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What Is New Media?

What is new media? We may begin answering this question by listing the categories commonly discussed under this topic in the popular press: the Internet, Web sites, computer multimedia, computer games, CD-ROMs and DVD, virtual reality. Is this all there is to new media? What about television programs shot on digital video and edited on computer workstations? Or feature films that use 3-D animation and digital compositing? Shall we also count these as new media? What about images and text-image compositions—photographs, illustrations, layouts, ads—created on computers and then printed on paper? Where shall we stop?

As can be seen from these examples, the popular understanding of new media identifies it with the use of a computer for distribution and exhibition rather than production. Accordingly, texts distributed on a computer (Web sites and electronic books) are considered to be new media, whereas texts distributed on paper are not. Similarly, photographs that are put on a CD-ROM and require a computer to be viewed are considered new media; the same photographs printed in a book are not.

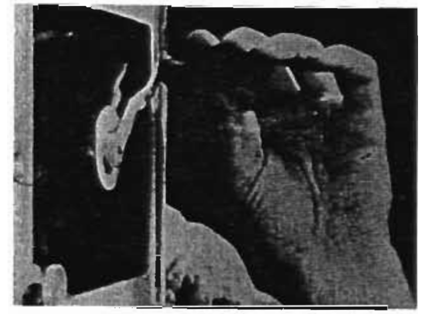
Shall we accept this definition? If we want to understand the effects of computerization on culture as a whole, I think it is too limiting. There is no reason to privilege the computer as a machine for the exhibition and distribution of media over the computer as a tool for media production or as a media storage device. All have the same potential to change existing cultural languages. And all have the same potential to leave culture as it is.

The last scenario is unlikely, however. What is more likely is that just as the printing press in the fourteenth century and photography in the nineteenth century had a revolutionary impact on the development of modern society and culture, today we are in the middle of a new media revolution—the shift of all culture to computer-mediated forms of production, distribution, and communication. This new revolution is arguably more profound than the previous ones, and we are just beginning to register its initial effects. Indeed, the introduction of the printing press affected only one stage of cultural communication—the distribution of media. Similarly, the introduction of photography affected only one type of cultural communication—still images. In contrast, the computer media revolution affects all stages of communication, including acquisition, manipulation, storage, and distribution; it also affects all types of media—texts, still images, moving images, sound, and spatial constructions.

How shall we begin to map out the effects of this fundamental shift? What are the ways in which the use of computers to record, store, create, and distribute media makes it "new"?

In the section "Media and Computation," I show that new media represents a convergence of two separate historical trajectories: computing and media technologies. Both begin in the 1830s with Babbage's Analytical Engine and Daguerre's daguerreotype. Eventually, in the middle of the twentieth century, a modern digital computer is developed to perform calculations on numerical data more efficiently; it takes over from numerous mechanical tabulators and calculators widely employed by companies and governments since the turn of the century. In a parallel movement, we witness the rise of modern media technologies that allow the storage of images, image sequences, sounds, and text using different material forms—photographic plates, film stocks, gramophone records, etc. The synthesis of these two histories? The translation of all existing media into numerical data accessible through computers. The result is new media—graphics, moving images, sounds, shapes, spaces, and texts that have become computable; that is, they comprise simply another set of computer data. In "Principles of New Media," I look at the key consequences of this new status of media. Rather than focusing on familiar categories such as interactivity or hypermedia, I suggest a different list. This list reduces all principles of new media to five—numerical representation, modularity, automation, variability, and cultural transcoding. In the last section, "What New Media Is Not," I address other principles that are often attributed to new media. I show that these principles can already be found at work in older cultural forms and media technologies such as cinema, and therefore in and of themselves are in sufficient to distinguish new media from old.

How Media Became New



On August 19, 1839, the Palace of the Institute in Paris was filled with curious Parisians who had come to hear the formal description of the new reproduction process invented by Louis Daguerre. Daguerre, already well known for his Diorama, called the new process *daguerreotype.* According to a contemporary, "a few days later, opticians' shops were crowded with amateurs panting for daguerreotype apparatus, and everywhere cameras were trained on buildings. Everyone wanted to record the view from his window, and he was lucky who at first trial got a silhouette of roof tops against the sky."[1] The media frenzy had begun. Within five months more than thirty different descriptions of the technique had been published around the world—Barcelona, Edinburgh, Naples, Philadelphia, St. Petersburg, Stockholm. At first, daguerreotypes of architecture and landscapes dominated the public's imagination; two years later, after various technical improvements to the process had been made, portrait galleries had opened everywhere—and everyone rushed to have her picture taken by the new media machine.[2]

In 1833 Charles Babbage began designing a device he called "the Analytical Engine." The Engine contained most of the key features of the modern digital computer. Punch cards were used to enter both data and instructions. This information was stored in the Engine's memory. A processing unit,

1. Quoted in Beaumont Newhall, *The History of Photography from 1839 to the Present Day,* 4th ed. (New York: Museum of Modern Art, 1964), 18.

2. Newhall, *The History of Photography,* 17–22.

which Babbage referred to as a "mill," performed operations on the data and wrote the results to memory; final results were to be printed out on a printer. The Engine was designed to be capable of doing any mathematical operation; not only would it follow the program fed into it by cards, but it would also decide which instructions to execute next, based on intermediate results. However, in contrast to the daguerreotype, not a single copy of the Engine was completed. While the invention of the daguerreotype, a modern media tool for the reproduction of reality, impacted society immediately, the impact of the computer was yet to be seen.

Interestingly, Babbage borrowed the idea of using punch cards to store information from an earlier programmed machine. Around 1800, J. M. Jacquard invented a loom that was automatically controlled by punched paper cards. The loom was used to weave intricate figurative images, including Jacquard's portrait. This specialized graphics computer, so to speak, inspired Babbage in his work on the Analytical Engine, a general computer for numerical calculations. As Ada Augusta, Babbage's supporter and the first computer programmer, put it, "The Analytical Engine weaves algebraical patterns just as the Jacquard loom weaves flowers and leaves."[3] Thus a programmed machine was already synthesizing images even before it was put to processing numbers. The connection between the Jacquard loom and the Analytical Engine is not something historians of computers make much of, since for them computer image synthesis represents just one application of the modern digital computer among thousands of others, but for a historian of new media, it is full of significance.

We should not be surprised that both trajectories—the development of modern media and the development of computers—begin around the same time. Both media machines and computing machines were absolutely necessary for the functioning of modern mass societies. The ability to disseminate the same texts, images, and sounds to millions of citizens—thus assuring the same ideological beliefs—was as essential as the ability to keep track of their birth records, employment records, medical records, and police records. Photography, film, the offset printing press, radio, and television

3. Charles Eames, *A Computer Perspective: Background to the Computer Age* (Cambridge, Mass: Harvard University Press, 1990), 18.

made the former possible while computers made possible the latter. Mass media and data processing are complementary technologies; they appear together and develop side by side, making modern mass society possible.

For a long time the two trajectories ran in parallel without ever crossing paths. Throughout the nineteenth and the early twentieth centuries, numerous mechanical and electrical tabulators and calculators were developed; they gradually became faster and their use more widespread. In a parallel movement, we witness the rise of modern media that allow the storage of images, image sequences, sounds, and texts in different material forms—photographic plates, film stock, gramophone records, etc.

Let us continue tracing this joint history. In the 1890s modern media took another step forward as still photographs were put in motion. In January 1893, the first movie studio—Edison's "Black Maria"—started producing twenty-second shorts that were shown in special Kinetoscope parlors. Two years later the Lumière brothers showed their new Cinématographie camera/projection hybrid, first to a scientific audience and later, in December 1895, to the paying public. Within a year, audiences in Johannesburg, Bombay, Rio de Janeiro, Melbourne, Mexico City, and Osaka were subjected to the new media machine, and they found it irresistible.[4] Gradually scenes grew longer, the staging of reality before the camera and the subsequent editing of samples became more intricate, and copies multiplied. In Chicago and Calcutta, London and St. Petersburg, Tokyo and Berlin, and thousands of smaller places, film images would soothe movie audiences, who were facing an increasingly dense information environment outside the theater, an environment that no longer could be adequately handled by their own sampling and data processing systems (i.e., their brains). Periodic trips into the dark relaxation chambers of movie theaters became a routine survival technique for the subjects of modern society.

The 1890s was the crucial decade not only for the development of media, but also for computing. If individual brains were overwhelmed by the amount of information they had to process, the same was true of corporations and of governments. In 1887, the U.S. Census Bureau was still

4. David Bordwell and Kristin Thompson, *Film Art: An Introduction,* 5th ed. (New York: McGraw-Hill), 15.

interpreting figures from the 1880 census. For the 1890 census, the Census Bureau adopted electric tabulating machines designed by Herman Hollerith. The data collected on every person was punched into cards; 46,804 enumerators completed forms for a total population of 62,979,766. The Hollerith tabulator opened the door for the adoption of calculating machines by business; during the next decade electric tabulators became standard equipment in insurance companies, public utility companies, railroad offices, and accounting departments. In 1911, Hollerith's Tabulating Machine Company was merged with three other companies to form the Computing-Tabulating-Recording Company; in 1914, Thomas J. Watson was chosen as its head. Ten years later its business tripled, and Watson renamed the company the "International Business Machines Corporation," or IBM.[5]

Moving into the twentieth century, the key year for the history of media and computing is 1936. British mathematician Alan Turing wrote a seminal paper entitled "On Computable Numbers." In it he provided a theoretical description of a general-purpose computer later named after its inventor: "the Universal Turing Machine." Even though it was capable of only four operations, the machine could perform any calculation that could be done by a human and could also imitate any other computing machine. The machine operated by reading and writing numbers on an endless tape. At every step the tape would be advanced to retrieve the next command, read the data, or write the result. Its diagram looks suspiciously like a film projector. Is this a coincidence?

If we believe the word *cinematograph,* which means "writing movement," the essence of cinema is recording and storing visible data in a material form. A film camera records data on film; a film projector reads it off. This cinematic apparatus is similar to a computer in one key respect: A computer's program and data also have to be stored in some medium. This is why the Universal Turing Machine looks like a film projector. It is a kind of film camera and film projector at once, reading instructions and data stored on endless tape and writing them in other locations on this tape. In fact, the development of a suitable storage medium and a method for coding data represent important parts of the prehistory of both cinema and the com-

5. Eames, *A Computer Perspective,* 22–27, 46–51, 90–91.

puter. As we know, the inventors of cinema eventually settled on using discrete images recorded on a strip of celluloid; the inventors of the computer—which needed much greater speed of access as well as the ability to quickly read and write data—eventually decided to store it electronically in a binary code.

The histories of media and computing became further entwined when German engineer Konrad Zuse began building a computer in the living room of his parents' apartment in Berlin—the same year that Turing wrote his seminal paper. Zuse's computer was the first working digital computer. One of his innovations was using punched tape to control computer programs. The tape Zuse used was actually discarded 35mm movie film.[6]

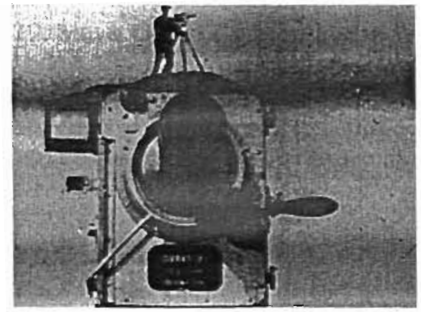
One of the surviving pieces of this film shows binary code punched over the original frames of an interior shot. A typical movie scene—two people in a room involved in some action—becomes a support for a set of computer commands. Whatever meaning and emotion was contained in this movie scene has been wiped out by its new function as data carrier. The pretense of modern media to create simulations of sensible reality is similarly canceled; media are reduced to their original condition as information carrier, nothing less, nothing more. In a technological remake of the Oedipal complex, a son murders his father. The iconic code of cinema is discarded in favor of the more efficient binary one. Cinema becomes a slave to the computer.

But this is not yet the end of the story. Our story has a new twist—a happy one. Zuse's film, with its strange superimposition of binary over iconic code, anticipates the convergence that will follow half a century later. The two separate historical trajectories finally meet. Media and computer—Daguerre's daguerreotype and Babbage's Analytical Engine, the Lumière Cinématographie and Hollerith's tabulator—merge into one. All existing media are translated into numerical data accessible for the computer. The result: graphics, moving images, sounds, shapes, spaces, and texts become computable, that is, simply sets of computer data. In short, media become new media.

This meeting changes the identity of both media and the computer itself. No longer just a calculator, control mechanism, or communication device,

6. Ibid., 120.

the computer becomes a media processor. Before, the computer could read a row of numbers, outputting a statistical result or a gun trajectory. Now it can read pixel values, blurring the image, adjusting its contrast, or checking whether it contains an outline of an object. Building on these lower-level operations, it can also perform more ambitious ones—searching image databases for images similar in composition or content to an input image, detecting shot changes in a movie, or synthesizing the movie shot itself, complete with setting and actors. In a historical loop, the computer has returned to its origins. No longer just an Analytical Engine, suitable only for crunching numbers, it has become Jacquard's loom—a media synthesizer and manipulator.



The identity of media has changed even more dramatically than that of the computer. Below I summarize some of the key differences between old and new media. In compiling this list of differences, I tried to arrange them in a logical order. That is, the the last three principles are dependent on the first two. This is not dissimilar to axiomatic logic, in which certain axioms are taken as starting points and further theorems are proved on their basis.

Not every new media object obeys these principles. They should be considered not as absolute laws but rather as general tendencies of a culture undergoing computerization. As computerization affects deeper and deeper layers of culture, these tendencies will increasingly manifest themselves.

1. Numerical Representation

All new media objects, whether created from scratch on computers or converted from analog media sources, are composed of digital code; they are numerical representations. This fact has two key consequences:

1. A new media object can be described formally (mathematically). For instance, an image or a shape can be described using a mathematical function.
2. A new media object is subject to algorithmic manipulation. For instance, by applying appropriate algorithms, we can automatically remove "noise" from a photograph, improve its contrast, locate the edges of the shapes, or change its proportions. In short, *media becomes programmable.*

When new media objects are created on computers, they originate in numerical form. But many new media objects are converted from various forms of old media. Although most readers understand the difference between analog and digital media, a few notes should be added on the terminology and the conversion process itself. This process assumes that data is originally *continuous,* that is, "the axis or dimension that is measured has no apparent indivisible unit from which it is composed."[7] Converting continuous data into a numerical representation is called *digitization.* Digitization consists of two steps: sampling and quantization. First, data is *sampled,* most often at regular intervals, such as the grid of pixels used to represent a digital image. The frequency of sampling is referred to as *resolution.* Sampling turns continuous data into *discrete* data, that is, data occurring in distinct units: people, the pages of a book, pixels. Second, each sample is *quantified,* that is, it is assigned a numerical value drawn from a defined range (such as 0–255 in the case of an 8-bit greyscale image).[8]

While some old media such as photography and sculpture are truly continuous, most involve the combination of continuous and discrete coding. One example is motion picture film: each frame is a continuous photograph, but time is broken into a number of samples (frames). Video goes one step further by sampling the frame along the vertical dimension (scan lines). Similarly, a photograph printed using a halftone process combines discrete and continuous representations. Such a photograph consists of a number of orderly dots (i.e., samples), although the diameters and areas of dots vary continuously.

As the last example demonstrates, while modern media contain levels of discrete representation, the samples are never quantified. This quantification of samples is the crucial step accomplished by digitization. But why, we may ask, are modern media technologies often in part discrete? The key assumption of modern semiotics is that communication requires discrete units. Without discrete units, there is no language. As Roland Barthes put it, "Language is, as it were, that which divides reality (for instance, the contin-

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7. Isaac Victor Kerlov and Judson Rosebush, *Computer Graphics for Designers and Artists* (New York: Van Nostrand Reinhold, 1986), 14.

8. Ibid., 21.

uous spectrum of the colors is verbally reduced to a series of discontinuous terms)."[9] In assuming that any form of communication requires a discrete representation, semioticians took human language as the prototypical example of a communication system. A human language is discrete on most scales: We speak in sentences; a sentence is made from words; a word consists of morphemes, and so on. If we follow this assumption, we may expect that media used in cultural communication will have discrete levels. At first this theory seems to work. Indeed, a film samples the continuous time of human existence into discrete frames; a drawing samples visible reality into discrete lines; and a printed photograph samples it into discrete dots. This assumption does not universally work, however: Photographs, for instance, do not have any apparent units. (Indeed, in the 1970s semiotics was criticized for its linguistic bias, and most semioticians came to recognize that a language-based model of distinct units of meaning cannot be applied to many kinds of cultural communication.) More important, the discrete units of modern media are usually not units of meanings in the way morphemes are. Neither film frames nor halftone dots have any relation to how a film or photograph affects the viewer (except in modern art and avant-garde film—think of paintings by Roy Lichtenstein and films of Paul Sharits—which often make the "material" units of media into units of meaning).

The most likely reason modern media has discrete levels is because it emerged during the Industrial Revolution. In the nineteenth century, a new organization of production known as the factory system gradually replaced artisan labor. It reached its classical form when Henry Ford installed the first assembly line in his factory in 1913. The assembly line relied on two principles. The first was standardization of parts, already employed in the production of military uniforms in the nineteenth century. The second, newer principle was the separation of the production process into a set of simple, repetitive, and sequential activities that could be executed by workers who did not have to master the entire process and could be easily replaced.

Not surprisingly, modern media follows the logic of the factory, not only in terms of division of labor as witnessed in Hollywood film studios, animation

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9. Roland Barthes, *Elements of Semiology,* trans. Annette Lavers and Colin Smith (New York: Hill and Wang, 1968), 64.

studios, and television production, but also on the level of material organization. The invention of typesetting machines in the 1880s industrialized publishing while leading to a standardization of both type design and fonts (number and types). In the 1890s cinema combined automatically produced images (via photography) with a mechanical projector. This required standardization of both image dimensions (size, frame ratio, contrast) and temporal sampling rate. Even earlier, in the 1880s, the first television systems already involved standardization of sampling both in time and space. These modern media systems also followed factory logic in that, once a new "model" (a film, a photograph, an audio recording) was introduced, numerous identical media copies would be produced from this master. As I will show, new media follows, or actually runs ahead of, a quite different logic of post-industrial society—that of individual customization, rather than mass standardization.

2. Modularity

This principle can be called the "fractal structure of new media." Just as a fractal has the same structure on different scales, a new media object has the same modular structure throughout. Media elements, be they images, sounds, shapes, or behaviors, are represented as collections of discrete samples (pixels, polygons, voxels, characters, scripts). These elements are assembled into larger-scale objects but continue to maintain their separate identities. The objects themselves can be combined into even larger objects—again, without losing their independence. For example, a multimedia "movie" authored in popular Macromedia Director software may consist of hundreds of still images, QuickTime movies, and sounds that are stored separately and loaded at run time. Because all elements are stored independently, they can be modified at any time without having to change the Director "movie" itself. These "movies" can be assembled into a larger "movie," and so on. Another example of modularity is the concept of "object" used in Microsoft Office applications. When an "object" is inserted into a document (for instance, a media clip inserted into a Word document), it continues to maintain its independence and can always be edited with the program originally used to create it. Yet another example of modularity is the structure of an HTML document: With the exemption of text, it consists of a number of separate objects—GIF and JPEG images, media clips, Virtual Reality Modeling Language (VRML) scenes, Shockwave and Flash movies—which are all stored independently, locally, and/or on a network. In short, a new media object consists of independent parts, each of which consists of smaller independent parts, and so on, down to the level of the smallest "atoms"—pixels, 3-D points, or text characters.

The World Wide Web as a whole is also completely modular. It consists of numerous Web pages, each in its turn consisting of separate media elements. Every element can always be accessed on its own. Normally we think of elements as belonging to their corresponding Web sites, but this is just a convention, reinforced by commercial Web browsers. The Netomat browser by artist Maciej Wisnewski, which extracts elements of a particular media type from different Web pages (for instance, images only) and displays them together without identifying the Web sites from which they are drawn, highlights for us this fundamentally discrete and nonhierarchical organization of the Web.

In addition to using the metaphor of a fractal, we can also make an analogy between the modularity of new media and structured computer programming. Structural computer programming, which became standard in the 1970s, involves writing small and self-sufficient modules (called in different computer languages *subroutines, functions, procedures, scripts*), which are then assembled into larger programs. Many new media objects are in fact computer programs that follow structural programming style. For example, most interactive multimedia applications are written in Macromedia Director's Lingo. A Lingo program defines scripts that control various repeated actions, such as clicking on a button; these scripts are assembled into larger scripts. In the case of new media objects that are not computer programs, an analogy with structural programming still can be made because their parts can be accessed, modified, or substituted without affecting the overall structure of an object. This analogy, however, has its limits. If a particular module of a computer program is deleted, the program will not run. In contrast, as with traditional media, deleting parts of a new media object does not render it meaningless. In fact, the modular structure of new media makes such deletion and substitution of parts particularly easy. For example, since an HTML document consists of a number of separate objects each represented by a line of HTML code, it is very easy to delete, substitute, or add new objects. Similarly, since in Photoshop the parts of a digital image usually kept placed on separate layers, these parts can be deleted and substituted with a click of a button.

3. Automation

The numerical coding of media (principle 1) and the modular structure of a media object (principle 2) allow for the automation of many operations involved in media creation, manipulation, and access. Thus human intentionality can be removed from the creative process, at least in part.[10]

Following are some examples of what can be called "low-level" automation of media creation, in which the computer user modifies or creates from scratch a media object using templates or simple algorithms. These techniques are robust enough so that they are included in most commercial software for image editing, 3-D graphics, word processing, graphics layout, and so forth. Image-editing programs such as Photoshop can automatically correct scanned images, improving contrast range and removing noise. They also come with filters that can automatically modify an image, from creating simple variations of color to changing the whole image as though it were painted by Van Gogh, Seurat, or another brand-name artist. Other computer programs can automatically generate 3-D objects such as trees, landscapes, and human figures as well as detailed ready-to-use animations of complex natural phenomena such as fire and waterfalls. In Hollywood films, flocks of birds, ant colonies, and crowds of people are automatically created by AL (artificial life) software. Word processing, page layout, presentation, and Web creation programs come with "agents" that can automatically create the layout of a document. Writing software helps the user to create literary narratives using highly formalized genre conventions. Finally, in what may be the most familiar experience of automated media generation, many Web sites automatically generate Web pages on the fly when the user reaches the site. They assemble the information from databases and format it using generic templates and scripts.

Researchers are also working on what can be called "high-level" automation of media creation, which requires a computer to understand, to a certain degree, the meanings embedded in the objects being generated, that is, their

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10. I discuss particular cases of computer automation of visual communication in more detail in "Automation of Sight from Photography to Computer Vision," *Electronic Culture: Technology and Visual Representation,* ed. by Timothy Druckrey and Michael Sand (New York: Aperture, 1996), 229–239; and in "Mapping Space: Perspective, Radar, and Computer Graphics," *SIGGRAPH '93 Visual Proceedings,* ed. by Thomas Linehan (New York: ACM, 1993), 143–147.

semantics. This research can be seen as part of a larger project of artificial intelligence (AI). As is well known, the AI project has achieved only limited success since its beginnings in the 1950s. Correspondingly, work on media generation that requires an understanding of semantics is also in the research stage and is rarely included in commercial software. Beginning in the 1970s, computers were often used to generate poetry and fiction. In the 1990s, frequenters of Internet chat rooms became familiar with "bots"—computer programs that simulate human conversation. Researchers at New York University designed a "virtual theater" composed of a few "virtual actors" who adjusted their behavior in real-time in response to a user's actions.[11] The MIT Media Lab developed a number of different projects devoted to "high-level" automation of media creation and use: a "smart camera" that, when given a script, automatically follows the action and frames the shots;[12] ALIVE, a virtual environment where the user interacts with animated characters;[13] and a new kind of human-computer interface where the computer presents itself to a user as an animated talking character. The character, generated by a computer in real-time, communicates with the through user natural language; it also tries to guess the user's emotional state and to adjust the style of interaction accordingly.[14]

The area of new media where the average computer user encountered AI in the 1990s was not, however, the human-computer interface, but computer games. Almost every commercial game included a component called an "AI engine," which stands for the part of the game's computer code that controls its characters—car drivers in a car race simulation, enemy forces in a strategy game such as *Command and Conquer,* single attackers in first-person shooters such as *Quake.* AI engines use a variety of approaches to simulate human intelligence, from rule-based systems to neural networks. Like AI expert systems, the characters in computer games have expertise in some well-defined but narrow area such as attacking the user. But because computer games are

11. http://www.mrl.nyu.edu/improv/.

12. http://www-white.media.mit.edu/vismod/demos/smartcam/.

13. http://pattie.www.media.mit.edu/people/pattie/CACM-95/alife-cacm95.html.

14. This research was pursued at different groups at the MIT lab. See, for instance, the home page of the Gesture and Narrative Language Group, http://gn.www.media.mit.edu/groups/gn/.

highly codified and rule-based, these characters function very effectively; that is, they effectively respond to the few things the user is allowed to ask them to do: run forward, shoot, pick up an object. They cannot do anything else, but then the game does not provide the opportunity for the user to test this. For instance, in a martial arts fighting game, I can't ask questions of my opponent, nor do I expect him or her to start a conversation with me. All I can do is "attack" my opponent by pressing a few buttons, and within this highly codified situation the computer can "fight" me back very effectively. In short, computer characters can display intelligence and skills only because programs place severe limits on our possible interactions with them. Put differently, computers can pretend to be intelligent only by tricking us into using a very small part of who we are when we communicate with them. At the 1997 SIGGRAPH (Special Interest Group on Computer Graphics of the Association for Computing Machinery) convention, for example, I played against both human and computer-controlled characters in a VR simulation of a nonexistent sports game. All my opponents appeared as simple blobs covering a few pixels of my VR display; at this resolution, it made absolutely no difference who was human and who was not.

Along with "low-level" and "high-level" automation of media creation, another area of media use subjected to increasing automation is media access. The switch to computers as a means of storing and accessing enormous amounts of media material, exemplified by the "media assets" stored in the databases of stock agencies and global entertainment conglomerates, as well as public "media assets" distributed across numerous Web sites, created the need to find more efficient ways to classify and search media objects. Word processors and other text-management software has long provided the capacity to search for specific strings of text and automatically index documents. The UNIX operating system also included powerful commands to search and filter text files. In the 1990s software designers started to provide media users with similar abilities. Virage introduced Virage VIR Image Engine, which allows one to search for visually similar image content among millions of images as well as a set of video search tools to allow indexing and searching video files.[15] By the end of the 1990s, the key Web search engines

15. See http://www.virage.com/products.

already included the option to search the Internet by specific media such as images, video, and audio.

The Internet, which can be thought of as one huge distributed media database, also crystallized the basic condition of the new information society: overabundance of information of all kinds. One response was the popular idea of software "agents" designed to automate searching for relevant information. Some agents act as filters that deliver small amounts of information given the user's criteria. Others allow users to tap into the expertise of other users, following their selections and choices. For example, the MIT Software Agents Group developed such agents as BUZZwatch, which "distills and tracks trends, themes, and topics within collections of texts across time" such as Internet discussions and Web pages; Letizia, "a user interface agent that assists a user browsing the World Wide Web by . . . scouting ahead from the user's current position to find Web pages of possible interest"; and Footprints, which "uses information left by other people to help you find your way around."[16]

By the end of the twentieth century, the problem was no longer how to create a new media object such as an image; the new problem was how to find an object that already exists somewhere. If you want a particular image, chances are it already exists—but it may be easier to create one from scratch than to find an existing one. Beginning in the nineteenth century, modern society developed technologies that automated media creation—the photo camera, film camera, tape recorder, videorecorder, etc. These technologies allowed us, over the course of 150 years, to accumulate an unprecedented amount of media materials—photo archives, film libraries, audio archives. This led to the next stage in media evolution—the need for new technologies to store, organize, and efficiently access these materials. The new technologies are all computer-based—media databases; hypermedia and other ways of organizing media material such as the hierarchical file system itself; text management software; programs for content-based search and retrieval. Thus automation of media access became the next logical stage of the process that had been put into motion when the first photograph was taken. The emergence of new media coincides with this second stage of a

16. http://agents.www.media.mit.edu/groups/agents/projects/.

media society, now concerned as much with accessing and reusing existing media objects as with creating new ones.[17]

4. Variability

A new media object is not something fixed once and for all, but something that can exist in different, potentially infinite versions. This is another consequence of the numerical coding of media (principle 1) and the modular structure of a media object (principle 2).

Old media involved a human creator who manually assembled textual, visual, and/or audio elements into a particular composition or sequence. This sequence was stored in some material, its order determined once and for all. Numerous copies could be run off from the master, and, in perfect correspondence with the logic of an industrial society, they were all identical. New media, in contrast, is characterized by variability. (Other terms that are often used in relation to new media and that might serve as appropriate synonyms of *variable* are *mutable* and *liquid.*) Instead of identical copies, a new media object typically gives rise to many different versions. And rather than being created completely by a human author, these versions are often in part automatically assembled by a computer. (The example of Web pages automatically generated from databases using templates created by Web designers can be invoked here as well.) Thus the principle of variability is closely connected to automation.

Variability would also not be possible without modularity. Stored digitally, rather than in a fixed medium, media elements maintain their separate identities and can be assembled into numerous sequences under program control. In addition, because the elements themselves are broken into discrete samples (for instance, an image is represented as an array of pixels), they can be created and customized on the fly.

The logic of new media thus corresponds to the postindustrial logic of "production on demand" and "just in time" delivery logics that were themselves made possible by the use of computers and computer networks at all stages of manufacturing and distribution. Here, the "culture industry"

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17. See my "Avant-Garde as Software," in *Ostranenie,* ed. Stephen Kovats (Frankfurt and New York: Campus Verlag, 1999) (http://visarts.ucsd.edu/~manovich).

(a term coined by Theodor Adorno in the 1930s) is actually ahead of most other industries. The idea that a customer might determine the exact features of her desired car at the showroom, transmit the specs to the factory, and hours later receive the car, remains a dream, but in the case of computer media, such immediacy is reality. Because the same machine is used as both showroom and factory, that is, the same computer generates and displays media—and because the media exists not as a material object but as data that can be sent through wires at the speed of light, the customized version created in response to the user's input is delivered almost immediately. Thus, to continue with the same example, when you access a Web site, the server immediately assembles a customized Web page.

Here are some particular cases of the variability principle (most of them will be discussed in more detail in later chapters):

1. Media elements are stored in a *media database;* a variety of end-user objects, which vary in resolution and in form and content, can be generated, either beforehand or on demand, from this database. At first, we might think that this is simply a particular technological implementation of the variability principle, but, as I will show in the "Database" section, in a computer age the database comes to function as a cultural form in its own right. It offers a particular model of the world and of the human experience. It also affects how the user conceives the data it contains.
2. It becomes possible to separate the levels of "content" (data) and interface. *A number of different interfaces can be created from the same data.* A new media object can be defined as one or more interfaces to a multimedia database.[18]
3. *Information about the user can be used by a computer program to customize automatically the media composition as well as to create elements themselves.* Examples: Web sites use information about the type of hardware and browser or user's network address to customize automatically the site the user will see; interactive computer installations use information about the user's body movements to generate sounds, shapes, and images, or to control the behavior of artificial creatures.

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18. For an experiment in creating different multimedia interfaces to the same text, see my *Freud-Lissitzky Navigator* (http://visarts.ucsd.edu/~manovich/FLN).

4. A particular case of this customization is *branching-type interactivity* (sometimes also called "*menu-based* interactivity"). The term refers to programs in which all the possible objects the user can visit form a branching tree structure. When the user reaches a particular object, the program presents her with choices and allows her to choose among them. Depending on the value chosen, the user advances along a particular branch of the tree. In this case the information used by a program is the output of the user's cognitive process, rather than the network address or body position.

5. *Hypermedia* is another popular new media structure, which is conceptually close to branching-type interactivity (because quite often the elements are connected using a branch tree structure). In hypermedia, the multimedia elements making a document are connected through hyperlinks. Thus the elements and the structure are independent of each other—rather than hard-wired together, as in traditional media. The World Wide Web is a particular implementation of hypermedia in which the elements are distributed throughout the network. Hypertext is a particular case of hypermedia that uses only one media type—text. How does the principle of variability work in this case? We can think of all possible paths through a hypermedia document as being different versions of it. By following the links, the user retrieves a particular version of a document.

6. Another way in which different versions of the same media objects are commonly generated in computer culture is through *periodic updates.* For instance, modern software applications can periodically check for updates on the Internet and then download and install these updates, sometimes without any action on the part of the user. Most Web sites are also periodically updated either manually or automatically, when the data in the databases that drive the sites changes. A particularly interesting case of this "updateability" feature is those sites that continuously update information such as stock prices or weather.

7. One of the most basic cases of the variability principle is *scalability,* in which different versions of the same media object can be generated at various sizes or levels of detail. The metaphor of a map is useful in thinking about the scalability principle. If we equate a new media object with a physical territory, different versions of this object are like maps of this territory generated at different scales. Depending on the scale chosen, a map provides more or less detail about the territory. Indeed, different versions of a new media object may vary strictly quantitatively, that is, in the amount of de-

tail present: For instance, a full-size image and its icon, automatically generated by Photoshop; a full text and its shorter version, generated by the "Autosummarize" command in Microsoft Word; or the different versions that can be created using the "Outline" command in Word. Beginning with version 3 (1997), Apple's QuickTime format made it possible to embed a number of different versions that differ in size within a single QuickTime movie; when a Web user accesses the movie, a version is automatically selected depending on connection speed. A conceptually similar technique called "distancing" or "level of detail" is used in interactive virtual worlds such as VRML scenes. A designer creates a number of models of the same object, each with progressively less detail. When the virtual camera is close to the object, a highly detailed model is used; if the object is far away, a less detailed version is automatically substituted by a program to save unnecessary computation of detail that cannot be seen anyway.

New media also allow us to create versions of the same object that differ from each other in more substantial ways. Here the comparison with maps of different scales no longer works. Examples of commands in commonly used software packages that allow the creation of such qualitatively different versions are "Variations" and "Adjustment layers" in Photoshop 5 and the "writing style" option in Word's "Spelling and Grammar" command. More examples can be found on the Internet where, beginning in the mid-1990s, it become common to create a few different versions of a Web site. The user with a fast connection can choose a rich multimedia version, whereas the user with a slow connection can choose a more bare-bones version that loads faster.

Among new media artworks, David Blair's *Wax Web,* a Web site that is an "adaptation" of an hour-long video narrative, offers a more radical implementation of the scalability principle. While interacting with the narrative, the user can change the scale of representation at any point, going from an image-based outline of the movie to a complete script or a particular shot, or a VRML scene based on this shot, and so on.[19] Another example of how use of the scalability principle can create a dramatically new experience of an old

19. http://jefferson.village.virginia.edu/wax/.

media object is Stephen Mamber's database-driven representation of Hitchcock's *The Birds.* Mamber's software generates a still for every shot of the film; it then automatically combines all the stills into a rectangular matrix one shot per cell. As a result, time is spatialized, similar to the process in Edison's early Kinetoscope cylinders. Spatializing the film allows us to study its different temporal structures, which would be hard to observe otherwise. As in *WaxWeb,* the user can at any point change the scale of representation, going from a complete film to a particular shot.

As can be seen, the principle of variability is useful in allowing us to connect many important characteristics of new media that on first sight may appear unrelated. In particular, such popular new media structures as branching (or menu) interactivity and hypermedia can be seen as particular instances of the variability principle. In the case of branching interactivity, the user plays an active role in determining the order in which already generated elements are accessed. This is the simplest kind of interactivity; more complex kinds are also possible in which both the elements and the structure of the whole object are either modified or generated on the fly in response to the user's interaction with a program. We can refer to such implementations as *open interactivity* to distinguish them from the *closed interactivity* that uses fixed elements arranged in a fixed branching structure. Open interactivity can be implemented using a variety of approaches, including procedural and object-oriented computer programming, AI, AL, and neural networks.

As long as there exists some kernel, some structure, some prototype that remains unchanged throughout the interaction, open interactivity can be thought of as a subset of the variability principle. Here a useful analogy can be made with Wittgenstein's theory of family resemblance, later developed into the theory of prototypes by cognitive psychologists. In a family, a number of relatives will share some features, although no single family member may possess all of the features. Similarly, according to the theory of prototypes, the meanings of many words in a natural language derive not through logical definition but through proximity to a certain prototype.

Hypermedia, the other popular structure of new media, can also be seen as a particular case of the more general principle of variability. According to the definition by Halasz and Schwartz, hypermedia systems "provide their users with the ability to create, manipulate and/or examine a network of informationcontaining nodes interconnected by relational links."[20] Because in new media individual media elements (images, pages of text, etc.) always retain their individual identity (the principle of modularity), they can be "wired" together into more than one object. Hyperlinking is a particular way of achieving this wiring. A hyperlink creates a connection between two elements, for example, between two words in two different pages or a sentence on one page and an image in another, or two different places within the same page. Elements connected through hyperlinks can exist on the same computer or on different computers connected on a network, as in the case of the World Wide Web.

If in old media elements are "hardwired" into a unique structure and no longer maintain their separate identity, in hypermedia elements and structure are separate from each other. The structure of hyperlinks—typically a branching tree—can be specified independently from the contents of a document. To make an analogy with the grammar of a natural language as described in Noam Chomsky's early linguistic theory,[21] we can compare a hypermedia structure that specifies connections between nodes with the deep structure of a sentence; a particular hypermedia text can then be compared with a particular sentence in a natural language. Another useful analogy is computer programming. In programming, there is clear separation between algorithms and data. An algorithm specifies the sequence of steps to be performed on any data, just as a hypermedia structure specifies a set of navigation paths (i.e., connections between nodes) that potentially can be applied to any set of media objects.

The principle of variability exemplifies how, historically, changes in media technologies are correlated with social change. If the logic of old media corresponded to the logic of industrial mass society, the logic of new media fits the logic of the postindustrial society, which values individuality over conformity. In industrial mass society everyone was supposed to enjoy the same goods—and to share the same beliefs. This was also the logic of media technology. A media object was assembled in a media factory (such as a Hollywood studio). Millions of identical copies were produced from a

20. Frank Halasz and Mayer Schwartz, "The Dexter Hypertext Reference Model," *Communication of the ACM* (New York: ACM, 1994), 30.

21. Noam Chomsky, *Syntactic Structures* (The Hague and Paris: Mouton, 1957).

master and distributed to all the citizens. Broadcasting, cinema, and print media all followed this logic.

In a postindustrial society, every citizen can construct her own custom lifestyle and "select" her ideology from a large (but not infinite) number of choices. Rather than pushing the same objects/information to a mass audience, marketing now tries to target each individual separately. The logic of new media technology reflects this new social logic. Every visitor to a Web site automatically gets her own custom version of the site created on the fly from a database. The language of the text, the contents, the ads displayed—all these can be customized. According to a report in *USA Today* (9 November 1999), "Unlike ads in magazines or other real-world publications, 'banner' ads on Web pages change with every page view. And most of the companies that place the ads on the Web site track your movements across the Net, 'remembering' which ads you've seen, exactly when you saw them, whether you clicked on them, where you were at the time, and the site you have visited just before."[22]

Every hypertext reader gets her own version of the complete text by selecting a particular path through it. Similarly, every user of an interactive installation gets her own version of the work. And so on. In this way new media technology acts as the most perfect realization of the utopia of an ideal society composed of unique individuals. New media objects assure users that their choices—and therefore, their underlying thoughts and desires—are unique, rather than preprogrammed and shared with others. As though trying to compensate for their earlier role in making us all the same, descendants of the Jacquard loom, the Hollerith tabulator, and Zuse's cinema-computer are now working to convince us that we are all unique.

The principle of variability as presented here has some parallels to the concept of "variable media," developed by the artist and curator Jon Ippolito.[23] I believe that we differ in two key respects. First, Ippolito uses variability to describe a characteristic shared by recent conceptual and some digital art, whereas I see variability as a basic condition of all new media, not

22. "How Marketers 'Profile' Users," *USA Today* 9 November 1999, 2A.

23. See http://www.three.org. Our conversations helped me to clarify my ideas, and I am very grateful to Jon for the ongoing exchange.

only art. Second, Ippolito follows the tradition of conceptual art in which an artist can vary any dimension of the artwork, even its content; my use of the term aims to reflect the logic of mainstream culture in that versions of the object share some well-defined "data." This "data," which can be a well-known narrative (*Psycho*), an icon (Coca-Cola sign), a character (Mickey Mouse), or a famous star (Madonna), is referred to in the media industry as "property." Thus all cultural projects produced by Madonna will be automatically united by her name. Using the theory of prototypes, we can say that the property acts as a prototype, and different versions are derived from this prototype. Moreover, when a number of versions are being commercially released based on some "property," usually one of these versions is treated as the source of the "data," with others positioned as being derived from this source. Typically, the version that is in the same media as the original "property" is treated as the source. For instance, when a movie studio releases a new film, along with a computer game based on it, product tie-ins, music written for the movie, etc., the film is usually presented as the "base" object from which other objects are derived. So when George Lucas releases a new *Star Wars* movie, the original property—the original *Star Wars* trilogy—is referenced. The new movie becomes the "base" object, and all other media objects released along with it refer to this object. Conversely, when computer games such as *Tomb Raider* are remade into movies, the original computer game is presented as the "base" object.

Although I deduce the principle of variability from more basic principles of new media—numerical representation and modularity of information—the principle can also be seen as a consequence of the computer's way of representing data—and modeling the world itself—as variables rather than constants. As new media theorist and architect Marcos Novak notes, a computer—and computer culture in its wake—substitutes every constant with a variable.[24] In designing all functions and data structures, a computer programmer tries always to use variables rather than constants. On the level of the human-computer interface, this principle means that the user is given many options to modify the performance of a program or a media object, be it a

24. Marcos Novak, lecture at the "Interactive Frictions" conference, University of Southern California, Los Angeles, 6 June 1999.

computer game, Web site, Web browser, or the operating system itself. The user can change the profile of a game character, modify how folders appear on the desktop, how files are displayed, what icons are used, and so forth. If we apply this principle to culture at large, it would mean that every choice responsible for giving a cultural object a unique identity can potentially remain always open. Size, degree of detail, format, color, shape, interactive trajectory, trajectory through space, duration, rhythm, point of view, the presence or absence of particular characters, the development of plot—to name just a few dimensions of cultural objects in different media—can all be defined as variables, to be freely modified by a user.

Do we want, or need, such freedom? As the pioneer of interactive filmmaking Grahame Weinbren argues, in relation to interactive media, making a choice involves a moral responsibility.[25] By passing on these choices to the user, the author also passes on the responsibility to represent the world and the human condition in it. (A parallel is the use of phone or Web-based automated menu systems by big companies to handle their customers; while companies have turned to such systems in the name of "choice" and "freedom," one of the effects of this type of automation is that labor is passed from the company's employees to the customer. If before a customer would get the information or buy the product by interacting with a company employee, now she has to spend her own time and energy navigating through numerous menus to accomplish the same result.) The moral anxiety that accompanies the shift from constants to variables, from traditions to choices in all areas of life in a contemporary society, and the corresponding anxiety of a writer who has to portray it, is well rendered in the closing passage of a short story by the contemporary American writer Rick Moody (the story is about the death of his sister):[26]

I should fictionalize it more, I should conceal myself. I should consider the responsibilities of characterization, I should conflate her two children into one, or reverse

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25. Grahame Weinbren, "In the Ocean of Streams of Story," *Millennium Film Journal* 28 (Spring 1995), http://www.sva.edu/MFJ/journalpages/MFJ28/GWOCEAN.HTML.

26. Rick Moody, *Demonology*, first published in *Conjunctions*, reprinted in *The KGB Bar Reader*, quoted in Vince Passaro, "Unlikely Stories," *Harper's Magazine* vol. 299, no. 1791 (August 1999), 88–89.

their genders, or otherwise alter them, I should make her boyfriend a husband, I should explicate all the tributaries of my extended family (its remarriages, its internecine politics), I should novelize the whole thing, I should make it multigenerational, I should work in my forefathers (stonemasons and newspapermen), I should let artifice create an elegant surface, I should make the events orderly, I should wait and write about it later, I should wait until I'm not angry, I shouldn't clutter a narrative with fragments, with mere recollections of good times, or with regrets, I should make Meredith's death shapely and persuasive, not blunt and disjunctive, I shouldn't have to think the unthinkable, I shouldn't have to suffer, I should address her here directly (these are the ways I miss you), I should write only of affection, I should make our travels in this earthly landscape safe and secure, I should have a better ending, I shouldn't say her life was short and often sad, I shouldn't say she had demons, as I do too.

5. Transcoding

Beginning with the basic, "material" principles of new media—numeric coding and modular organization—we moved to more "deep" and far-reaching ones—automation and variability. The fifth and last principle of cultural transcoding aims to describe what in my view is the most substantial consequence of the computerization of media. As I have suggested, computerization turns media into computer data. While from one point of view, computerized media still displays structural organization that makes sense to its human users—images feature recognizable objects; text files consist of grammatical sentences; virtual spaces are defined along the familiar Cartesian coordinate system; and so on—from another point of view, its structure now follows the established conventions of the computer's organization of data. Examples of these conventions are different data structures such as lists, records, and arrays; the already-mentioned substitution of all constants by variables; the separation between algorithms and data structures; and modularity.

The structure of a computer image is a case in point. On the level of representation, it belongs on the side of human culture, automatically entering in dialog with other images, other cultural "semes" and "mythemes." But on another level, it is a computer file that consists of a machine-readable header, followed by numbers representing color values of its pixels. On this level it enters into a dialog with other computer files. The dimensions of this dialog are not the image's content, meanings, or formal qualities, but rather file size, file type, type of compression used, file format, and so on. In short, these dimensions belong to the computer's own cosmogony rather than to human culture.

Similarly, new media in general can be thought of as consisting of two distinct layers—the "cultural layer" and the "computer layer." Examples of categories belonging to the cultural layer are the encyclopedia and the short story; story and plot; composition and point of view; mimesis and catharsis, comedy and tragedy. Examples of categories in the computer layer are process and packet (as in data packets transmitted through the network); sorting and matching; function and variable; computer language and data structure.

Because new media is created on computers, distributed via computers, and stored and archived on computers, the logic of a computer can be expected to significantly influence the traditional cultural logic of media; that is, we may expect that the computer layer will affect the cultural layer. The ways in which the computer models the world, represents data, and allows us to operate on it; the key operations behind all computer programs (such as search, match, sort, and filter); the conventions of HCI—in short, what can be called the computer's ontology, epistemology, and pragmatics—influence the cultural layer of new media, its organization, its emerging genres, its contents.

Of course, what I call "the computer layer" is not itself fixed but rather changes over time. As hardware and software keep evolving and as the computer is used for new tasks and in new ways, this layer undergoes continuous transformation. The new use of the computer as a media machine is a case in point. This use is having an effect on the computer's hardware and software, especially on the level of the human-computer interface, which increasingly resembles the interfaces of older media machines and cultural technologies—VCR, tape player, photo camera.

In summary, the computer layer and the culture layer influence each other. To use another concept from new media, we can say that they are being composited together. The result of this composite is a new computer culture—a blend of human and computer meanings, of traditional ways in which human culture modeled the world and the computer's own means of representing it.

Throughout the book, we will encounter many examples of the principle of transcoding at work. For instance, in "The Language of Cultural Interfaces," we will look at how conventions of the printed page, cinema, and traditional HCI interact in the interfaces of Web sites, CD-ROMs, virtual spaces, and computer games.

The "Database" section will discuss how a database, originally a computer technology to organize and access data, is becoming a new cultural form in its own right. But we can also reinterpret some of the principles of new media already discussed as consequences of the transcoding principle. For instance, hypermedia can be understood as one cultural effect of the separation between an algorithm and a data structure, essential to computer programming. Just as in programming, where algorithms and data structures exist independently of each other, in hypermedia data is separated from the navigation structure. Similarly, the modular structure of new media can be seen as an effect of the modularity in structural computer programming. Just as a structural computer program consists of smaller modules that in turn consist of even smaller modules, a new media object has a modular structure.

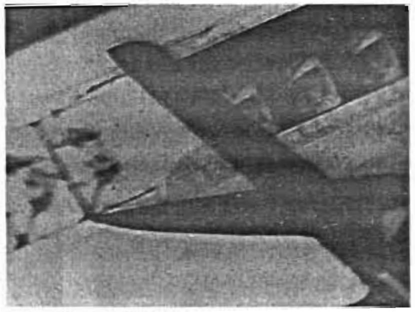
In new media lingo, to "transcode" something is to translate it into another format. The computerization of culture gradually accomplishes similar transcoding in relation to all cultural categories and concepts. That is, cultural categories and concepts are substituted, on the level of meaning and/or language, by new ones that derive from the computer's ontology, epistemology, and pragmatics. New media thus acts as a forerunner of this more general process of cultural reconceptualization.

Given the process of "conceptual transfer" from the computer world to culture at large, and given the new status of media as computer data, what theoretical framework can we use to understand it? On one level new media is old media that has been digitized, so it seems appropriate to look at new media using the perspective of media studies. We may compare new media and old media such as print, photography, or television. We may also ask about the conditions of distribution and reception and patterns of use. We may also ask about similarities and differences in the material properties of each medium and how these affect their aesthetic possibilities.

This perspective is important and I am using it frequently in this book, but it is not sufficient. It cannot address the most fundamental quality of new media that has no historical precedent—programmability. Comparing new media to print, photography, or television will never tell us the whole story. For although from one point of view new media is indeed another type of media, from another it is simply a particular type of computer data, something stored in files and databases, retrieved and sorted, run through algorithms and written to the output device. That the data represent pixels and that this device happens to be an output screen is beside the point. The computer may perform perfectly the role of the Jacquard loom, but underneath it is fundamentally Babbage's Analytical Engine—after all, this was its identity for 150 years. New media may look like media, but this is only the surface.

New media calls for a new stage in media theory whose beginnings can be traced back to the revolutionary works of Harold Innis in the 1950s and Marshall McLuhan in the 1960s. To understand the logic of new media, we need to turn to computer science. It is there that we may expect to find the new terms, categories, and operations that characterize media that became programmable. *From media studies, we move to something that can be called "software studies"—from media theory to software theory.* The principle of transcoding is one way to start thinking about software theory. Another way, which this book experiments with, is to use concepts from computer science as categories of new media theory. Examples here are "interface" and "database." And last but not least, along with analyzing "material" and logical principles of computer hardware and software, we can also look at the human-computer interface and the interfaces of software applications used to author and access new media objects. The two chapters that follow are devoted to these topics.

What New Media Is Not



Having proposed a list of the key differences between new and old media, I now would like to address other potential candidates. Following are some of the popularly held notions about the difference between new and old media that I will subject to scrutiny:

1. New media is analog media converted to a digital representation. In contrast to analog media, which is continuous, digitally encoded media is discrete.
2. All digital media (texts, still images, visual or audio time data, shapes, 3-D spaces) share the same digital code. This allows different media types to be displayed using one machine—a computer—which acts as a multimedia display device.
3. New media allows for random access. In contrast to film or videotape, which store data sequentially, computer storage devices make it possible to access any data element equally fast.
4. Digitization inevitably involves loss of information. In contrast to an analog representation, a digitally encoded representation contains a fixed amount of information.
5. In contrast to analog media where each successive copy loses quality, digitally encoded media can be copied endlessly without degradation.
6. New media is interactive. In contrast to old media where the order of presentation is fixed, the user can now interact with a media object. In the process of interaction the user can choose which elements to display or which paths to follow, thus generating a unique work. In this way the user becomes the co-author of the work.

Cinema as New Media

If we place new media within a longer historical perspective, we will see that many of the principles above are not unique to new media, but can be found in older media technologies as well. I will illustrate this fact by using the example of the technology of cinema.

> (1) New media is analog media converted to a digital representation. In contrast to analog media, which is continuous, digitally encoded media is discrete.

Indeed, any digital representation consists of a limited number of samples. For example, a digital still image is a matrix of pixels—a 2-D sampling of space. However, cinema was from its beginnings based on sampling—the sampling of time. Cinema sampled time twenty-four times a second. So we can say that cinema prepared us for new media. All that remained was to take this already discrete representation and to quantify it. But this is simply a mechanical step; what cinema accomplished was a much more difficult conceptual break—from the continuous to the discrete.

Cinema is not the only media technology emerging toward the end of the nineteenth century that employed a discrete representation. If cinema sampled time, fax transmission of images, starting in 1907, sampled a 2-D space; even earlier, the first television experiments (Carey 1875; Nipkow 1884) already involved sampling of both time and space.[27] However, reaching mass popularity much earlier than these other technologies, cinema was the first to make the principle of discrete representation of the visual public knowledge.

> (2) All digital media (texts, still images, visual or audio time data, shapes, 3-D spaces) share the same digital code. This allows different media types to be displayed using one machine—a computer—which acts as a multimedia display device.

Although computer multimedia became commonplace only around 1990, filmmakers had been combining moving images, sound, and text

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27. Albert Abramson, *Electronic Motion Pictures: A History of the Television Camera* (Berkeley: University of California Press, 1955), 15–24.

(whether the intertitles of the silent era or the title sequences of the later period) for a whole century. Cinema was thus the original modern "multimedia." We can also point to much earlier examples of multiple-media displays, such as medieval illuminated manuscripts that combine text, graphics, and representational images.

> (3) New media allow for random access. In contrast to film or videotape, which store data sequentially, computer storage devices make it possible to access any data element equally fast.

For example, once a film is digitized and loaded in the computer's memory, any frame can be accessed with equal ease. Therefore, if cinema sampled time but still preserved its linear ordering (subsequent moments of time become subsequent frames), new media abandons this "human-centered" representation altogether—to put represented time fully under human control. Time is mapped onto two-dimensional space, where it can be managed, analyzed, and manipulated more easily.

Such mapping was already widely used in the nineteenth-century cinema machines. The Phenakisticope, the Zootrope, the Zoopraxiscope, the Tachyscope, and Marey's photographic gun were all based on the same principle—placing a number of slightly different images around the perimeter of a circle. Even more striking is the case of Thomas Edison's first cinema apparatus. In 1887 Edison and his assistant, William Dickson, began experiments to adopt the already proven technology of a phonograph record for recording and displaying motion pictures. Using a special picture-recording camera, tiny pinpoint-size photographs were placed in spirals on a cylindrical cell similar in size to the phonography cylinder. A cylinder was to hold 42,000 images, each so small (1/32 inch wide) that a viewer would have to look at them through a microscope.[28] The storage capacity of this medium was twenty-eight minutes—twenty-eight minutes of continuous time taken apart, flattened on a surface, and mapped onto a two-dimensional grid. (In short, time was prepared for manipulation and reordering, something soon to be accomplished by film editors.)

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28. Charles Musser, *The Emergence of Cinema: The American Screen to 1907* (Berkeley: University of California Press, 1994), 65.

The Myth of the Digital

Discrete representation, random access, multimedia—cinema already contained these principles. So they cannot help us to separate new media from old media. Let us continue interrogating the remaining principles. If many principles of new media turn out to be not so new, what about the idea of digital representation? Surely, this is the one idea that radically redefines media? The answer is not so straightforward, however, because this idea acts as an umbrella for three unrelated concepts—analog-to-digital conversion (digitization), a common representational code, and numerical representation. Whenever we claim that some quality of new media is due to its digital status, we need to specify which of these three concepts is at work. For example, the fact that different media can be combined into a single digital file is due to the use of a common representational code, whereas the ability to copy media without introducing degradation is an effect of numerical representation.

Because of this ambiguity, I try to avoid using the word *digital* in this book. In "Principles of New Media" I showed that numerical representation is the one really crucial concept of the three. Numerical representation turns media into computer data, thus making it programmable. And this indeed radically changes the nature of media.

In contrast, as I will show below, the alleged principles of new media that are often deduced from the concept of digitization—that analog-to-digital conversion inevitably results in a loss of information and that digital copies are identical to the original—do not hold up under closer examination; that is, although these principles are indeed logical consequences of digitization, they do not apply to concrete computer technologies in the way in which they are currently used.

> (4) Digitization inevitably involves loss of information. In contrast to an analog representation, a digitally encoded representation contains a fixed amount of information.

In his important study of digital photography *The Reconfigured Eye,* William Mitchell explains this principle as follows: "There is an indefinite amount of information in a continuous-tone photograph, so enlargement usually reveals more detail but yields a fuzzier and grainier picture. . . . A digital image, on the other hand, has precisely limited spatial and tonal resolution and contains a fixed amount of information."[29] From a logical point of view, this principle is a correct deduction from the idea of digital representation. A digital image consists of a finite number of pixels, each having a distinct color or tonal value, and this number determines the amount of detail an image can represent. Yet in reality this difference does not matter. By the end of the 1990s, even cheap consumer scanners were capable of scanning images at resolutions of 1,200 or 2,400 pixels per inch. So while a digitally stored image is still comprised of a finite number of pixels, at such resolution it can contain much finer detail than was ever possible with traditional photography. This nullifies the whole distinction between an "indefinite amount of information in a continuous-tone photograph" and a fixed amount of detail in a digital image. The more relevant question is how much information in an image can be useful to the viewer. By the end of new media's first decade, technology had already reached the point where a digital image could easily contain much more information than anyone would ever want.

But even the pixel-based representation, which appears to be the very essence of digital imaging, cannot be taken for granted. Some computer graphics software has bypassed the main limitation of the traditional pixel grid—fixed resolution. *Live Picture,* an image-editing program, converts a pixel-based image into a set of mathematical equations. This allows the user to work with an image of virtually unlimited resolution. Another paint program, *Matador,* makes possible painting on a tiny image, which may consist of just a few pixels, as though it were a high-resolution image. (It achieves this by breaking each pixel into a number of smaller sub-pixels.) In both programs, the pixel is no longer a "final frontier"; as far as the user is concerned, it simply does not exist. Texture-mapping algorithms make the notion of a fixed resolution meaningless in a different way. They often store the same image at a number of different resolutions. During rendering, the texture map of arbitrary resolution is produced by interpolating two images that are closest to this resolution. (A similar technique is used by VR software, which stores the number of versions of a singular object at different degrees of detail.) Finally, certain compression techniques eliminate pixel-based

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29. William J. Mitchell, *The Reconfigured Eye* (Cambridge, Mass: MIT Press, 1982), 6.

representation altogether, instead representing an image via different mathematical constructs (such as transforms).

(5) In contrast to analog media where each successive copy loses quality, digitally encoded media can be copied endlessly without degradation.

Mitchell summarizes this as follows: "The continuous spatial and tonal variation of analog pictures is not exactly replicable, so such images cannot be transmitted or copied without degradation. . . . But discrete states can be replicated precisely, so a digital image that is a thousand generations away from the original is indistinguishable in quality from any one of its progenitors."[30] Therefore in digital culture, "an image file can be copied endlessly, and the copy is distinguishable from the original by its date since there is no loss of quality."[31] This is all true—in principle. In reality, however, there is actually much more degradation and loss of information between copies of digital images than between copies of traditional photographs. A single digital image consists of millions of pixels. All of this data requires considerable storage space in a computer; it also takes a long time (in contrast to a text file) to transmit over a network. Because of this, the software and hardware used to acquire, store, manipulate, and transmit digital images rely uniformly on *lossy compression*—the technique of making image files smaller by deleting some information. Examples of the technique include the JPEG format, which is used to store still images, and MPEG, which is used to store digital video on DVD. The technique involves a compromise between image quality and file size—the smaller the size of a compressed file, the more visible the visual artifacts introduced in deleting information become. Depending on the level of compression, these artifacts range from barely noticeable to quite pronounced.

One may argue that this situation is temporary, that once cheaper computer storage and faster networks become commonplace, lossy compression will disappear. Presently, however, the trend is quite the opposite, with lossy

30. Ibid., 6.

31. Ibid., 49.

compression becoming more and more the norm for representing visual information. If a single digital image already contains a lot of data, this amount increases dramatically if we want to produce and distribute moving images in a digital form. (One second of video, for instance, consists of thirty still images.) Digital television with its hundreds of channels and video on-demand services, the distribution of full-length films on DVD or over the Internet, fully digital post-production of feature films—all of these developments are made possible by lossy compression. It will be a number of years before advances in storage media and communication bandwidth will eliminate the need to compress audio-visual data. So rather than being an aberration, a flaw in the otherwise pure and perfect world of the digital, where not even a single bit of information is ever lost, lossy compression is the very foundation of computer culture, at least for now. Therefore, while in theory, computer technology entails the flawless replication of data, its actual use in contemporary society is characterized by loss of data, degradation, and noise.

The Myth of Interactivity

We have only one principle still remaining from the original list: interactivity.

> (6) New media is interactive. In contrast to old media where the order of presentation is fixed, the user can now interact with a media object. In the process of interaction the user can choose which elements to display or which paths to follow, thus generating a unique work. In this way the user becomes the co-author of the work.

As with *digital* I avoid using the word *interactive* in this book without qualifying it, for the same reason—I find the concept to be too broad to be truly useful.

In relation to computer-based media, the concept of interactivity is a tautology. Modern HCI is by definition interactive. In contrast to earlier interfaces such as batch processing, modern HCI allows the user to control the computer in real-time by manipulating information displayed on the screen. Once an object is represented in a computer, it automatically becomes interactive. Therefore, to call computer media "interactive" is meaningless—it simply means stating the most basic fact about computers.

Rather than evoking this concept by itself, I use a number of other concepts, such as menu-based interactivity, scalability, simulation, image-interface, and image-instrument, to describe different kinds of interactive structures and operations. The distinction between "closed" and "open" interactivity is just one example of this approach.

Although it is relatively easy to specify different interactive structures used in new media objects, it is much more difficult to deal theoretically with users' experiences of these structures. This aspect of interactivity remains one of the most difficult theoretical questions raised by new media. Without pretending to have a complete answer, I would like to address some aspects of the question here.

All classical, and even moreso modern, art is "interactive" in a number of ways. Ellipses in literary narration, missing details of objects in visual art, and other representational "shortcuts" require the user to fill in missing information.[32] Theater and painting also rely on techniques of staging and composition to orchestrate the viewer's attention over time, requiring her to focus on different parts of the display. With sculpture and architecture, the viewer has to move her whole body to experience the spatial structure.

Modern media and art pushed each of these techniques further, placing new cognitive and physical demands on the viewer. Beginning in the 1920s, new narrative techniques such as film montage forced audiences to bridge quickly the mental gaps between unrelated images. Film cinematography actively guided the viewer to switch from one part of a frame to another. The new representational style of semi-abstraction, which along with photography became the "international style" of modern visual culture, required the viewer to reconstruct represented objects from a bare minimum—a contour, a few patches of color, shadows cast by the objects not represented directly. Finally, in the 1960s, continuing where Futurism and Dada left off, new forms of art such as happenings, performance, and installation turned art explicitly participational—a transformation that, according to some new me-

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32. Ernst Gombrich analyzes "the beholder's share" in decoding the missing information in visual images in his classic *Art and Illusion: A Study in the Psychology of Pictorial Representation* (Princeton, N.J.: Princeton University Press, 1960).

dia theorists, prepared the ground for the interactive computer installations that appeared in the 1980s.[33]

When we use the concept of "interactive media" exclusively in relation to computer-based media, there is the danger that we will interpret "interaction" literally, equating it with physical interaction between a user and a media object (pressing a button, choosing a link, moving the body), at the expense of psychological interaction. The psychological processes of filling-in, hypothesis formation, recall, and identification, which are required for us to comprehend any text or image at all, are mistakenly identified with an objectively existing structure of interactive links.[34]

This mistake is not new; on the contrary, it is a structural feature of the history of modern media. The literal interpretation of interactivity is just the latest example of a larger modern trend to externalize mental life, a process in which media technologies—photography, film, VR—have played a key role.[35] Beginning in the nineteenth century, we witness recurrent claims by the users and theorists of new media technologies, from Francis Galton (the inventor of composite photography in the 1870s) to Hugo Munsterberg, Sergei Eisenstein and, recently, Jaron Lanier, that these technologies externalize and objectify the mind. Galton not only claimed that "the ideal faces obtained by the method of composite portraiture appear to have a great deal

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33. The notion that computer interactive art has its origins in new art forms of the 1960s is explored in Söke Dinkla, "The History of the Interface in Interactive Art," ISEA (International Symposium on Electronic Art) 1994 Proceedings (http://www.uiah.fi/bookshop/isea_proc/nextgen/08.html; "From Participation to Interaction: Toward the Origins of Interactive Art," in Lynn Hershman Leeson, ed., *Clicking In: Hot Links to a Digital Culture* (Seattle: Bay Press, 1996), 279–290. See also Simon Penny, "Consumer Culture and the Technological Imperative: The Artist in Dataspace," in Simon Penny, ed., *Critical Issues in Electronic Media* (Albany: State University of New York Press, 1993), 47–74.

34. This argument relies on a cognitivist perspective that stresses the active mental processes involved in comprehension of any cultural text. For examples of a cognitivist approach in film studies, see Bordwell and Thompson, *Film Art,* and David Bordwell, *Narration in the Fiction Film* (Madison: University of Wisconsin Press, 1989).

35. For a more detailed analysis of this trend, see my article "From the Externalization of the Psyche to the Implantation of Technology," in *Mind Revolution: Interface Brain/Computer,* ed. Florian Rötzer (Münich: Akademie Zum Dritten Jahrtausend, 1995), 90–100.

in common with . . . so-called abstract ideas" but in fact he proposed to rename abstract ideas "cumulative ideas."[36] According to Münsterberg, who was a Professor of Psychology at Harvard University and an author of one of the earliest theoretical treatments of cinema entitled *The Film: A Psychological Study* (1916), the essence of film lies in its ability to reproduce or "objectify" various mental functions on the screen: "The photoplay obeys the laws of the mind rather than those of the outer world."[37] In the 1920s Eisenstein speculated that film could be used to externalize—and control—thinking. As an experiment in this direction, he boldly conceived a screen adaptation of Marx's *Capital.* "The content of CAPITAL (its aim) is now formulated: to teach the worker to think dialectically," Eisenstein writes enthusiastically in April of 1928.[38] In accordance with the principles of "Marxist dialectics" as canonized by the official Soviet philosophy, Eisenstein planned to present the viewer with the visual equivalents of thesis and anti-thesis so that the viewer could then proceed to arrive at synthesis, that is, the correct conclusion, as pre-programmed by Eisenstein.

In the 1980s, VR pioneer Jaron Lanier similarly saw VR technology as capable of completely objectifying—better yet, transparently merging with—mental processes. His descriptions of its capabilities did not distinguish between internal mental functions, events, and processes and externally presented images. This is how, according to Lanier, VR can take over human memory: "You can play back your memory through time and classify your memories in various ways. You'd be able to run back through the experiential places you've been in order to be able to find people, tools."[39] Lanier also claimed that VR will lead to the age of "post-symbolic communication," communication without language or any other symbols. Indeed, why should there be any need for linguistic symbols if everyone

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36. Quoted in Allan Sekula, "The Body and the Archive," *October* 39 (1987): 51.

37. Hugo Münsterberg, *The Photoplay: A Psychological Study* (New York: D. Appleton and Company, 1916), 41.

38. Sergei Eisenstein, "Notes for a Film of 'Capital,'" trans. Maciej Sliwowski, Jay Leuda, and Annette Michelson, *October* 2 (1976): 10.

39. Timothy Druckrey, "Revenge of the Nerds: An Interview with Jaron Lanier," *Afterimage* (May 1991), 9.

rather than being locked into a "prison-house of language" (Fredric Jameson),[40] will happily live in the ultimate nightmare of democracy—the single mental space that is shared by everyone, and where every communicative act is always ideal (Jürgen Habermas).[41] This is Lanier's example of how post-symbolic communication will function: "You can make a cup that someone else can pick when there wasn't a cup before, without having to use a picture of the word 'cup.'"[42] Here, as with the earlier technology of film, the fantasy of objectifying and augmenting consciousness, extending the powers of reason, goes hand in hand with the desire to see in technology a return to the primitive happy age of pre-language, pre-misunderstanding. Locked in virtual reality caves, with language taken away, we will communicate through gestures, body movements, and grimaces, like our primitive ancestors . . .

The recurrent claims that new media technologies externalize and objectify reasoning, and that they can be used to augment or control it, are based on the assumption of the isomorphism of mental representations and operations with external visual effects such as dissolves, composite images, and edited sequences. This assumption is shared not only by modern media inventors, artists, and critics but also by modern psychologists. Modern psychological theories of the mind, from Freud to cognitive psychology, repeatedly equate mental processes with external, technologically generated visual forms. Thus Freud in *The Interpretation of Dreams* (1900) compared the process of condensation with one of Francis Galton's procedures that became especially famous: making family portraits by overlaying a different negative image for each member of the family and then making a single print.[43] Writing in the same decade, the American psychologist Edward Titchener

40. Fredric Jameson, *The Prison-house of Language: A Critical Account of Structuralism and Russian Formalism* (Princeton, N.J.: Princeton University Press, 1972).

41. Jürgen Habermas, *The Theory of Communicative Action: Reason and Rationalization of Society* (The Theory of Communicative Action, Vol. 1), trans. Thomas McCarthy (Boston: Beacon Press, 1985).

42. Druckrey, "Revenge of the Nerds," 6.

43. Sigmund Freud, *Standard Edition of the Complete Psychological Works* (London: Hogarth Press, 1953), 4: 293.

opened the discussion of the nature of abstract ideas in his textbook of psychology by noting that "the suggestion has been made that an abstract idea is a sort of composite photograph, a mental picture which results from the superimposition of many particular perceptions or ideas, and which therefore shows the common elements distinct and the individual elements blurred."[44] He then proceeds to consider the pros and cons of this view. We should not wonder why Titchener, Freud, and other psychologists take the comparison for granted rather than presenting it as a simple metaphor—contemporary cognitive psychologists also do not question why their models of the mind are so similar to the computer workstations on which they are constructed. The linguist George Lakoff asserted that "natural reasoning makes use of at least some unconscious and automatic image-based processes such as superimposing images, scanning them, focusing on part of them,"[45] and the psychologist Philip Johnson-Laird proposed that logical reasoning is a matter of scanning visual models.[46] Such notions would have been impossible before the emergence of television and computer graphics. These visual technologies made operations on images such as scanning, focusing, and superimposition seem natural.

What to make of this modern desire to externalize the mind? It can be related to the demand of modern mass society for standardization. The subjects have to be standardized, and the means by which they are standardized need to be standardized as well. Hence the objectification of internal, private mental processes, and their equation with external visual forms that can easily be manipulated, mass produced, and standardized on their own. The private and individual are translated into the public and become regulated.

What before had been a mental process, a uniquely individual state, now became part of the public sphere. Unobservable and interior processes and representations were taken out of individual heads and placed outside—as drawings, photographs, and other visual forms. Now they could be discussed in public, employed in teaching and propaganda, standardized, and mass-

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44. Edward Bradford Titchener, *A Beginner's Psychology* (New York: Macmillan, 1915), 114.

45. George Lakoff, "Cognitive Linguistics," *Versus* 44/45 (1986): 149.

46. Philip Johnson-Laird, *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness* (Cambridge: Cambridge University Press, 1983).

distributed. What was private became public. What was unique became mass-produced. What was hidden in an individual's mind became shared.

Interactive computer media perfectly fits this trend to externalize and objectify the mind's operations. The very principle of hyperlinking, which forms the basis of interactive media, objectifies the process of association, often taken to be central to human thinking. Mental processes of reflection, problem solving, recall, and association are externalized, equated with following a link, moving to a new page, choosing a new image, or a new scene. Before we would look at an image and mentally follow our own private associations to other images. Now interactive computer media asks us instead to click on an image in order to go to another image. Before, we would read a sentence of a story or a line of a poem and think of other lines, images, memories. Now interactive media asks us to click on a highlighted sentence to go to another sentence. In short, we are asked to follow pre-programmed, objectively existing associations. Put differently, in what can be read as an updated version of French philosopher Louis Althusser's concept of "interpellation," we are asked to mistake the structure of somebody's else mind for our own.[47]

This is a new kind of identification appropriate for the information age of cognitive labor. The cultural technologies of an industrial society—cinema and fashion—asked us to identify with someone else's bodily image. Interactive media ask us to identify with someone else's mental structure. If the cinema viewer, male and female, lusted after and tried to emulate the body of the movie star, the computer user is asked to follow the mental trajectory of the new media designer.

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47. Louis Althusser introduced his influential notion of ideological interpellation in "Ideology and Ideological State Apparatuses (Notes towards an Investigation)," in *Lenin and Philosophy,* trans. Ben Brewster (New York: Monthly Review Press, 1971).