The Evolution of the Interface
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Thanks to: Karen Shenfeld and Michael McCool

Are the ‘new’ media of the 21st century fundamentally different from the media which inspired Max Horkheimer and T.W. Adorno to propose the term “culture industry” (1972) to describe the relationship between mass media and capitalism? The analysis of media by these members of the Frankfurt School addressed the industrialization of mass-produced culture focusing on the social impact of the relationship between mass media and the capitalist economic imperative (including commodification and standardization). The critique of mass culture and communication by these and other members of the Frankfurt School, generally considered the role of media in legitimizing and reinforcing the infrastructure of the capitalist society. These media, they proposed, exerted an unassailable ideological influence on individual consumers/citizens, and encouraged adherence to the goals of capitalism.

It is my intention to demonstrate that the underlying nature of media has changed since Horkheimer and Adorno’s analysis which concentrated on film, popular music, radio and television. Not only has the technology behind the media changed (our analysis must now include the Internet, computer graphics and immersive systems which are often digital rather than analog), but the interfaces, that is, the methodologies which we invent to impose order on our experiences – whether digital or analog – have also evolved. Therefore, the relationship between these media, these interfaces and capitalism, must also be re-examined.

In order to accomplish this task, it is first necessary to establish and define the basic terminology which will be key to this discussion: analog, digital, interface, interactive. I will also elaborate on the metaphor which has been adopted to examine the relationship between these elements (through media), which is the geometry of space and time and topological spaces: 1D, 2D, 3D, 4D. After laying this basic groundwork, this paper will discuss the role of interactivity.

The underlying purpose of this analysis is to initiate a discussion regarding the significance of interactivity, particularly its role within capitalism. In this context we will examine the extent to which the theorists of the Frankfurt School continue to contribute to our understanding of the relationship between media and capitalism. With this framework in place it will be possible to consider the relevance and limitations of the media critique which is part of the Frankfurt School’s cultural theory.

In focusing on the relationship between technology and culture, Horkheimer and Adorno’s analysis was typical of the Frankfurt School, proposing that in a capitalist society, both technology (applied science) and culture (creative techniques) are inevitably directed toward the perpetuation of the economic system. Centered, as their analysis was, primarily in the realm of leisure activities, these media represented for them powerful agents of socialization which exerted subtle effects on politics and economics. (Kellner) The assertion that mass media(s) are controlled and dominated by capitalist values and priorities was an observation which subsequently led to Jurgen Habermas' description of the reconstitution of the public sphere as one dominated by individuals whose primary motivation was passive consumerism (1989).

There is no disputing the influence of the Frankfurt School on contemporary cultural theory regarding media. However, the technology on which these theorists based their analysis has long since been eclipsed. It is no longer adequate to restrict an analysis of the 'culture industry' to (analog) film, television, radio and the other forms of mass culture which dominated capitalist societies during the mid or late 20th century. With the new millennium, the parameters of the discussion have changed. The territory itself (capitalism) has expanded and the boundaries (media) have shifted.

On the periphery of the Frankfurt School was a theorist who remained in Europe when the rest of his colleagues immigrated to the United States in the 1930's. Walter Benjamin was interested in the potential of media culture to demystify 'high' culture. In "The Work of Art in the Age of Mechanical Reproduction" (1969) Benjamin discussed the tensions which were developing between older forms of culture with their emphasis on originality, and the new forms of culture which involved mass reproduction: photography, film, etc. Part of his analysis of the new technologies of cultural production presented a more optimistic interpretation. The most important outcome which he proposed (for the purpose of the current discussion) was that those involved with the development of these cultural products, as well as the audience which receives them (the consumers of this new culture) might in fact be best prepared and equipped to critique these cultural products. Being immersed in the production and/or consumption of these cultural products does not necessarily lead to passive acceptance of their message or associated ideologies.

How might the ideas of the Frankfurt School be applied to 'new' media technologies such as the internet? How may their analysis be applied to media which have only recently entered the public sphere described by Habermas? Benjamin would perhaps agree that although this is an important analysis to pursue, it is most effectively undertaken by those who have an intimate knowledge and understanding of the technology on which these media are based.

In "The Artist as Producer" Benjamin asserted that cultural creators might "refunction" the tools of cultural production in order to develop a forum conducive to political enlightenment and action (1999). Perhaps it is the acknowledgement of this 'potential' which is key to understanding technology's role in (ironic) postmodern culture. The role of entrenched capitalist institutions (eg. the military) in funding and supporting the development of many of the technologies and media which we currently employ, is not at issue. It must be recognized, however, that many of these technologies (both products and interfaces) were originally envisioned, and/or subsequently re-appropriated by cultural creators and producers with the intention of critiquing the capitalist system. Virtuality is capitalism's blindspot. Capitalism encourages competition and (in theory if not in practice) rewards innovation. Therefore, the development of new technologies can potentially meet both the needs of the capitalist system itself, and the needs of those who would challenge or subvert the sytem. In particular, interfaces which prioritize interactivity (eg. immersive systems) may embody both a symptom of capitalism and one aspect of its cure or treatment.

In order to explore this dual potential, it is necessary to first establish some basic terminology. Analog and digital are essentially different ways of describing energy. The natural world is analog; verbal communication uses sound waves, and light travels in waves received by the eye. The electromagnetic spectrum is a powerful visual representation of the range of sensory experiences which are analog.

Digital representation involves quantization to restrict the possible values of an observable quantity or magnitude (or to express as multiples of a given quantity or quantum). Quantization is essentially a metaphor. Digital and analog are different, but not opposite nor exclusive of one other. Computers were once analog, now they are digital; the computer is simply a tool. Technology-based definitions, which are akin to encouraging a driver to navigate a course by 'turning left when you pass Farmer Miller's cow' are to be discouraged. Cows have a tendency to wander and such directions, while well-intentioned, are essentially useless. The cow keeps moving; technology keeps changing. While it is important to describe details of the progress which mass media has made since Adorno and Horkheimer conducted their famous study of the culture industries (1972), it is equally essential to provide a conceptual framework which allows for future developments.

As humans, our perception of media, whether that media is presented to us as analog or digitally-encoded, will always be based on biological computation performed within our bodies through electrical-chemical interactions. These interactions are not based on binary logic. "Think of it as a packet-switching deployment of chemical agents. The result is that the computational basis is dynamic, capable of rapid, fundamental change. Affect, emotion, and mood all play a powerful – and as yet poorly understood – role in human cognition." (Norman)

As analog beings, we see (light waves), we hear (sound waves). The sensory experiences of recognizing pleasure and pain, or distinguishing between degrees of hot or cold, illustrate how even tactual input is experienced and evaluated in a manner typical of most analog devices, involving a range or spectrum of values. Devices which utilize analog signals are either of the real world, or analogous to it. "If the physical process is discrete, so too will be the analog one. If the physical process is continuous, then so too will be the analog one. Digital, however, is always discrete: one of a limited number of values, usually one of two..." (Norman) The original purpose of digital encoding was the elimination of 'noise' which interfered with the processing of information. Because binary signals are relatively insensitive to noise, by transforming physical events into a series of numbers (quantization) that describe the original, information can be processed more accurately and efficiently.

Although 'digital' has come to be associated strictly with high-tech applications, in fact digital systems need not be binary nor electronic. A non electronic example of a digital system would be smoke signals. A non-binary, possibly electronic example of a digital system would be Morse code or the use of an electrical telegraph. A beacon is perhaps the simplest non-electronic digital signal with just two states; the beacon is either lit, or it is not.

Analog systems do not involve quantization of information. Any information can be conveyed by an analog signal and often such a signal is a measured response to changes in physical phenomena, such as sound, light, temperature, position or pressure. These measurements are made and conveyed using transducers, devices which convert one type of energy to another, or respond to a physical parameter. Transducers may be mechanical (gears, etc.), electromechanical (circuit breakers, motors, etc.), electrochemical (batteries, fuel cells, etc.), photoelectric (laser diodes, solar cells, etc.), electromagnetic (light bulbs, cathode ray tubes, etc.), electronic (diodes, transistors, etc.), electrical (capacitors, resistors, etc.), magnetic, electrostatic, or thermoelectric. A microphone is an example of a transducer which converts sound to electrical energy. The process which is being represented by the interface for an analog system is that of transduction.

Is ‘analog/digital’ the crucial dichotomy of the 21st century? In the early 1960’s Marshall McLuhan remarked that living with electric and mechanical technologies at the same time was the peculiar drama of the twentieth century. (1964). It may be argued that the peculiar drama of the twenty-first century is our attempt to reconcile analog and digital technologies. As analog beings, we live in an increasingly digitally processed or represented world. However, the real drama today may be found in exploring the various points of contact between humans and both analog and digital systems. It is the form and function of the interface itself which is the key to understanding our relationship(s) to media.

The interface describes the various points of contact between humans and analog/digital systems. When associated with digital technologies, interfaces are often assumed to be input/output devices for the ‘personal computer’. In fact, the ‘computer’ is a sufficient but not a necessary condition for the development of an interface. If the computers which we are currently familiar with are digital, the components which comprise various interfaces are less straightforward. Particularly with cultural products, the interface(s) are often manifested as a combination of analog and digital processes.

“These metaforms, these bitmappings will come to occupy nearly every facet of modern society: work, play, romance, family, high art, pop culture, politics. But the form itself will be the same, despite its many guises, laboring away in that strange new zone between medium and message. That zone is what we call the interface.” (Johnson 1997: 41)

To clarify the role of the interface, the interface is situated on a separate plane from the process which it represents. This enables the interchange between digital and analog systems which will probably always be necessary. For example, a microphone (transducer) from an analog system may be connected to a computer, which is a digital device which processes audio input, in turn outputting it through an amplifier and speaker (again, an analog device) or directly through the computer, as a digital file.

Interface

process of transduction	process of quantization
Analog System	Digital System

We are surrounded by digital media and their associated interfaces which challenge our traditional understandings of communication, learning, knowledge, process, proximity, time, narrative, etc. As our exposure to various electronic/computer-based media is extended, definitions and boundaries are in a constant state of flux. Simply by sheer quantity, the incorporation of digital media into daily life alters our perception of their uses and usefulness. Concerning creative practice, traditional distinctions between author and reader, visual artist and audience, and musician and listener have been thrown into chaos by various manifestations of digital media. The effect of digital media on both the production and distribution of cultural objects raises many interesting issues regarding democratization of digital media, collaboration, and notions of ownership.

However, the challenge presented by the ubiquity of media relates to our ability to engage with various media objects and products at a more basic level. Before we can hope to address concepts such as interactivity and authorship, we must understand the purpose and the meaning of the interface, the instrument of our engagement.

"When the concept of the interface first began to emerge, it was commonly understood as the hardware and software through which a human and a computer could communicate. As it has evolved, the concept has come to include the cognitive and emotional aspects of the user's experience as well." (Laurel 1990: xi) A commonly overlooked characteristic of the interface is its function as a means to present complexity and depth. While the interface is expected to provide a point of access or a point of contact, the systems or information which are presented through the interface are certainly not simplistic in themselves. The progress of scientific knowledge, for example, demands interfaces which are able to present the visualization of complex data in a meaningful way while accommodating input or feedback which is similarly complex. While it is true that the best interfaces are intuitive, human intuition is also a work in progress.

> Human beings are fundamentally metaphoric animals, and all our creative intellectual endeavors (including both software and philosophy) are constituted by the patterns of bodily feelings which motivate metaphors. The metaphors we use to understand ideas, minds and user interfaces are not separable from the "things themselves." There are no minds which are metaphysically distinct from bodies, and there are no ideas or user interfaces which are metaphysically distinct from bodily metaphors. Successful user interface metaphors tap into a reservoir of bodily feeling on the part of the user and successfully exploit our embodied knowledge. The problem of disembodied users is that we ordinarily think of user

> interface design as if the users were disembodied minds when they are not. (Rohrer)

Particularly since the Renaissance, geometry has emerged as a powerful visualization metaphor for understanding our relationships in the world, with far-reaching effects in the fields of science and art as well as mathematics. Interestingly, the interface has progressed through an evolution which is conceptually similar to the system of dimensions which form the basis of geometry.

A dimension is simply a measure of something; for each class of features to be measured, another dimension is added. There are three known and obvious spatial dimensions – the x, y and z coordinates of basic geometry. Represented in two dimensions, two axes are placed at right angles to each other, forming an x-y plane. Adding a third axis (normally labeled z) provides a sense of a third dimension of space measurement – at right angles to both.

0D refers to vertices or points. 1D refers to edges, lines and text. 2D (Euclidean space) uses 'faces' and includes still images, moving images (film/video) and the 2D World Wide Web. 3D refers to solids rendered on screen via computer graphic software; it involves algebraic geometry, beginning with the historical emergence of the use of coordinates and algebraic equations connecting them. Examples of 3D visualizations include computer-graphics and some VR (virtual reality) systems. 4D hypervolumes inhabit hyperspaces. In this 'manifold' there are no 'objects,' only 'relationships.'

Following the trajectory of the interface through the first three levels of geometric dimensions might be manifested as follows. In the real world, an apple is a 3D object. Writing a description of an apple presents this object through a 1D interface (text). A drawing, painting, photograph or even a video/film clip of an apple presents this concept through a 2D interface (the page, the screen). In this case, even though the object represented has body/mass/volume clearly exists as a 3D object in the real world, the process of capturing this object on the page or on the screen strips it of the third dimension, relegating it to 2D. You cannot reach into a photograph to turn an apple over nor reach into a video to knock it rolling off a tabletop. Still, to capture and represent the 3D essence of an object requires more than the ability to simulate body/mass/volume. A flip book can be used to simulate animation. 'Fake 3D' can be used to produce a similar illusion. True 3D requires the use of 3D computer software which enables the production of a 3D object, a wire-frame with appropriate texture-mapping, to simulates an object – in this case an apple. This 3D representation is, in fact, more 'real' for our purposes than a photograph or video of an actual apple. Even if this 3D simulated apple is presented through a 2D interface (computer screen) to the viewer, what it embodies is all of the inherent possibilities of the actual object. With the appropriate user interface, the viewer could manipulate the 3D representation, turn that apple around and experience its volume and mass. Interactivity between the viewer and the visualized object becomes possible and loaded with significancel at this level.

We have described the representation of an apple through 1D – 2D – 3D. What would characterize a 4D representation of that same apple? 4D does not merely add another spatial dimension to an equation concerned with visual representation. For mathematicians and scientists, the fourth dimension is time.

During the Enlightenment (late 1700's) Immanuel Kant had proposed that philosophy's purpose was the critical appraisal of the capacities of pure reason. Knowledge which did not depend on sense experience, he termed 'a priori' – this knowledge, he contended, arose out of the human faculty for rational judgment; mathematical propositions fall into this category. Kant argued that space and time were 'forms of intuition' which the human mind imposes on the world of sense-perception. According to Kant, objects of the world are perceived as existing in space and time for this reason. While Kant held that the mind's 'form of space' was Euclidean, this view – the relationship between the truths of Euclidean geometry and the properties of physical space was, in the 19th century, challenged by the development of non-Euclidean geometry.

Whereas in the formulation of Euclidean geometry a fourth dimension was not even considered, in 1854 mathematician Bernhard Riemann described revisions to Euclidean geometry which would allow for curved spaces and any number of higher dimensions. Riemann introduced the concept of 'mathematical space' or 'manifold.' Subsequently, Einstein proposed that the true geometry of our world is not Euclidean, but hyperbolic, or Riemannian, having at least four dimensions: the three familiar spatial ones, plus the fourth one: time. A major proponent of the fourth dimension was a mathematician Charles Hinton who subsequently named the four-dimensional hypercube, the tesseract. Hermann Minkowski realized that Einstein's special theory of relativity could be mathematically described using a four-dimensional space-time. "In Minkowski space-time, time was conceived as a continuous extra dimension, resulting in the notion that reality consists of a series of frames of space, set out along a time dimension." (Brown) Because the fourth dimension is time, an apple presented through a 4D interface might look (initially) much like a 3D representation. However, unlike a 3D interface, which essentially presents the apple as a 'still life,' a 4D interface would enable us to watch the apple as it evolved through time, as a dynamic object. We would watch the apple ripen, age or otherwise 'move' through time.

The mathematical meaning of the term 'space' had been forever transformed by Riemann's concept of a 'multiply-extended manifold.' Riemann's higher dimensions enabled mathematicians (and others) to begin to imagine, explore and visualize a variety of abstract and complex spaces.

What drove the evolution of the interface? How were these transitions manifested in art, technology and science? It was an artist's technique for creating the illusion of depth on a two-dimensional surface (Brunelleschi and Alberti) which revolutionized the spatial language of European painting. This shift of perspective had implications for many fields as it "centered the visual field on the human point of view, instead of a disembodied or divine locus, a shift that was imitated in countless disciplines throughout the fourteenth and fifteenth centuries as scholars and artists and scientists grounded their work in the physical, lived reality of the human body." (Johnson 1997: 214)

Similarly, considering screen-based, (digital) computer interfaces, the transition from 1D to 2D (ie. text/command prompt to Windows) began in 1968 when Doug Engelbart demonstrated a new information space involving the following three elements:
1/ Bitmapping (each pixel on the computer screen is assigned to a small chunk of the computer's memory). With bitmapping the screen is conceived of as a grid of pixels, a two-dimensional space.
2/ Principle of direct manipulation – providing users with control over the images – instead of typing in obscure commands, the user could point at something and 'open' it, drag it across the screen, etc.
3/ The mouse – served as the user's representative in dataspace – much more than a pointing device, provided user with a direct link (Johnson 1997)

In essence, the introduction of the bitmapped datasphere by Engelbart, effectively produced a disruption of visualization techniques similar to that produced by Renaissance artists. The overlapping 'windows' subsequently conceived by Alan Kay and the desktop interface which was first popularized by Apple became the standard by which all screen-based computer interfaces continue to be judged. Although it is a metaphor which has endured, the fact that the dominant model for interface design to date has been architectural (interfaces imagine binary code as space to be explored), does not mean that this is the only or best metaphor available to us. "Most of the time we talk about the graphic interface as though it were a logical culmination of the digital revolution, its crowning glory, but the truth is, the interface serves largely as a corrective to the forces unleashed by the information age." (Johnson 1997: 236, 237)

2D screen-based interfaces remain, for the time being, the most common and familiar means of experiencing media. 3D representations of data were presented first through 2D interfaces; the shift to the use of 3D interfaces to display 3D visualizations has only recently begun. We are beginning to envision 3D data spaces which are not represented on (2D) screens. Commercial applications which are emerging from development include notebooks with lenticular screens and virtual keyboards which can be projected on any available surface.[1]

In fact, we are at a particularly interesting point in the evolution of the interface, spanning 2D, 3D and 4D visualization and presentation techniques. The Hollywood film industry discovered the visual appeal and economic benefits of using 3D computer graphics with movies such as the 1993 film 'Jurassic Park' which combined real actors with computer-

[1] Lenticular images are specially constructed pictures that 'move' or simulate depth in order to generate attention and visual interest. Viewing 'interlaced' pictures through plastic screens that are made of many 'lenticules' or lenses creates these images. Common techniques include combining different images together that 'flip' between each other, creating video-like motion and simulating a 3-dimensional effect.
Although lenticular images have existed for almost 90 years, and commercially produced for the last 30, only a few large companies have had access to production materials. Definition courtesy of: www.getflipped.com/lenticular.htm

generated characters and subsequently movies such as ‘Toy Story,’ the first feature film which had no human actors. However, the incorporation of 3D CG (computer graphics) in movies has not fundamentally changed the nature of the presentation or output (display) interface. Various technologies have been developed which are intended to simulate 3D for the audience, such as Douglas Trumbull’s Showscan, IMAX (flat screen), OMNIMAX (dome screen) and stereoscopic 3D movies. These systems may utilize eclipse or field sequential technology, requiring the audience to wear LCD shutter glasses (synchronized with alternating right and left images from the projector) or achieve a 3D effect by filling all or most of the audience member’s field of vision with a high resolution steady image. The 2D interface (screen) is the current standard for film/video based entertainment. While the film industry has embraced 3D techniques in the production phase of projects, primarily because they are cost effective, allowing the use of virtual actors and avoiding the construction of costly sets, combined with the possibility of presenting otherwise impossible effects, 3D presentations of these media are (to date) a novelty presentation experience.

Still screen-based for presentation, Hollywood movies today are also no more interactive than they were more than 50 years ago, with the exception of movie-theme websites and distribution on DVD for home viewing (which often includes some interactive elements). However, if current trends in entertainment spending persist, the transition to 3D and interactive interfaces is imminent.

The Price Waterhouse Entertainment and Media Outlook: 2003-2007 projects that filmed entertainment spending (consumer spending at the box office for theatrical motion pictures plus spending on the rental and purchase of home video products in both VHS and DVD formats) in North America will rise at a 7.2 percent compound annual rate, reaching $49.1 billion in 2007. This can be compared to the video game market (spending on console games, PC games, online games, and wireless games – not including the purchase of consoles or other hardware) which will expand from $7.8 billion in 2002 to $13.5 billion in 2007, growing at an 11.7 percent compound annual rate (Price Waterhouse)

In 2002, the Interactive Entertainment Industry Report (Wedbush Morgan Securities) reported that world-wide game sales reached over US $27 billion and that by the end of 2004, interactive entertainment software sales would be half of movie (VHS and DVD) rentals and sales (approx. $20 B in the US in 2002) (Zamaria). This figure, combined with the increase in revenue in the US video game market (11.7 percent compound annual rate) vs. the 7.2 percent compound annual rate in filmed entertainment spending demonstrates the consumer shift towards interactive products.

> Only five years ago, music sales were booming. Today, the industry is nearly paralyzed by piracy. Illegal downloads and file-sharing were partly responsible for last year’s loss of an estimated $2.6 billion in worldwide music revenues, about 8%, says PriceWaterhouseCoopers...Can Hollywood avoid getting Napsterized? Right now, the pirates are only nibbling at the $65 billion-a-year film and TV business....The ripping and burning of movies to DVDs is growing into a global

> underground industry that last year cost film studios an estimated $3 billion in lost DVD sales. (Grover & Green)

The challenges being faced by media companies is twofold, and both challenges are due to advances in technology. The first challenge deals with distribution, and the issues relating to this include piracy, peering, downloading, file-swapping, ripping, and burning. The second issue deals with the media itself, and the impetus towards interactivity.

In terms of interactivity, the most successful transition into three dimensional space has been video/computer games with their related graphics/physics/game engines. Currently, computers can store entire (fully rendered) 3D worlds in main memory, allowing faster manipulation. Historically, the most common type of 3D image which is presented through a screen-based interface is not fully rendered and may be more properly described as 'fake 3D' (a 2D equivalent would be the flip-book which can be used to present a simulated animation). To the end-user there may appear to be no difference. However, only true 3D data sets can be taken 'off the screen' where they exhibit the mass and volume with which they have been constructed. The significance of this advance in methods of visualization becomes important with the transition from 3D to 4D interfaces.

> To move beyond the current generation of graphics screen and mouse, to transport the user through the screen into the computer, we need hardware and software that provide the user a three-dimensional simulacrum of a world and that allow interaction in ways that mimic interaction with real-world objects. Cyberspace means a three-dimensional domain in which cybernetic feedback and control occur. (Walker 1990: p. 444)

If our model for the evolution of the interface is accurate, we should be beginning to see evidence of a move towards 4D representation within 3D as well as 2D interfaces. In fact, artists have been involved with the representation of higher dimensions from the moment of their conception. In the same year that Einstein published his theory of relativity, 1907, Hinton wrote 'An Episode on Flatland,' a reference to an earlier work published by Edwin Abbot in 1884 titled 'Flatland,' a literary exploration of relational space. This was an example of 4D concepts being manifested in 1D (text) Visual artists, in particular the Cubists, offered an analytic view of reality, ignoring perspective while providing faceted views from divergent points – an example of 4D concepts manifested in 2D (flat images).

Film, video and audio, the media of Adorno and Horkheimer's 'culture industry,' are time-based themselves and therefore eminently suitable for representing 4D. And while it is true that linear, narrative productions have been favored in Hollywood productions, Hollywood films do incorporate rudimentary techniques such as split-screen to show multiple points of view simultaneously. Examples of additional nonlinear, non-narrative techniques may be seen in productions such as Robert Altman's 'Short Cuts'. Recent production techniques such as the Cubist Camera, a non-traditional imaging technique which would capture a multitude of perspectives simultaneously, are suggested as alternatives to the 20th century orthogonal point of view. (Glassner)

These 2D (screen-based) examples of 4D (time-based, interactive experiences) suggest opportunities for the use of 3D techniques for 4D visualization. The incorporation of enhanced computer graphics effects into Hollywood productions is one possible avenue. In fact, CG effects are entirely different from special effects (FX) which involve staged events which often involve fake blood, fire, explosions, etc. For example, in the film 'The Matrix' the main character (Neo) is involved in a fight scene with the protagonist (Smith). The technique used in the representation of this scene represents a tentative foray into the use of interfaces for advanced representation. The protagonist is not simply mirrored, but is multiplied. Each 'Smith' represents an additional dimension. What would this look like if this 4D-based concept was presented as 3D? At present, it would be projected as a hologram. What would this look like if it were presented through a 4D interface? The experience would happen in 'real' time, viewers would be participants; it would be entirely interactive.

In order to grasp the relationship between the visualization of higher dimensions, interactivity, and the role which they play within a capitalist system, it is necessary to acknowledge that time, the fourth dimension, is an essential component of human experience. The 'real' world in which we live is not a 3D world; it is a 4D world. Regardless of how we choose to define or measure time, it is the context in which our experience of the world takes place. We do not merely experience the world (as 3D), we are active participants in it.

Interactivity belongs to any dynamic system, whether or not it involves the direct participation of a user or viewer. 'Dynamic systems' refer to objects, organisms or systems which exhibits transformation over time. Cellular automata, in the context of this definition, meet the criteria for interactivity.[2] Cellular automata, and other computer programs which are 'real world' simulations are interactive because although they do not involve human participation or intervention once they are underway, they each constitute a dynamic, active system which evolves over time.

When interactivity is applied to the human-computer or human-machine interface, it describes a sequence of action involving a user and I/O (input/output) devices. The user has access to a range of input devices (keyboard, mouse, touchscreen, etc.) through which they can activate or control the technology or media which they are engaged with. The result of this action is some form of visual or audio output (text, graphics, etc.). The entire process constitutes the interaction. Various authors have described numerous levels of interaction, the most basic being: reactive, proactive and mutual. (Rhodes and Azbell (1995), Jonassen (1988) and Schwier and Misanchuk (1993)) Different media are obviously better suited to facilitating certain types and degrees of interactivity.

Much discussion about interactivity to date has been about screen-based interfaces. Television (video) broadcast media and the film industry have been on the leading edge of utilizing visualization techniques (computer graphics) which were originally developed for

[2] For a comprehensive description of cellular automata, see: http://www.brunel.ac.uk/depts/AI/alife/a1-ca.htm

military applications. However, the common characteristic of broadcast media is that the same content is distributed to a great number of receivers. Interactivity is limited to: on/off. Viewers have created their own techniques for incorporating interactivity into these experiences (surfing, or flipping between channels when they are bored or to avoid advertising). This is not encouraged by the broadcasters who desire to maintain control over what we watch, and how we watch it; this is necessary in order for them to sustain (advertising) revenue.[3]

The next generation of television, which has been named 'interactive TV' is, in fact, only marginally more interactive than what has been traditionally broadcast. Interactive television currently uses MPEG2, a standard developed and approved by the Motion Picture Group which enables the viewer to alternate between viewing (TV) and navigating (internet web pages).[4] With MPEG2, data (and URL links) are embedded in line 21, a thin slice of data space, the only space in the VBI (vertical blanking interval) which is a coast to coast must-carry line in an analog video signal. Normally used for closed captioning, this space is also sufficient for embedding URLs which can be accessed by the viewer as they 'watch' TV. MPEG4, a more advanced standard, allows up to 19 different layers of video to be 'addressable' or linked to external data or information. MPEG7 allows for different objects in a video stream to be addressable. These and more advanced MPEG standards are fully digital but are currently being held back by broadcasters and cablecasters who are determined to sell MPEG2-based 'Interactive TV' (set-top boxes) as the ultimate in digital interactivity to the home. Work is underway in research labs to extrude 3D from 2D scenes so that once we are allowed access to the full range of interactivity enabled by MPEG standards, we may begin to see advanced visualizations and interactivity which combine addressable video (objects in the scene) and computer graphics together.

Interactivity will be to the 21st century what film was to the 20th. Passive viewing is a subset of active viewing, not the other way around. There will always be a market for programming which allows viewers to be passive. However, this will be a choice among many others, the bulk of which will be characterized by interactivity. If the transition towards interactive 4D interfaces is problematic with television because of how the media has evolved, the world wide web is another case entirely. A visualization of the decentralized communications network which is the internet, the world wide web presents content in 2D and 3D formats, and it is entirely characterized by interactivity.

Psychologists are actively analyzing the nature of interactivity with regard to the internet; a substantial number of studies have been conducted, ranging from its suitability for distance education to the possibilities of the media for social interaction. At best, this space is occupied by sophisticated users interested only in the acquisition of data,

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[3] In July 2002, Broadcast Engineering magazine pointed out that there are actually two fronts of resistance: resistance to changes in the underlying business model and the technology for delivering television programming to viewers. See: http://broadcastengineering.com/ar/broadcasting_change_inevitable/

[4] Motion Picture Experts Group. MPEG is commonly understood to refer to a type of audio/video (multimedia) file. MPEG is an algorithm for compressing audio and video. Various standards have been developed, including MPEG2, MPEG4, MPEG7 and MPEG21.

knowledge or information; at worst it is populated by active consumers, but certainly not the passive consumers which Habermas had anticipated and feared. Communication researchers and marketing professionals are struggling to come to terms with the transition from 'passive' to 'active' consumers, encompassing an entirely new set of expectations. (Jee and Wei-Na; Newhagen and Rafaeli)

Tracking 'clickstreams' and 'click-through rate,' are just two techniques which are being employed as a means for determining what is of interest to viewers.[5] The surveillance of users through such techniques is perhaps the most troubling outcome of the transformation from passive to active to interactive viewers, and certainly requires further attention and study.

Interestingly, this network is capable of carrying much more sophisticated content and opportunities for interaction than is currently the case. Various technologies, both client and server-side, have been developed for interactivity on the internet, including javascript, php, flash, etc. From its beginnings as an academic resource, the internet has evolved to be a model of interactivity, both 2D and 3D. VRML and X3D standards are being developed to codify how 3D data is presented, and 3D browsers are also emerging. Future standards for interactivity on the internet include XML, MHEG and others.[6]

Beyond the 2D screen-based interface, immersive environments and experiences provide the best examples of interactive visualizations. Some of the most interesting work being

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[5] Click-through is the process of clicking through an online advertisement to the advertiser's destination. Clickstreams are the paths a user takes as they navigate a web page; it is the sequence of mouse clicks made by a user. Advertisers and online marketers have developed software which can track users' clickstreams. That way they can deliver targeted ad banners based on what the user has clicked on in the past (presumably corresponding to the user's interests). Web beacons (also called web bugs or pixel tags) are used in combination with cookies. A web beacon is an often transparent graphic image that is placed on a web site or in an email in order to monitor the behavior of the user visiting the web site or sending the email. When the HTML code for the web beacon points to a site to retrieve the image, at the same time it can pass along information such as the IP address of the computer that retrieved the image, the time the web beacon was viewed and for how long, the type of browser that retrieved the image and previously set cookie values. Web beacons are typically used by a third-party to monitor the activity of a site. Cookies are passed from a Web server through a Web browser to the user's hard drive. This information is essential for many of the features taken for granted on the Web, such as shopping carts and personalized portals. Privacy advocates have raised concerns over the role of cookies in online advertisements. They fear that large companies could piece together information which could be used against individuals, especially if offline information is merged with online information. Definitions courtesy of www.marketingterms.com/dictionary, www.webopedia.com and C|Net Glossary.

[6] The X3D Graphics Working Group is designing and implementing the next-generation Extensible 3D (X3D) Graphics specification. They are extending and upgrading the geometry and behavior capabilities of the Virtual Reality Modeling Language (VRML 97) using the Extensible Markup Language (XML). VRML is an open, extensible, industry-standard scene description language for 3D scenes on the internet. Extensible Markup Language (XML) is a simple, very flexible text format. Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere. WG12 is the ISO/IEC/JTC1SC 29 working group, commonly known as MHEG, which provides standards for the coded representation of multimedia hypermedia information objects that are interchanged among applications and services using a variety of media. The objects define the structure of a multimedia hypermedia presentation.

done outside of the development of military applications of this technology, is in the hands of creative individuals. VR (virtual reality) experiences began as battlefield simulations and after a brief period during which artists developed content and applications, they were reclaimed as commercial products. Head-mounted displays used for these systems in theme parks provide a tangible sense of 'high tech,' and one which is easily commodified. These systems are very popular at DisneyQuest in Orlando, where you can pay to experience: Star Wars, Aladdin, and a number of other immersive experiences which use various configurations of displays and inputs. CAVEs, however, which are essentially small spaces in which the viewer/participant is surrounded on all 6 sides by screens which display synchronized rear-projected imagery involve a substantial amount of hardware, and will be cost-efficient for mass consumption as the price of flat screens decreases.

There are also a wide range of artists' projects which incorporate 4D interfaces through a combination of analog and digital devices such as touchscreens and microphones. Any number of these may be seen at the SIGGRAPH (Special Interest Group on Computer Graphics) Art Show which is held annually in the U.S. or at New Media exhibits such as ARS ELECTRONICA in Austria.[7] Sometimes associated with well funded institutions (eg. MIT's Media Lab), but often working independently, these individuals are creating on the 'edge of chaos.' Using virtual reality and interactivity technologies, creative individuals are imaging and conceptualizing n-dimension topologies.

When the double-slit experiment (1961) made the transition from being a conceptual exercise or 'thought experiment' to being physically demonstrated, the result had profound implications for quantum physics. Beyond the fact that the result was similar to a bad television set (diffusing rather than focusing the electrons) it was a remarkable outcome, a metaphor manifested, which took its place at the heart of quantum mechanics. (Physicsweb) Human imagination allows us to traverse a certain distance. At some point the visualization of emerging information and relationships becomes necessary, and we have reached the point where 4D interfaces may assist us to understand complexity.

The semantic web proposes an invisible 4D interface between the user and the information space which is the internet.[8] The semantic web carries the evolution of interactivity on the internet further. Personal software agents roaming the internet, will be empowered to gather and analyze data in order to carry out complex tasks for their human user.[9] Currently web pages can be parsed for layout and routine processing but

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[7] see: http://www.siggraph.org/artdesign and www.aec.at for more details about these two exhibitions

[8] In 1994 Tim Berners-Lee founded the World Wide Web Consortium (he had proposed a global hypertext project in 1989 which was realized as the internet's 'world wide web' in 1991). The infrastructure and architecture of the Semantic Web is being coordinated by the W3C (World Wide Web Consortium).

[9] Intelligent agents are programs that carry out a task unsupervised and apply some degree of intelligence to the task. The intelligence may be pretty minimal but often will include some degree of learning from past experience. For example, an agent that searches the internet for interesting material can be told by the user whether what it found was interesting or not. In this way it can be trained to be more successful in the future. Some intelligent agents can also interact with one another. Definition courtesy of www.compinfo-center.com

there are presently no reliable ways to process the meaning or semantics of a web page or the links between a set of web pages. Rather than simply building sophisticated intelligent agents, although intelligent agents are definitely a requirement of this system, this proposal also requires that intelligence can be built into the data itself. Once information is given well-defined meaning(s), these agents will be better able to understand how different items relate to one another and determine how to use information (which is readily available) to answer queries. This scenario situates the locus of interactivity between the data and the software agent, essentially removing the user from the equation except as the beneficiary of the process.

The initial response of the capitalist market to this move towards interactivity has been predictable. Industry/capitalism has attempted to use the courts to crush competition and hold up technological advancement. The global music market is controlled primarily by less than a handful of companies. File-sharing programs such as Napster, MP3 and gnutella prove that you can't stop people from peering and downloading, regardless of the drive to legislate against such technologies.[10] There is a new paradigm evolving – open source and interactivity point the way towards profits in the future. MP3 is just one example demonstrating how new media interfaces are evolving towards interactivity. Peering has been described ominously as the 'Darknet' in a report commissioned by Microsoft. (Biddle, England, Peinado & Willman 2002) The prospect of interactivity and the more proactive role of the consumer in acquiring media products has had a tremendous impact on the production and marketing strategies of traditional media such as film, video and audio.

Walter Benjamin's recognition of the potential for media to be appropriated in order to subvert capitalism, is a starting point for the proposal that interfaces which are extended into the fourth dimension are essential to the visualization of complex, dynamic and interactive systems. These systems are increasingly being studied and utilized in science and math as well as in art and interactivity is a significant characteristic.

While there is no denying the social, political and economic influence exerted by the producers working within the 'culture industry' in support of the capitalist system, the democratizing and mobilizing effect of new media technologies is also a powerful tool. The influence of users or consumers is growing as the technology evolves. Listservs and cell phones are increasingly used to organize political demonstrations (both real and virtual). Websites can be hacked, corporate servers can be brought down by well placed attacks. A website describing a recent demonstration in Brussels against EU software patent plans, encouraged both on-site participation, and also asked for participation by

[10] Peering is the arrangement of traffic exchange between points or nodes on the internet as well as between internet service providers (ISPs). Larger ISPs with their own backbone networks agree to allow traffic from other large ISPs in exchange for traffic on their backbones. They also exchange traffic with smaller ISPs so that they can reach regional end points. Essentially, this is how a number of individual network owners put the internet together. To do this, network owners and access providers, the ISPs, work out agreements that describe the terms and conditions to which both are subject. Bilateral peering is an agreement between two parties. Multilateral peering is an agreement between more than two parties. Definition courtesy of http://searchnetworking.techtarget.com

"more or less gently blocking access to webpages in a concerted manner at certain times."[11]

Lev Manovich refers to 'totalitarian interactivity' in describing the choices which 'interactive' art forms offer the viewer (2001). In this he agrees with Adorno and Horkheimer. However, if the choices offered to the viewer through rudimentary interactive systems are programmed and manipulative as he suggests, the outcome is not always as intended. There is a limit to how much of human activity can be "forced into the mold of the computer's algorithms, broken down into a series of steps that leaves little room for creativity or informed decision making" (Friesen). We are beginning to see evidence of resistance.

The relationship between capitalism and media is a tenuous one. The essential choice which we face is between the pessimism of Adorno/Horkheimer, and the optimism of Walter Benjamin. Interfaces enable us to visualize and interact with (analog and digital) systems and processes; as our means for accessing complex concepts, they are the key to the future of science, technology and art.

[11] see 'Aug. 27 Demonstration against EU Software Patent Plans' http://swpat.ffi.org/news/03/demo0819/index.en.html

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