can often be observed in the dark regions of a compressed video clip.

Fig. 6. Image from *The Perfect Storm* (Peterson 2000) encoded in *Xvid* at 732kbps bitrate, magnified 500% and brightened.

Compression follows the logic of algorithmic randomness. For example, when computer scientists are attempting to determine how random a string of information is they may analyse it for Kolmogorov Complexity. Here the string is analysed to see how much computation resource is required to specify the content of the string. If the string has a very simple pattern, it can be solved into a very small piece of information. If it is very complex and has no patterns, it requires a lot more resources to specify its content. Resolution or information richness therefore equals the lack pattern. Uncompressed and unintelligible noise therefore represents a form of infinite analogue information.

This gradient from signal to noise can in fact be observed in film. If one zooms-in on a photographic image, as in Antonioni's *Blow Up* (1966), more visual information is revealed, even if that information becomes less recognizable and more mysterious. However, if one continues to zoom closer a film image is eventually reduced to unintelligible film grain: noise which can no longer be decoded into meaningful information. Analogue media such as film theoretically have an infinite capacity for storing information, for storing mysteries and things that the spectator cannot easily translate as information. Realist film theories such as those of Kracauer and Bazin tend to treat the filmic threshold of meaning as a source of ambiguity and mystery, while theories of digital media such as those of Manovich, Engstrom and Selinger seem to disavow the existence of anything beyond this threshold of intelligibility.

I would argue that a stochastically rendered digital image such as the one offered by CFD makes use of the threshold of meaning and noise. CFD uses noise and randomness in a way perhaps not unlike film. CFD creates compelling images because it uses both the order of the natural laws of physics as well as the randomness and indeterminacy of reality. Is this not the same thing photochemical film does? Film is itself a technology which is predicated on the predicable behaviour of a chemical reaction: on the behaviour of matter. When light strikes silver-halide crystals it reacts in a way which science can predict, much in the same way science can predict certain aspects of the movement of a fluid. At some point that predictability turns into grain, noise and randomness. Depending on the ISO of the film, the threshold where predictability and patter dissolves into the entropy of film grain can be quite apparent indeed.

Approaching digital images from this perspective it seems unnecessary for Engstrom, Selinger or Manovich to limit the potential of digital media to things in the world which can be expressed through numbers. Indeed the things which they define digital media as not (sublime, opaque, ambiguous, free from the indeterminacies of nature) are all features of CFD. Digital media's numerical nature can be embraced in a way which explores the mysterious things in the world which elude specific meaning. Digital media and photochemical images cannot be divided into a neat and tidy dichotomy. Indeed, pre-cinema and early cinema practices further illustrate the similarities between some digital and filmic practices.

Reality through Abstract Means in the Work of Étienne-Jules Marey

The many experiments Étienne-Jules Marey conducted in his career are extremely diverse. Those who cite his work in a narrative of the birth of film often focus only on his chronophotography.[14] Chronophotography is of course the technique where a figure is recorded in multiple exposures over time on the same photograph. Marey conducted many other experiments though. Prior to his of use chronophotography, Marey designed several instruments for measuring physiological aspects of animals in motion. His book *La Machine animale*

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[14] For examples see: Richard Abel, *Encyclopedia of Early Cinema* (Taylor & Francis, 2005), 592 ; Nancy Mowll and Charles Musser, *Moving Pictures: American Art and Early Film* 1880-1910 (Hudson Hills, 2005), 95 and Deac Rossell, *Living Pictures: The Origins of the Movies* (SUNY Press, 1998), 31.

gathered data from instruments that measured the movement of muscles for instance. In this book Marey extensively used "myograph" diagrams which graphed the measurements of muscle movement over time (Fig. 7). This is the same style of output he also used for his series of studies on the vascular system where he used his "sphygmograph." These graphs take the form of a line which runs from left to right with various undulations, the x axis being time and the y axis being the amplitude of the measured phenomenon. These graphs render physical information gathered over time abstractly.

FIG 11 – Gradual coalescence of the shocks produced by electric excitations of increasing frequency.

Fig. 7. Myograph from Marey's *La Machine Animale,1873, page 35.*

In addition to the chronographs, *La Machine Animale* had a second important source of visual information: the illustrations of Marey's apparatuses. Information he gathered is meaningless without explaining the principals of his methods of observation, and explaining his methods required an understanding of the specific mechanical workings of his devices. Marey's understanding of nature was not completely without an understanding of his technical media's ontological link to nature. His was not just a new technique for measurement; it was a new way of thinking about movement in nature. Mary Ann Doane notes that Marey frequently referred to the chronographic process as "automatic." [15] This suggests a strong affinity with the discourses that would later emerge around the film camera. Doane further notes that Francois Dagognet refers to the chronograph as a "trace" of reality, emphasising that it was a direct causal record of nature recorded in time.[16] Marey's chronograph was a technical medium with an automatic and physical connection to that which it represented, yet the chronograph was not photographic. The chronograph was an image of animal movement, but obviously animals do not have ink lines under their skin. The chronograph represents an early example of a film-like discourse (involving trace, time and the automatic) that was visually abstract.

Gathering information about movement in an abstract form continued to be the primary purpose of Marey's work as he began to use chronophotography. Even the nature of his single frame chronophotographs seems to suggest this. The frequency and overlap of the figures as they move across the page causes the viewer to see abstract shapes of motion rather than an iconic figure in movement. An image shows a curving shape rather than a leg in successive positions. The shapes which motion gives rise to were clearly a preoccupation for Marey. He conducted several geometrical experiments utilising chronophotography. His experiments involved the rhythmic mechanical movement of objects recorded over time.[17] The result was the formation of a shape made of the various positions of an object. For example a spinning string with a weight on it would produce a conical shape.[18] While these experiments obviously had the potential to reveal something about the physical properties of the object in motion, it is significant that he

[15] Doane, *The Emergence of Cinematic Time*, 48.

[16] Ibid., 48.

[17] La Cinematheque Francaise. *Chronophotographie Geometrie Experimentale*, 1889, http://www.cinematheque.fr/marey/center-font-color-8c7853/center-font-color-8c78531/1160389501.html (accessed 1 March 2012).

[18] Marta Braun, *Picturing Time: The Work of Etienne-Jules Marey (1830-1904)* (University of Chicago Press, 1995), 73.

label these tests *Géométrie Expérimentale*. The geometric shape that motion created was of primary significance to him in these experiments.

Marey's focus on rendering the abstract shape of motion can be contrasted with film which presents a realistic image combined with the realistic motion of its duration. Marey's work provides an example of the neglected idea of natural motion without a realistic image. His work is not the only example though. Abstract natural motion can actually be found in a variety of contemporary digital cinematic practices as well.

As Doan many others have noted, Marey conducted multiple experiments where he used a black suit with white lines along the limbs and white disks at the joints in chronophotographs. [19]When the camera was set up with the correct exposure the body of the figure wearing the suit became invisible and all that was left what the white skeletal shape. These lines cause an even greater abstraction of the body, reducing each limb to a data point. This technique strongly resembles the early work of James Hay and the practice of motion capture that has become a common cinematic industrial practice. Dr. Hay conducted work in the early 90s which utilized computer tracking to record human movements for biomechanical research. His work represents an important connection between the scientific practices of Marey and contemporary cinematic practices of motion capture.[20]

A typical contemporary motion capture system consists of a series of reflective or radiating points distributed on key location of a human or animal figure. The motion of these points is collected over time in three dimensions by multiple sensors. This raw data can then be inputted into a computer-generated figure which will rehearse the original figure's recorded motion. This practice has become extremely common because it is a relatively cost-effective way

[19] Doane, *The Emergence of Cinematic Time*, 54.
[20] Vince, *Visualization and Modelling*, 6.

of creating very realistic looking movement. The irony of this practice is that it would seem to be a concession to the filmic tradition of Marey. Though digital media theorists like Manovich, Engstrom and Evan Selinger see the future of cinema as diverting from recorded reality, here is a practice which can be directly connected to one of the ancestors of film.

Marey also conducted research in fluid dynamics. Marey constructed a wind-tunnel-like structure and was the first to devise a method for visualizing and recording the flow of air over time (Fig. 8). Much like with his earlier chronographs, the chronophotographs of fluids required a medium of some sort. Smoke from burning tinder was introduced at specific points into the flow of air.[21] While it could not be said that he made the air itself visible, he introduced a medium which would be caught up in its flows. Much in the same way the movement of muscle had to be mapped with ink in the chronograph, the movement of fluid had to be traced through the movement and displacement of the smoke. The photographs were thus images of a medium, in addition to being media themselves.

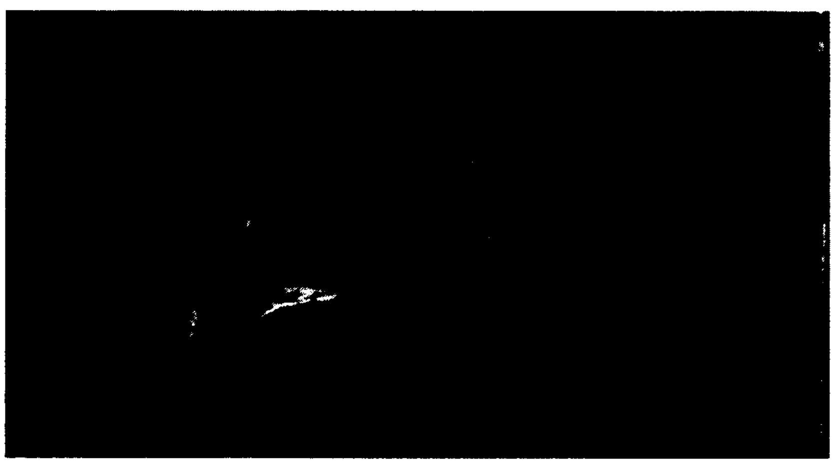

Fig. 8. One of Marey's experiments in air flow, 1901. Note how the even streams of air swirl chaotically into dissipation. © Cinémathèque Française, http://www.musee-orsay.fr/en/events/exhibitions/in-the-museedorsay/exhibitionsinthemuseedorsaymore.html?zoom=1&tx_damzoom_pi1[showUid]=100376&cHash=1686fa3a77 (accessed 1 March 2012).

[21] Braun, *Picturing Time*, 219.

Through his work with various fluids Marey was the first to produce visual evidence that air behaved essentially like any other fluid.[22] Making such a conclusion required repeated observations of phenomenon and reliable results. This was why his experiments had to be contained within a glass wind-tunnel structure. With the elimination of extraneous factors, the scientists can make reproducible experiments in order to prove their hypotheses. Once again it was the balance between the unpredictable behaviour of fluids and technical mechanical repeatability that was at the core of these experiments. Marey's smoke was itself a film-like medium, a material trace of movement exhibiting a tension between predictability and contingency.

Marey certainly must have been faced with variations within his many experiments, but he was able to identify regularity and predictability. Approaching his work from this angle changes the way we should consider his experiments. Through the flexing of a muscle, the flow of blood and the flow of fluids, Marey was attempting to establish underlying structures and homologies. When he recorded a duck in flight, a man running or the path of air over a wing, he was not attempting to capture that event in a moment. Instead, he was attempting to create an image of the average bird's flight, the average man's gait, or the principles of how these mechanisms work. His use of abstract outputs served this purpose very well. In this sense his work treats motion same way that CFD does. Both imagine each incidence of movement as a non-deterministic yet somewhat predictable manifestation of matter. The experiments of Marey, film and CFD all are invested in the tension between predicable regularity and unpredictable randomness and emergence.

Film combines the photographic image over time with natural movement and with

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[22] Ibid,. 217.

temporal displacement. Marey's work and contemporary practices like CFD illustrate that though the combination of all these elements belongs only to film, many of these elements are not the exclusive domain of film. Natural motion need not necessarily be connected to a realistic photographic image and motion over time need not be connected to temporal displacement.

Actuality and Abstract Reality

Marey's work blurs the lines of what can be considered the filmic tradition. It problematizes the assumption that film is the only technical medium capable of presenting a compelling and nuanced connection to reality and that digital media can only meaningfully connect to reality when they are employed to visualize concrete connections and discreet data. Marey's work, and by extension CFD, can be positioned somewhere between these two opposing points. Marey reveals a different source of reality through his use of natural motion. His image of natural motion is undeniably real, yet it does not offer an image that is a visual copy of reality like a photograph. Instead the chronograph or smoke trail offers a sort of data stream from nature recorded in trace. This approach to motion is not limited to Marey's experiments either. In early cinema and even the historical avant-garde there are examples of this approach to natural motion.

The correlation between movement and nature in the earliest films has become well engrained in the history of cinema. In his book *Theory of Film*: *The Redemption of Reality*, Siegfried Kracauer quotes a Parisian reporter referring to the rustling trees in the Lumière's *Repas de Bebe* (1895) as "nature caught in the act." [23]One could well question what this "act" actually is. When a criminal is "caught in the act" they are discovered while breaking the law. Nature's "act" must be the act of being itself. One can observe the breeze rustling a leafy tree

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[23] Kracauer, *Theory of Film*, 31.

and say that they are beholding nature in the act of being. An actuality like *Repas De bebe* can be linked to Marey's work both through the concepts of random natural motion and through the homologous consistency of natural phenomenon. As with Marey's experiments, an account of movement in nature is captured in itself through technology, and that anecdotal moment of movement can be said to be evidence for a sort of state of affairs of nature. The image of leaves rustling in the Lumière's yard in 1895 derives its uncanny appeal because it perfectly rehearses the way we know leaves to move.

The public discourse that accompanied the first screenings of images of nature follows this logic. Dai Vaughn describes this effect in the early screenings of actualities in an essay on documentary and the Lumières. While we are all familiar with the often told and likely embellished story of people fleeing the theatre during *Train Arriving at the Station* (Lumière 1896), Vaughn tells a different story. He uses as his example the Lumière film *Boat leaving the Harbour* (1896). At the end of the program some gentleman allegedly pocked the screen with their canes to prove to themselves that it was actually just a screen. Vaughn believes this story, and explains it by saying "The gentleman with sticks were not trying to discover how the trick worked. Their concern was not that they might have been the victims of an illusion, but that they experienced something which transcended the cosy world of illusionism altogether." [24] There is something in the unpredictable yet recognizable nature of the waves which spoke to the viewer irrefutably. Film allowed the sea to just be the sea: "a sea liberated from the laboriousness of painted highlights and the drudgeries of metaphor." [25] Vaughn gives a great deal of weight to the single-shot simplicity of early actuality footage as a synecdoche for film, not just as a self-

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[24] Vaughan, *For Documentary*, 4.

[25] Ibid., 6.

sufficient unit of reality but as an image which contains natural motion.

Vaughn's opinion on the subject strongly resembles Kracauer's in *Theory of Film.* Kracauer identifies the popular motif of smoke in the Lumière's films. Of Louis Lumière's role in recording these actualities, Kracauer writes, "And he seemed anxious to avoid personal interference with the given data. Detached records, his shots resemble the imaginary shot of the grandmother which Proust contrasts with the memory image of her." [26] Once again, there is an emphasis on nature as a sort of brute presence in the film when it is left un-assailed by aesthetics, described here by Kracauer as "data". Going on, Kracauer describes nature in the Lumière films as "life at its least controllable and most unconscious moments, a jumble of transient, forever dissolving patterns accessible only to the camera." [27] The dissolving pattern reflects once again the tension between nature's physical shape and its random variation in instances. It is also interesting to note that Kracauer mentions the concept of the unconscious.

The uncanny effect of cinema has of course been utilized in various ways. D.N. Rodowick connects this effect with surrealism. Rodowick makes a clear distinction between film and digital media on the basis that digital media lacks an "automatism" of transcription. He chooses this word, first used by Stanley Cavell, in part because of its significance to surrealism. According to Rodowick digital media which mimics reality can often be "very strange and hyperreal, but never surreal." [28] The surreal effect comes from the recontextualization of something from reality which inspires a certain reaction in the spectator. Rodowick includes under surrealism Jean Epstein's concept of *photogénie*, as something which can "suggest underlying uncanny, and unrecognized powers flowing through objects and ordinary

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[26] Kracauer, *Theory of Film,* 31.

[27] Ibid., 31.

[28] Rodowick, *The Virtual Life of Film*, 107.

experiences." [29]

It was film's uncanny real-yet-not-real effect which drove a concept like photogénie. Surely one of the most consummate examples of this effect can be found in Epstein's use of natural movement such as waves, smoke, fabric in the wind and fire in *The House of Usher* (1928) for example. Gilles Deleuze identified the use of water in particular as a source of natural motion in the pre-war French cinema.

> ... an even deeper impulse ran through French cinema: a general predilection for water, the sea or rivers (L'Herbier, Epstein, Vigo, Germillion). This was in no sense a renunciation of the mechanical: on the contrary, it was the transition from a mechanics of solids to a mechanics of fluids which, from a concrete point of view, was to find in the liquid image a new extension of the quantity of movement as a whole. It provided better conditions to pass from the concrete to the abstract, a greater possibility of communicating an irreversible duration to movements, independently of their figurative characters, a more certain power of extracting movement from the thing moved.[30]

Deleuze refers to the curious idea of a mechanics of fluids here. It is an idea that allows movement to exist separately from the thing that moves, rendering the movement itself as a self-sufficient presence in film. This is something Deleuze observes in the compositions of a director like Epstein, but it can be connected to the work of Marey and by extension to CFD as well. Marey's line graphs, his geometric shapes of motion and his fluid experiment all extracted movement from nature as a self sufficient entity. This is of course a process that could only be facilitated through an automatic and mechanical process of imaging. The automatic medium sits in a position of tension between the predictability of movement and its natural tendency to change. CFD can be described in the same way. In the broad tradition which includes film and CFD, natural motion is understood both as something which happens in a moment and as

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[29] Ibid,. 107.

[30] Gilles Deleuze, *Cinema 1: The Movement Image*, trans. Hugh Tomlinson (Continuum Publishing, 2005), 43.

something which is physical and automatic. All of these examples deal with the "pass(age) from the concrete to the abstract."

A *Perfect Storm*

One of the first films to feature CFD waves as a central element of setting demonstrates the way natural motion continues to be aesthetically important, even in a contemporary Hollywood blockbuster. *The Perfect Storm* features many of the tropes and devices that could be found in *Twister* and it takes as its centrepiece a giant, dark, menacing CFD storm. At the key turning point in the film a meteorologist is analysing data on a computer screen and witnesses the convergence of three weather systems into a single storm cell: an unprecedented occurrence. The camera shows an image of the computer screen and then beings to track in. As it tracks in the viewer is taken from the level of the screen to an aerial view of the storms. Continuing down, it passes through the clouds and eventually arrives at a fishing boat that is unwittingly traveling straight into the center of the anomaly. The spectator is taken from a scientific visualization seamlessly through to the storm itself, foregrounding the relationship between reality and abstract visualization.

The churning ocean of *The Perfect Storm* is clearly structured as the spectacle at the center of the film. Whereas most disaster films focus on destruction, this film maintains a sort of purity of natural disaster, focusing on a spectacular ocean with very little in it. The image of a boat rolling over ocean waves recalls many examples from the history of film. From the Lumière's *Boat leaving the Harbour*, to John Grierson's *Drifters* (1929) to Fred Zinnemann's *Redes* (1936), all of these films use the rolling of a boat on waves as a source of natural movement.

For many years water has presented a problem for cinema special effects. The use of scale models in conjunction with water often created problems as the natural motion can often be instantly identified by the viewer as out of scale. The CFD waves in *A Perfect Storm* have no such problem of course (Fig. 9). The uncanny appearance of natural motion is unmistakable in the movement of the waves. Given that the film consists largely of ocean shots and the inside of a fishing boat, the producers could hardly have allowed for the ocean to fail as a fascinating spectacle. If one believes that Gunning's "cinema of attractions" has resurfaced in the action film, this is certainly an example. At times is seems as though all the rest of the film simply functions to deliver more images of the churning ocean. Structuring a film as an opportunity to witness natural motion on-screen is a conceptual gesture similar to that of the actuality.

Fig. 9. Still from *The Perfect Storm* (Peterson 2000).

The Perfect Storm's central theme is evident in its title. It follows a fishing crew caught in a storm known as the "Halloween Nor'easter" of 1991. The fishing crew does little wrong to deserve this fate but they are helpless in the face of a cascade of unlikely things going wrong. Above all, the fishing boat is in the wrong place at the wrong time. An improbable set of circumstances puts the fishing crew in the middle of a highly improbable weather event. A "perfect storm" has become a by-word for an unlikely set of circumstances which coincide to aggravate a situation. It has taken on even more specific meaning in the last few years, as it was used frequently in press stories regarding to the global financial crisis.[31] Weather and financial markets are both classic examples of complex systems which continue to outstrip our ability to understand them. The use of the phrase perfect storm seems to conflate nature with any complex system which is beyond human control. Like a sublime work of art, it puts the spectator in a position of frailty before something greater than themselves which cannot be understood or controlled. This is the sort of thing digital media should not be capable of representing according to the media theorists like Manovich, Engstrom and Selinger. Film should be far better suited to this task. Stochastic equations pay their due to unpredictability though. Rather than attempting to be able to calculate everything, stochastic equations set a threshold past which the unknown resides. The methods of CFD are perfectly suited to portraying such a mysterious anomaly.

Clearly the cinema seems to be able to imagine a use for digital technology which goes beyond the capabilities of discreet numerical values. Through the use of natural motion, CFD taps into an aesthetic resource which has been present throughout the history of film. This type of content is opaque and mysterious in a way that is generally not attributed to digital images. The storm confronts the spectator with surface, with events and questions rather than reasons and answers. Beyond the threshold of our understanding of systems and of nature lies what we can only call randomness.

[31] For one of many examples see: Manav Tanneeru, *"How a 'perfect storm' led to the economic crisis,"* *CNN*, 29 January 2009, http://articles.cnn.com/2009-01-29/us/economic.crisis.explainer_1_housing-bubble-housing-market-wall-street?_s=PM:US (accessed 12 January 2012).

CHAPTER 3

CFD, TIME AND THE PROCESS OF THE VIRTUAL BECOMING ACTUAL

Is not the existence of time the proof of indeterminism in nature?

-Henri Bergson, *The Possible and the Real*

In chapter 2, computational fluid dynamics was discussed in connection with film's automatic relationship with natural motion. I argued that in these terms film and CFD could be imagined as part of the same tradition. This is not the case when CFD and film are compared in terms of their articulation of time however. Though they can both be understood as an organization of time, some important distinctions can also be made between CFD and film. The photograph has a relationship to time in that it takes an image and preserves it, keeping it the same as time moves forward past the moment it was taken. Film's relationship is a little more complicated, as it captures a duration of time and preserves it. This combination of duration and capture has shaped much of film theory, perhaps the most consummate example being the work of Bazin. Indeed temporality seems to be a particularly important subject in contemporary film theory. This is likely because temporality has been used to differentiate between film and digital media in current film theory.

This chapter will illustrate that time is one point where CFD diverges from a filmic tradition. Rather than capturing something from the past, CFD presents an actuality in the present which is based on past or future conditions. By way of illustration this chapter will look at yet another weather disaster film, Roland Emmerich's *The Day After Tomorrow* (2004). This film endeavours to render the immediate reality of a state of climate change (discovered through climate science) by depicting our current world suffering environmental disaster. The name of the film itself indicates the placement of the world of the text in a present future. This relationship to time is the result of the film's attempt to address the remote and conceptually difficult concept of climate change. Though it is in most ways quite a conventional film, *The Day After Tomorrow* articulates a curious approach to time and emergence and demonstrates the way these contemporary issues can be negotiated through the use of CFD effects. CFD can articulate an expanded yet meaningful concept of time which better suits some of the conceptual issues raised by science and computation.

Filmic Time in Modernity

In order to discuss CFD's relationship to time, it is necessary to first address discourses of film time and the changes that digital technology is thought to bring about. In her work *The Emergence of Cinematic Time*, Mary Ann Doane positions film and cinema as separate concepts in relation to time and contingency. Film, as a physical medium and a technology, has a certain relationship to temporality, while cinema as a practice and a set of conventions inflects film's time and creates something different. Doane's work addresses examples in history when film's articulation of time is not defined by cinematic conventions. She provides examples such as actualities, trick films and the work of Étienne-Jules Marey. Doane's approach to time and contingency in these examples was addressed through the topic of movement in chapter 2 of this thesis. Doane proceeds to take this image of film time as unpredictable and entropic and discusses the way cinema tames it into something more simple, comprehensible and meaningful.

Doane positions both film and cinema in the context of modernity. She specifically addresses a conceptual turn in modern science related to the discovery of entropy and the development of laws of thermodynamics. Entropy is an often misused word in common speech, so it is worth taking a moment to explain. In a hot cup of coffee the particles are in an excited state. They are not hot enough to break apart, thus boiling the coffee into vapour, but they are more excited than the ambient particles in the air around them. Entropy dictates that all energy diffuses over time. So, if the cup is left alone, the particles in the coffee will transfer their energy to the ambient air until the coffee particles are at the same level of excitedness as the air. Energy will always diffuse itself into a homeostatic state. Doane links entropy to the idea that a system will inevitably dissolve into chaos over time. She notes that before thermodynamics physics had never before been linked to duration.[1] Unlike the rotation of the earth which is apparently constant and unchanging, entropy demonstrated for the first time that time was actually moving forward irreversibly.[2] This was, of course, until modern atomic science came about and revealed that on some levels time appears to be constant and reversible.

Doane connects the modern science of thermodynamics to the rise of probability as a concept which shaped the sciences.[3] Statistics in physics and the social sciences presented a way of containing contingency so that the maxims of science might still be useful.[4] Probability, she notes, was also a way of dealing with the realities of modernity such as mass populations. The concept of a million individuals living together in a modern metropolis traveling to work and enjoying their leisure time seems somehow unfathomable if one considers a million different individual agents with unpredictable behaviour. But, if people tend to behave in a given way things can be simplified into probability. The mass becomes manageable.[5] Her overarching

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[1] Doane, *The Emergence of Cinematic Time*, 117.

[2] Ibid., 136.

[3] Ibid., 125.

[4] Ibid., 135.

[5] Ibid., 129.

theme is of contingency as a threat revealed by science and the structures of modernity as a response to that threat.

Chaos can be seen as a source of anxiety in many films. Siegfried Kracauer identified a fear of chaos manifested as the dichotomy of anarchy and totalitarian rule in Weimar cinema.[6] Though Kracauer discusses chaos in terms of narrative here, his statement can be connected to larger themes. Elsewhere in his work *From Caligari to Hitler* Kracauer describes the German tendency to stage things in the studio rather than in the open air. He claims that while a Swedish production would go to great lengths to capture a real snowstorm, a German production could not permit such contingency. Instead they would have to produce the storm in a studio, controlling its every aspect. This willingness to control, this fear of encounter or contingency, coincides with the fear he describes of chaos. The film studio thus becomes the tyrant, controlling things for the good of the people.[7]

Though it is tempting to see this in Doane's work, modernity's crusade against chaos had a more specific cause than a fear of what might be called the collective unconscious. Chaos and contingency are threats to the making of meaning. In the case of science, universal principals and the use of experimentation for proof are meaningless in a world of total possibility. This is also the case with symbolic making of meaning. In reference to the work of Claude Levi Strauss Doane writes, "Unalloyed contingency is constituted as a danger, as the site of semiotic failure. Structuralism as a movement, in order to produce knowledge, evicts the event from the epistemological domain; it disdains the contingent." [8] Meaningful and systematic symbolic

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[6] Siegfried Kracauer, *From Caligari to Hitler: A Psychological History of German Film* (Princeton University Press, 2004), 82.

[7] Ibid., 74.

[8] Doane, *The Emergence of Cinematic Time* (Harvard University Press, 2002), 165.

meaning in language required stability.

The cinema, as a place where narrative technique is employed and meaning is created thus also must deal with contingency. The raw material of a Lumière-style actuality represents contingency, while a formal system which imposes order, like the classical Hollywood system, represents order. Cinema transformed film into a "representational system while maintaining both its threat and allure." [9] While the contingent can be utilised for its attractive qualities, it must never be allowed to escape and, "fall outside the domain of structure." [10]

Philip Rosen offers a very similar picture of the cinema as a discursive site in his book *Change Mummified*, yet he sees the process of "taming" time happening on an even deeper conceptual level. Much like Doane he notes that, "technically produced, mass distributed images are heavily invested in the representation and management of temporality." [11] Temporal displacement is thus the stabilisation of the complexity of unruly time. Rather than looking at film as un-tamed contingency the way Doane does, Rosen sees film taming and ordering our concept of time. The direct and absolute empirical nature of an idea like the index lends a sort of certainty to what is a very abstract idea. Concepts like the index give "reassurances" in the face of the "instabilities focused through the consciousness of the continual recession of presentness into pastness." [12] Our disposition in the present, comprehending ourselves as separated from a concrete past, is thus delineated through our construction of the medium of film.

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[9] Ibid., 138.

[10] Ibid., 171.

[11] Rosen, *Change Mummified*, 352.

[12] Ibid., 352.

Process Philosophy, Science and Time

The index is of course one of three semiotic categories identified by C.S. Peirce. Peirce's philosophy can be more specifically connected to the issues of time in modernity which Doane and Rosen describe. Peirce saw the world as profoundly contingent and unpredictable, Meaning was relative in the world which he saw in constant change. This is a profound contrast to Doane's quote from Levi-Strauss. Peirce's semiotics is a pragmatic understanding of meaning in a world of indeterminacy.[13] Peirce can be considered in the company of philosophers such as Henri Bergson and Alfred North Whitehead under the general category of process philosophy. According to American philosopher Nicholas Rescher, process philosophy holds that, "material objects are ultimately comprised of energy that is in an ongoing state of flux and motion." [14] Process philosophy assumes the metaphysical existence of things but holds that they cannot be completely defined due to the nature of constant change in duration. Each of these philosophers had a different concept which can be associated with this view: for Whitehead "process," for Peirce "tychism" and for Bergson "duration".

Peirce's tychism is a response to empirical determinism. Rather than seeing order and exact causality driven by simple laws, Peirce saw constant exceptions and unlikely discoveries in the world. These exceptions were ignored by determinist science because they do not fit existing theories. Peirce describes the position of determinism as assuming that, "...given the state of the universe in the original nebula, and given the laws of mechanics, a sufficiently powerful mind could deduce from these data the precise form of every curlicue of every letter I am now

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[13] Nicholas Rescher, *Process Metaphysics: An Introduction* (SUNY Press, 1996), 14.

[14] Ibid., 27 .

writing." [15] Contrary to this notion, Peirce holds that there is much which cannot be accounted for or explained in the world. As an illustration Peirce talks about the throw of dice. The determinist must hold that the results of any given dice throw can be predicted through the mechanical knowledge of the dice. This is absurd to Peirce, who writes, "the chance lays in the diversity of throws; and this diversity cannot be due to laws which are immutable." [16]

Peirce's philosophy does not reject the practice of science of course, it simply stresses respect for the limits of knowledge. Much like his contemporaries in the late nineteenth and early twentieth century, Peirce was influenced by emerging scientific discoveries such as entropy and the second law of thermodynamics.[17]

Like Peirce, Henri Bergson was influenced by the sciences and saw the need for concepts that resided outside of the reach of determinism. This was particularly the case in regards to time. Bergson's concept of time as duration, as a state of change, could not be quantified by deterministic science. Rodowick describes the Bergsonian elements of duration that science could not accommodate as, "unpredictable change, the unforeseen appearance of the new, the interactivity of observer and nature, or change as heterogeneous continuum..."[18] Bergson believed that there are things which are "objective", but are also other more elusive things which are "subjective." The objective can be numerically divided or reduced to numbers without being changed but the same could not be said for subjective.[19] According to Gilles Deleuze, Bergson

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[15] Charles Sanders Peirce, "The Doctrine of Necessity Examined," *The Monist*, 1892, http://danmahony.com/peirce1892a.htm (accessed 1 March 2012).

[16] Ibid.

[17] Andrew Reynolds, *Peirce's Scientific Metaphysics: The Philosophy of Chance, Law, and Evolution* (Vanderbilt University Press, 2002), 42.

[18] David Norman Rodowick, *Gilles Deleuze's Time Machine* (Duke University Press, 1997), 20.

[19] Gilles Deleuze, *Bergsonism,* Trans. Hugh Tomlinson (Zone Books, 1988), 41.

makes a distinction along these lines between the actual and the virtual. The objective is "exterior", "quantitative", "numerical" and "actual" while the subjective is "interior", "qualitative", "continuous" and "virtual." [20] The interior subjective represents a location of pure duration where time is not coordinated to space and thus takes on the virtual and theoretical form of change.[21] This virtual state of duration is metaphysically extant yet it can never be determined because it is in a constant state of becoming.

English mathematician Alfred North Whitehead's philosophy bears a strong resemblance to Bergson and Peirce in many ways. He was also strongly influenced by discovery in the sciences. As Steven Shaviro notes,

> ...Whitehead always seeks – as does Deleuze, after him – to conciliate his arguments with the findings of experimental science. Too many twentieth century philosophers reject science and technology as abusive enframing (Heidegger), or as exercises in "instrumental reasoning" (Horkheimer and Adorno). Whitehead, however, is positively stimulated by the science of his day: the theory of relativity, and to a lesser extent quantum mechanics.[22]

Rather than being a rejection of science, Whitehead's process philosophy, Peirce's tychism and Bergson's duration all emphasise the things which can be meaningful in the actual material world if science does not take a deterministic approach to it.

Whitehead's concept of process defines existence through change as opposed to stability. In a very similar way to Bergson, Whitehead identifies two levels of existence in his central work *Process and Reality*: one the level of the real and the other the actual. The actual is made up of imminent objects of materiality, while the real is more remote and indeterminate.

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[20] Ibid., 38.

[21] Ibid., 37.

[22] Steven Shaviro, "Deleuze's Encounter With Whitehead," http://www.shaviro.com/Othertexts/DeleuzeWhitehead.pdf (1 March 2012), 6.

Whitehead criticises those who imagine a stable order in the real which dictates the shape of the actual. He states that imagining the actual as "settled" and "already become", "... limits its potentiality for creativeness beyond itself." [23] Whitehead even uses the English word for Bergson's "devenir" or "becoming" here. Like Bergson, Whitehead's process of moving from the real to the actual is a process of becoming:

> The macroscopic process is the transition from attained actuality to actuality in attainment; while the microscopic process is the conversion of conditions which are merely real into determinate actuality. The former process effects the transition from the 'actual' to the 'merely real'; and the latter process effects the growth from the real to the actual. The former process is efficient; the latter process is teleological. The future is merely real, without being actual; whereas the past is a nexus of actualities.... the present is the immediacy of teleological process whereby reality becomes actual.[24]

Keeping close to Bergson, Whitehead also associated numeric divisibility with two levels of existence. Like the objective and subjective of Bergson's philosophy which are associated with the actual and the virtual, Whitehead describes an "extensive" and "intensive" where the former is dependent on scale and the latter is the invariant of scale.[25]

Neither Peirce nor Whitehead nor Bergson see the concept of process and unpredictable emergence as something which precludes our ability to discuss reality in meaningful ways. Rather they highlight the danger of assuming order beyond the threshold of the material. The challenge thus becomes how to discuss things meaningfully in materiality.

As Doane's quotation of Levi-Strauss illustrated, meaning was constructed against chaos and indeterminacy. Discoveries in science like thermodynamics thus created potential threats to the making of meaning. The very orderly and causal structure of cinema was one way of making

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[23] Alfred North Whitehead, *Process and Reality: An Essay in Cosmology* (Simon and Schuster, 1979), 101.

[24] Ibid., 326.

[25] Ibid., 95.

sense of things in a reality which was increasingly being thought of as fundamentally indeterminate. Rosen's insistence on film as a constructed concept which imposes order and meaning to time is all the more applicable in this context. The very material nature of the index, for example, and of course the fact that it originated in the work of Peirce, makes it all the more appropriate here. The examples which Peirce uses to describe the index are conspicuously material.[26] The weathercock, which points to the direction of the wind, is the visible manifestation of the materiality of air currents. The footprint in the sand which points to the person that walked there is especially material. The soft ground must be displaced by the foot, its loose molecular structure re-arranged by the force of the step. The index is the perfect example of actual material meaning in a world of virtual indeterminacy.

If these concepts originated in the context of nineteenth century science, why then do they endure in the digital age? Both Rosen and Doane seem to see the practices which temporally organized the world through cinema as continuing even as technology changes. Rosen sees digital technology as continuing with the historicising tendencies of film. Rosen sees the form of digital images as generally appropriating filmic form, noting "it is common for the digital image to retain compositional forms associated with indexicality." [27] Thus the cultural practice of making meaning in the face of indeterminacy continues.

Similarly Doane seems to see cinematic concepts at work in digital video. She addresses a television station's video coverage of the demolition of the Oklahoma City government building which was damaged severely by a domestic terrorist bombing. She emphasises that even though it is shot on video the discursive value of the footage emphasises "thereness." The

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[26] Peter Wollen, *Signs and Meaning in the Cinema* (Indiana University Press, 1972), 122.

[27] Rosen, *Change Mummified*, 314.

capture of the event of the destruction of the building is indexical in the sense that "indexicality is inevitably linked with the singular, the unique, with the imprint of time and all its differentiating force." [28] The destruction of a building is a beautiful manifestation of the indeterminacy which film is capable of accessing. The collapse and the unpredictably complex dust cloud which ensues recalls the Lumière film *Destruction of a Wall* (1896) where workers knock down an old brick wall. Clearly digital video is adhering to the cinematic taming of chance.

Though the way we construct time in the cinema seems to have mostly stabilized according to Doane and Rosen, our scientific understanding of the complexity of existence has certainly deepened in the past century. The exploration of stochastic visualization in chapter one of this thesis itself addresses this issue; computation has presented some curious conceptual challenges to order and meaning. The hypothetical mind which Peirce describes that could comprehend the birth of the universe is now much easier to imagine as computation increases in power exponentially over time. Of course a computer could never calculate all of existence. In this way Peirce's words are quite prophetic. The computer model which calculates the birth of the universe must accept things which are incalculably complex or indeterminate. This is the conceptual gesture of the stochastic, of the computational dice throw. CFD is an example of the ontological engagement of this approach to calculation. CFD engages what meaning can be found in the current scientific conceptual climate.

When we are confronted with the use of CFD in a film, it is therefore a very difficult to account for what we are seeing and what relationship it has to reality and time. It is necessary to develop a conceptual vocabulary to assess the ontology of the things we are confronted with. The

[28] Doane, *The Emergence of Cinematic Time*, 208.

analysis of *The Perfect Storm* in chapter 2 presents an example of this. The film portrays a storm that happened in history, in a specific time and place, yet the storm which we see is not the same. The CFD used to make the storm grounds the materiality of the behaviour of the storm in reality, both in terms of the scientific understanding of material behaviour and in terms of a stochastic capacity for indeterminacy. The relationship between the film storm and the historical storm is clearly not temporally indexical, yet it is material. What is the ontological meaning of such a form of representation?

CFD and a Broadened Concept of Time

CFD illustrates the need for more expanded conception of time which can account for virtual existence in computation. We need to be able to evaluate what meaning exists in computer simulations which involve scientific determinacy as well as stochastic indeterminacy. Much like the cinema in modernity, we need something that helps us find meaning in our world. At the center of this is an ontological question: what is the relationship between reality and the visualization of a computer simulation? The issues presented by process philosophy are still quite useful and applicable here. The movement from the virtual to the actual and the temporal process that this entails is perfectly suited to CFD. An application of the theories of Gilles Deleuze and Andrew Pickering (who, like Deleuze, draws on process philosophy) to CFD demonstrates this quite clearly and specifically.

Gilles Deleuze is easily the most influential philosopher to have used process philosophy in the context of film theory. Following Bergson, Deleuze sees "a world of matter in constant flux, with no anchorage or assignable points of reference." [29] Central to this is the process of

[29] Paul Patton, "Deleuze-Bergson: an Ontology of the Virtual," *Deleuze: A Critical Reader* (Wiley-Blackwell, 1996), 4.

becoming. Becoming describes the process whereby the virtual becomes the actual. The actual is what we experience in the world and the virtual is somewhere in-between the real and the possible, the "modality of the differentiation at the heart of ideas." [30] Along with the concept of becoming goes the concept of multiplicity. Any incidence of the actual or material can only be understood as one incidence of the process of becoming. Deleuze describes this as the "virtual coexistence of all the degrees of a single identical time." [31] The ideas of succession or causality are therefore abandoned. The beginning of something may not be the result of its past because its past was itself merely a multiplicity of different possibilities. Clearly Deleuze's approach to time is not the ordered, sequential and causal construction of time which many technological forms in modernity, such as classical Hollywood, has given us.

Deleuze refers to the process of becoming as a "dice throw" where the cosmos emerge from "the chaosmos." [32] Deleuze describe a world "of the whole sky open space and of throwing as the only rule." [33] It is interesting to note that Deleuze invokes the same language of chance and dice outcomes as Peirce does in describing tychism, a word which is based on the Greek for chance. His use of words here provides an opportunity to draw some connections between CFD and the concept of process and becoming. The "dice throw" could, of course, not be a better metaphor. The architects of the first computational stochastic process dubbed it the "Monte Carlo process" for exactly the same reason. Games of chance evoke profound arbitrariness and a lack of order. The process of creating materiality within a computer environment utilising randomness could itself be described as a process of becoming. The algorithms of a CFD process

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[30] Gilles, Deleuze. *Difference and Repetition*. Trans. Paul Patton (Continuum International Publishing, 2004), 350.

[31] Deleuze, *Bergsonism*, 85.

[32] Deleuze, *Difference and Repetition*, 249.

[33] Ibid., 248.

are by definition non-deterministic; within a stochastic algorithm any number of possibilities for actuality reside. When an instance of movement is calculated in a computer, it could manifest itself in a multiplicity of ways and it will proceed to behave in an unpredictable manner.

The ideas of process philosophy and the approaches of Doane and Rosen all position cinema as a sort of enframement of time. Bergson in fact condemned the cinema for the way that it falsely structures time.[34] Conversely, in his two books on the cinema, Deleuze chose to view cinema as something which could expand our understanding of time. He utilized the cinema, in the words of Jan Harris, "not to produce a philosophy of cinema, but to make of cinema an occasion for philosophy." [35] John Rajchman sees Deleuze's concept of the "time-image" as an articulation of "time no longer defined by succession, space no longer defined by simultaneity and permanence no longer based in eternity." [36] There are certain films, different than the ones Bergson, Doane or Rosen have in mind, which provide opportunities for thinking about the nature of time. In the time-image film is free from causality and teleology. Instead, the films focus on characters, space and action.[37]

Deleuze contrasts the time-image with the movement-image in *Cinema 2*. The movement-image represents the construction of time and space through what Deleuze refers to as "aberrant movement" which still drives the "sensory motor schema" of the spectator.[38] A classic example of this is the dialectical effect of Eisenstein's constructivist films. Whereas Eisenstein

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[34] Jan Harris, "Cinema and its Doubles," *Technology in Motion Pictures,* eds. Bruce Bennett, Marc Furstenau and Adrian Mackenzie (Palgrave Macmillan, 2008), 96.

[35] Ibid.

[36] John Rajchman, "Deleuze's Time, or How the Cinematic Changes Our Idea of Art," in *Afterimages of Gilles Deleuze's Film Philosophy* , ed. David Norman Rodowick (University of Minnesota Press, 2010), 285.

[37] Ibid., 286.

[38] Gilles Deleuze, *Cinema 2: The Time Image*, Trans. Hugh Tomlinson (Continuum Publishing, 2005), 35.

constructed a sort of mechanical automated construction of time and space in films like *Oktober* (1927) or *Battleship Potemkin* (1925), the time-image is by contrast disoriented and uncertain, "the image no longer has space and movement as its primary characteristics but topology and time." [39] Time is visible only as duration, as the change and deformation of things, "not space but force, the force of time as change," as Rodowick describes it.[40] An example Deleuze provides of this is the Alain Resnais' *Last Year at Marienbad* (1961), where the characters seem to experience different instances of time within the same text. The time-image is a result of the breakdown of the "sensory motor schema" which drove the movement-image, a breakdown "between man and his world." [41]

The key concept which underlies the time-image is the bifurcation of reality into the immediate actual material and the remote and elusive virtual. The actual or material is merely the immediate manifestation of something which is elusively in a constant state of change. Rodowick describes the deepest sense of the virtual as "the potentiality of the actual." [42] Deleuze describes the image of the actual as "visible and limpid" while the virtual is "...referred elsewhere, invisible, opaque and shadowy." [43] The time-image alludes to a pure state of duration where movement (or change over time) is divorced from space.

Though it is described by Deleuze in the context of an ontology, the time-image is in essence achieved through the implementation of an aesthetic system. Deleuze did not think

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[39] Ibid., 159.

[40] David Norman Rodowick, *Reading the Figural, or, Philosophy after the New Media* (Duke University Press), 199.

[41] Deleuze, *Cinema 2:The Time Image*, 173.

[42] Rodowick, *Reading the Figural, or, Philosophy after the New Media*, 228.

[43] Deleuze, *Cinema 2: The Time Image*, 70.

cinema could literally could make the virtual visible, this would be impossible. The time-image merely refigures cinematic codes in such a way that the cinema can allude to the existence of the virtual. I would not suggest that CFD or any computational physics processes employed in the cinema adheres exactly to what Deleuze sees in the work of Resnais and others. I would like to suggest though, that a broadened and nuanced articulation of time through materiality like the one the time-image offers is appropriate for an analysis of CFD. Like the time-image, CFD offers an opportunity to think about time through seeing a process of time. When CFD presents a simulation of a storm, it, like the time-image, does not make the claim that it is the same as that which it represents; instead they are both treated as material instances which allude to something more elusive.

A CFD storm like the one found in *The Perfect Storm* has a similar ontology as scientific simulations like the NCSA visualisation *Study of Numerically Modeled Severe Storm* which was addressed in chapter 2. If we take a photo of the storm which killed 7 people in Oklahoma in 1964, we can say that this is an image *of* that storm preserved from the past. When we look at an image of the numerical simulation of that same storm system we do not say that this is an image of the storm that killed 7 people in Oklahoma in 1964. Yet it is not entirely separate from it either. We could not simply say that this image is *of* the recorded conditions of the storm, because there it is an actual material representation before us. The simulated storm and the 1964 storm are both material incidences of the process of the virtual becoming actual. The concept of an actuality with multiple virtual existence is therefore necessary to discuss what we are seeing. The stochastic nature of the simulation points to a multitude of actual possibilities.

Materiality and Emergence

The material is a central concept for philosopher of science Andrew Pickering. Pickering, like Deleuze, is indebted to the ideas of process philosophy. His work provides an example of how materiality and technology interact with human elements in science. His work keenly illustrates how CFD can be a useful conceptual tool for addressing materiality.

After a career examining the sociology of science, Andrew Pickering turned against his discipline to focus on a contrary approach. Rather than examining the way reality was enframed by the human element of science, he began to advocate for the material world's role in scientific discovery. In his book *The Mangle of Practice* he argues for a conception of science which consists of both human agency and material agency. His "mangle" refers to the reciprocal interaction between these two types of agency. Pickering describes the sciences as "a realm of instruments, devices, machines, and substances that act, perform, and do things in the material world." [44] A sociological critic of science might focus on how we build a flawed model, seek proof for it and then inflect our discovery to suit our concepts. As Picking puts it, "we construct goals that refer to presently nonexistent future states and then seek to bring them about." [45] Sometimes things emerge that require us to reshape our concepts though. Pickering sees the scientist as using technology to "tune" their devices like a radio, to attenuate their work in response to things which emerge. His approach is thus strongly related to the anti-deterministic project of process philosophy.

Process philosophy advocates for the primacy of materiality over laws and maxims. Key to Pickering's theory is the idea of "emergence," or as we might call it in process terms,

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[44] Andrew Pickering, "The Mangle of Practice: Agency and Emergence in the Sociology of Science," *American Journal of Sociology* 99, no. 3 (1993), 563.

[45] Ibid., 566.

"becoming". Pickering is arguing against the practice of assuming the shape of things before they emerge; his mangle entails the fact that we can only discuss materiality in terms of our interaction with it. As new characteristics or behaviours emerge about something, our understanding of it changes. The constant process of emergence and discovery means our understanding of things is in a constant state of becoming. This concept of material agency is an interesting one to apply to CFD and film because the moments of natural motion that these media can produce can be thought of as incidence of material behaving of its own accord, expressing its own agency. A wave on film or in CFD, for example, simply moves and changes shape as it wishes. Pickering's ideas are also important because they involve technical media as a kind of materiality themselves. His approach helps to elucidate how CFD, the product of a numerical and electronic device, can articulate materiality through the act of emergence.

Pickering attempts to illustrate the mangle at work by discussing abstract art. He contrasts Piet Mondrian with Willem de Kooning, whose differences are, quite obviously, many. Pickering argues that while Mondrian would have a systemic plan for his work, De Kooning would allow his work to unfold during the process of painting. Pickering's description of De Kooning's process illustrates the mangle of practice. Both artists make abstract images, but Pickering applauds de Kooning because his "smeary canvasses speak powerfully of dense, embodied, material engagement with the world." [46] De Kooning works with the paint itself to discover the things that can arise from it, an example of what Pickering refers to as "a joint project of human and non-human." [47] Betraying his indebtedness to Deleuze and process philosophy, Pickering

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[46] Andrew Pickering, "New Ontologies," 2006, http://lifeboat.com/papers2/andrew.pickering.pdf (accessed 1 March 2012. 2).

[47] Ibid., 2.

refers to this process as an "ontology of becoming." [48]

Pickering's example can be extended out to include other American "action painters" like de Kooning to apply his ideas to CFD. Harold Rosenberg, who coined the term action painting, described the movement as steeped in a sort spiritual mysticism. In his book *The Tradition of the New,* Rosenberg claims that action painters do not care about theory; they seek something more vague and elusive with their work. He derisively offers some characteristic quotes from action painters: "My painting is not art, it's an is" or "It doesn't reproduce nature; it is nature." [49] Though he does not give a great deal of credence to these statements, they demonstrate something that can be connected back to Pickering's discussion of materiality.

The splatter work of action painter Jackson Pollock is another example of emergent materiality. Unlike de Kooning, Pollock's splatter work does not involve manipulating the paint once it has come in contact which the canvas. His painting *One: Number 31* (1950), for example, features overlapping splatters of paints that were pulled by gravity, centrifugal force and momentum from Pollock's arm to the canvas where they impacted and "splattered." Pollock's work shares a connection to the liquid impact experiments of Arthur Worthington discussed in chapter 1. Both concern the shape of liquid in motion. Worthington's work attempted to take a moment of the splatter in time, whereas Pollock recorded the duration of the splatter on the canvas.

Pollock's arm is the source of action and the source of momentum which creates the arc of the splatters. Indeed it might be said that paths of the successive splatters are themselves a Marey-like trace of the shape of human movement. The character of the splatter itself is the

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[48] Ibid., 3.

[49] Harold Rosenberg, *The Tradition of the New* (Da Capo Press, 1994), 32.

result of the viscous properties of the paint and the complex interacting tidal forces within it. Rather than shaping the paint as a collaborative work between human and material, the way Pickering describes De Kooning, the fluid of Pollock's paint contains within it the sum of forces of both materiality and human art in one. In some ways the paint acts predictably but it is also profoundly unpredictable because of the complexity of the system. This co-presence of complex un-traceable force, natural unities and human intervention is an ideal analogy for CFD. One could imagine a CFD model for Pollock's paint as it travels through the air towards the canvas. The equation would have to calculate for the momentum, for gravity, for the viscosity of the paint. It would be a collection of forces combined with the regularity of the material composition of the paint, yet it would be profoundly non-deterministic. It would be exactly like any other CFD calculation: a complex set of forces in a fluid which could only be calculated with a stochastic appreciation for chance and emergence.

Here the quotes which Rosenberg dismissed take on a more important meaning. The painting "is" in the sense that it has painted itself. The expression of the shapes of the splatters is a result of the physical makeup of the paint. In this sense too this work can be called a work of "nature." The materiality of the paint, the linkages of its particles and the way it behaves, are themselves natural. Through the shape of the splatters the nature of the paint is revealed to be profoundly non-deterministic and stochastic. The thing that emerges from materiality is unpredictable and uncontrollable. CFD, like the splatter painting, demonstrates an appreciation for the absolute insolvability of the order which lies beyond materiality. Much like the time-image it is a material instance which transparently alludes to a virtual existence. It alludes to the elusiveness of a virtual existence by allowing the material to speak for itself. CFD thus represents the primacy of materiality in a world where the virtual or real exists elusively as something in a constant state of becoming.

The Day After Tomorrow

The Perfect Storm provides an example of the distinctions that can be made between a filmic image of an event and a CFD image. The storm featured in the film is compelling because it is conspicuously material. Through the visibly stochastic behaviour of the waves and the discursive knowledge that they came from a computer, the image resonates as a material instance alluding to the elusive virtual existence of the 1991 Halloween Nor'Easter. Storms are phenomena which unfold as the result of conditions, much like CFD storms. *The Perfect Storm* is an example of the pastness of the filmic image contrasted with the presentness of the CFD image. Unlike the filmic image though, CFD can also represent presentness as a sort of futureness.

As with *Twister* and *The Perfect Storm*, Roland Emmerich's *The Day After Tomorrow* addresses catastrophic weather and complexity. Unlike these other films though, *The Day After Tomorrow* endeavours to make its audience consider a future which is residing virtually in the present. This film is a rather unique kind of disaster film. It depicts the present world in a situation where the effects of global warming destabilise the flow of air currents on earth, precipitating a variety of catastrophic natural disasters including a giant wave that hits New York City. The public reception of this concept was incredulous to say the least. Given that Emmerich's past films included disaster brought on by aliens and Godzilla, an equally spectacular disaster film about a real and important issue seemed out of place. The general consensus amoung the press was that the scenario was absurd but the spectacle was undeniably effective. Dennis Lim at the *Village Voice* said, "Needless to say, the movie fails as a cautionary tale. But it fulfills its summer air-conditioning duties with flippant ease, and its enjoyably cloddish attempts at political relevance add a fascinating layer of incongruity." [50]

This "fascinating" effect should not be written off too quickly. It is an uncanny cognitive dissonance which drives the effect of the cinema in the first place, after all. Public reception seems to indicate that no one believed climate change could cause a catastrophic wave to hit New York, yet there was something in the image, something fascinating and incongruous, which resonated with audiences and led the film to gross triple its production costs.

Science fiction is a film genre which extends back at least as far as Méliès, and though the genre is conventional it also inspires works of creativity and imagination. *The Day After Tomorrow*, given its environmental rhetoric, does not wish to create an image of unlikely creativity but instead wishes to impel the viewer to imagine the future which climate change, left unchecked, is taking them towards. A condition of climate change is that the future resides virtually in the present: rising carbon dioxide levels will bring about future climate change. A strong theme in the film is the notion that it is "already too late". There is thus a strange ambiguity between future-ness and present-ness in the film. The film never actually declares the year it is portraying, and the title itself alludes to an immediate and present future.

The Day After Tomorrow took some public criticism for presenting an image of New York in a state of catastrophe so soon after the events of September 11th, 2001. It could be argued that in fact the film draws on that memory. Part of the poignancy of the events of September 11th stemmed from its effect of utter surprise on the public. The thousands of people commuting to work on that morning could not imagine the disaster that was about to befall them. This how Doane views the Oklahoma City bombing as well. The emergence of such an event is a

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[50] Dennis Lim, "Cold Comfort: Review of The Day After Tomorrow," *Village Voice*, May 2004, http://www.villagevoice.com/2004-05-25/film/cold-comfort/1/ (accessed 1 March 2012).

very keen illustration of contingency. Indeed it could be argued that this idea of what could happen has driven foreign and domestic security policy in the United States ever since. The emergence of disaster in the past has become tacitly equated with the emergence of disaster in the future.

The Day After Tomorrow attempts to tap-in to this same logic. New York could be said to be being approached as a topology in time where things emerge. Much like the European estate in *Last Year at Marienbad* which seems to be inhabited by many simultaneous histories, the future and the past of New York cannot be said to be ordered and displaced from a present. The immersion of New York in a deluge of stochastic materiality in the film could itself allude to its immersion in the very real smoke and dust cloud of the fallen World Trade Centre towers (Fig. 10). Thus it is the virtual existence of cataclysm which is being evoked.

Fig. 10. CFD water flows over a photographically composed New York City in *The Day After Tomorrow* (Emmerich 2004).

This can be considered as a contrast to Doane's description of video coverage of the Oklahoma City building destruction. In that example the contingent event was being contained and ordered. In the case of *The Day After Tomorrow* the threat of the contingent is being evoked and encouraged by the image of the wave enveloping New York City. The spectators are immersed in the possibility of their world becoming different. *The Day After Tomorrow* creates an image which is familiar and recognizable yet unlikely; this is the "fascinating" effect which viewers describe. It is not persuasive because it is photorealistic; it is compelling because it calls forth the threat of contingency in the spectator's world. This potential for change is made all the more threatening for its immanence. The event is not safely in the past or in a seemingly remote future, it is materially present on screen, brought to life, as it were.

The ethics of the film's claims remain debatable. It is effective, though, in using CFD to allude to an expanded concept of time which is very relevant to climate science. *The Day After Tomorrow* can be usefully contrasted with the contemporaneous documentary *An Inconvenient Truth* (Guggenheim 2006). This documentary predominantly consists of former vice-president Al Gore's travelling lecture on climate change. A key portion of this lecture is an extremely carefully crafted PowerPoint presentation. Though the documentary was released after *The Day After Tomorrow,* Gore was lecturing at the time of the film. Gore and some of the producers of the film actually participated in a rally that coincided with the premier of *The Day After Tomorrow.*[51] Gore's presentation is a consummate example of graphic visualization. His set-piece is a gigantic line graph which charts past carbon dioxide and temperature levels and projects them into the future. The line goes so high it leaves the confines of the screen. This graph quite specifically represents linear time and a determined outcome. It follows the established sequential and casual order of time in modernity.

Unlike *The Day After Tomorrow,* Gore's line does not call on possibility or the unknown, instead it authors a future. It endeavours to tell its audience that this abstract line is their current reality and their future. Though it may be quite accurate, a single line does call on the fear of

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[51] Elizabeth Jensen, "Activists take 'The Day After' for a Spin," *Los Angeles Times*, 26 May 2004.

chance and emergence in the future. With its combination of film and CFD *The Day After Tomorrow* does not so much try to predict the future as it does introduce the possibility of profound change in the spectator's material world. CFD may not be being used as an effective ontological medium yet, but the threat of its material immanence is clearly being used as an aesthetic resource in disaster films.

CONCLUSION

The purpose of this thesis has been to prove that even as photochemical film disappears from the cinema its tradition and function continues on. My argument was not that the digital camera and projector are more-or-less the same as film technology. Indeed, I have purposefully ignored digital camera recording practices. Rather I mean to suggest that the borders of what can be considered film are justifiably complex and overdetermined, and that the filmic discourse which reigned from 1895 to 2011 can be positioned in a greater continuum.

What does the medium of film do for us? Many answers have been cited in this thesis. Film provides an automatic yet malleable image of the world; through this it captures nuance and ambiguity. Through its ability to capture unpredictable emergence, film is able to convey the contingent nature of the world, with all of its mysteries and aporias where meaning gives way to indeterminacy. Film in the cinema allows us to shape and structure unruly reality, to give structure and logic to things like time and space in order to make them meaningful and intelligible. The bigger question we can ask is thus: are these functions still at work in the digital cinema? The answer I have offered is, yes, there is still a profound preoccupation with ontology in the cinema, but it is not completely unaffected by the digital revolution. CFD deals with this same tension between order and indeterminacy. In CFD the scientific properties of physical matter are combined with an automatic and unpredictable process which produces an image of natural motion.

When film was the dominant medium of the cinema it could unflinchingly be called the consummate ontological art. In his book *The World Viewed*, Stanley Cavell emphasises the enduring difficulty of divorcing reality from film.[1] Cavell writes, "My feeling is rather that we have forgotten how mysterious these things are, and in general how *different* different things are from one another, as though we have forgotten how to value them. This is in fact something movies teach us." [2] For Cavell the complex proximity of film to reality is what made it important and philosophically useful.

Because film was so uncomfortably close to reality, the cinema became the ideal subject of ontological thought. This is what Bazin means when he claims that sound "fulfill(ed) the old testament of the cinema." [3] Sound was not on film at first. The record was introduced to the cinema and became institutionalised in part because it too was ontological, and when it was combined with film the effects were uncanny. This is why CFD is such a useful concept to apply to the cinema. It exhibits the same uncomfortably and philosophically fecund closeness between reality and medium. It continues the tradition and affirms cinema as the consummately ontological art. Witnessing CFD water reminds us to consider "how *different* different things are."

When Arthur Worthington first photographically captured the image of a moving droplet of liquid, he discovered through this precise mechanical process that the rules which shape the material world can be profoundly indeterminate. Like the theories of thermodynamics and molecular science, this discovery contributed to a view of the universe as contingent and unpredictable. This view of the universe is reflected in the various works of process philosophy. Following Doane, these same scientific discoveries of randomness and contingency can be seen

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[1] Stanley, Cavell, *The World Viewed* (Harvard University Press, 1979), 16.

[2] Ibid., 19.

[3] Andre, Bazin, "The Evolution of the Language of Cinema," in *What is Cinema?Vol. 1*, trans. Hugh Gray (University of California Press, 2004), 23.

in film as an attraction and also as something that must be contained in order to create meaning. The haunting presence of the unpredictable and contingent could indeed be understood as a vital part of film's uncanny nearness to reality. The negotiation of indeterminacy through concepts like the index and formal cinematic conventions is continuing in CFD through different (numerical) means. Through CFD we are continuing the complicated search for meaning.

Science made efforts to deal with the newly discovered indeterminate nature of existence as well. The mathematical concept of Brownian motion, and later the Monte Carlo method, use stochastic equations to better understand the nature of the physical world. CFD extends from these scientific concepts to create simulations of reality which have an intimate relationship with contingency. While film has a relationship to reality and indeterminacy through a mechanical and technical process that is precise to the level of film grain, CFD's relationship to reality and indeterminacy is mathematical and computational. If we are trying to imagine the future of film studies in the digital age, it seems to me that we need to look no further than CFD for a perfect example.

Friedrich Kittler, following Aristotle, has suggested that the way we account for ontologies of technical media should not be through relationships of time and space but through the relationships of matter and form.[4] Matter in the Aristotelian sense is the stuff which an object is made of, while form is the shape that it takes. Kittler thus advocates for ontology defined by the physical reality of technical media. In the case of digital media this is a definition that involves architectures, physics and mathematics. "Technical media", Kittler says, "are but the visible side of some moon whose dark side would be mathematics and physics." [5] He has also

[4] Friedrich Kittler, "Towards an Ontology of Media," *Theory, Culture and Society* 26, no .2 (2009), 24.

[5] Ibid., 30.

been quoted as saying that silicon, the matter of semiconductors, “is nature." [6] Rather than understanding media through its abstract connections to nature, Kittler imagines media as made of nature. The logic of connections between media and nature is immediate and technical, the stuff of physics, to Kittler.

In a sense it could be said that the indexicality discourse in film theory follows Kittler’s logic. The light trace captured in chemical emulsion is directly and physically connected to the photons reflected from the world. Kittler is in effect advocating for a similar approach to digital media, one which gives primacy to the material existence of the medium.

The a treatment of digital media as precise and abstract ignores the physical and numerical connections between digital media and material reality. This false construction of digital media has led high-concept projects such as data art to construct the content of digital media into something which falls well short of its ability to speak to reality. The practices of special effects, fuelled as they are by practical concerns like audience appeal and pure spectacle, are able to tap into a latent potential in digital media the way data art does not. CFD relates to reality from within a digital environment through its numerical and physical nature.

As I stated in the introduction, one may get the impression that CFD has a rather peripheral and unimportant role in the cinema. The texts which I have discussing in this thesis are unremarkable Hollywood studio fare aside from their use of CFD. It may seem inappropriate to draw broad conclusions about digital media based on such a minor practice, even if it is a useful illustration of digital concepts. Here I would like note the future potential of CFD and emphasise how important it may be to future cinematic practices. There are two ideas I would like to discuss: CFD as a potential medium for experimental art, and computational physics as a

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[6] Nicholas Gane and Stephen Sale, "Interview with Mark Hansen and Friedrich Kittler," *Theory, Culture and Society* 34, no. 7 (2007), 342.

total cinema.

CFD began as a resource intensive experiment and then evolved into a tool for making compelling spectacles in films like *The Perfect Storm* and *The Day After Tomorrow* which both had budgets well in excess of 100 million dollars. Presently though, it is increasingly becoming a very common and cost effective tool. Open source animation software like Blender now comes packaged with CFD capability. This tool is now in the hands of the artists who do not need gigantic budgets. This is where I hope the potential I have seen in CFD will finally be realised.

One potential is for artists to create fluids which do not exist in reality. CFD's rules can be skewed to create things seemingly strange yet still materially coherent. The effects of this can be quite remarkable. Examples of this potential can even be found in technical demonstrations made by coders and programmers. One example is the *Meshy Mess* demo by Eric Mootz which was rendered entirely on a consumer-level computer. In the demo various fluids of different colour and viscosity pour from a tap and trickle down an oddly-shaped rock-like structure. The liquid looks and behaves like something recognizable, yet at the same time is not. The fluid has a sort of surreal effect, dragging something realistic out of its context and contorting it. Indeed it looks like a Dali painting come to life. This is achieved not through cutting, framing, or changing the speed of film as it might have been in the historical avant-garde. Instead, this effect is achieved through the manipulation of the physical numerical properties of a CFD liquid.

The second potential I see is computational physics as "total cinema." Though we have focused exclusively on fluids in this thesis, solid plastic and elastic objects can also be created using physics and stochastic processes. One notable recent experiment involved researchers creating a physical human extremity, with bone, fat, muscle and skin.[7] Each component of the

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[7] Joseph Teran et al. "Creating and Simulating Skeletal Muscle from the Visible Human Data Set," *IEE Transactions on Visualization and Computer Graphics* 11, no. 3 (2005), 317-327.

human body can be calculated for its specific physical properties. This process is being explored as a way of animating bodies, as possible alternative to traditional animation or motion capture. This experiment prompts us to consider a future cinema where all that we see on screen is a calculated representation of reality rather than a captured one. Experiments like this seem to point to the fact that CFD is conforming to the same sort of ontological usefulness that film has. Both attempt to address reality through the logic of a technical medium. This practice demonstrates that the film tradition is far from disappearing in a digital age.

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