theNewMediaReader

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New Media from Borges to HTML

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The New Media Field: a Short Institutional History

The appearance of *The New Media Reader* is a milestone in the history of a new field that, just a few years ago, was somewhat of a cultural underground. Before taking up the theoretical challenge of defining what new media actually is, as well as discussing the particular contributions this reader makes to answering this question, I would like very briefly to sketch the history of the field for the benefit of whose who are newcomers to it.

If we are to look at any modern cultural field sociologically, measuring its standing by the number and the importance of cultural institutions devoted to it such as museum exhibitions, festivals, publications, conferences, and so on, we can say that in the case of new media (understood as computer-based artistic activities) it took about ten years for it to move from cultural periphery to the mainstream. Although SIGGRAPH in the United States and Ars Electronica in Austria had already acted as annual gathering places of artists working with computers since the late 1970s, the new media field began to take real shape only in the end of the 1980s. Around that time new institutions devoted to the production and support of new media art were founded in Europe: ZKM in Karlsruhe (1989), New Media Institute in Frankfurt (1990), and ISEA (Inter-Society for the Electronic Arts) in the Netherlands (1990). (Jeffrey Shaw was appointed to be director of the part of ZKM focused on visual media while the Frankfurt Institute was headed by Peter Weibel.) In 1990 as well, Intercommunication Center in Tokyo began its activities in new media art (it moved into its own building in 1997). Throughout the 1990s, Europe and Japan remained the best places to see new media work and to participate in high-level discussions of the new field. Festivals such as ISEA, Ars Electronica, and DEAF have been required places of pilgrimage for interactive installation artists, computer musicians, choreographers working with computers, media curators, critics, and, since the mid-1990s, net artists.

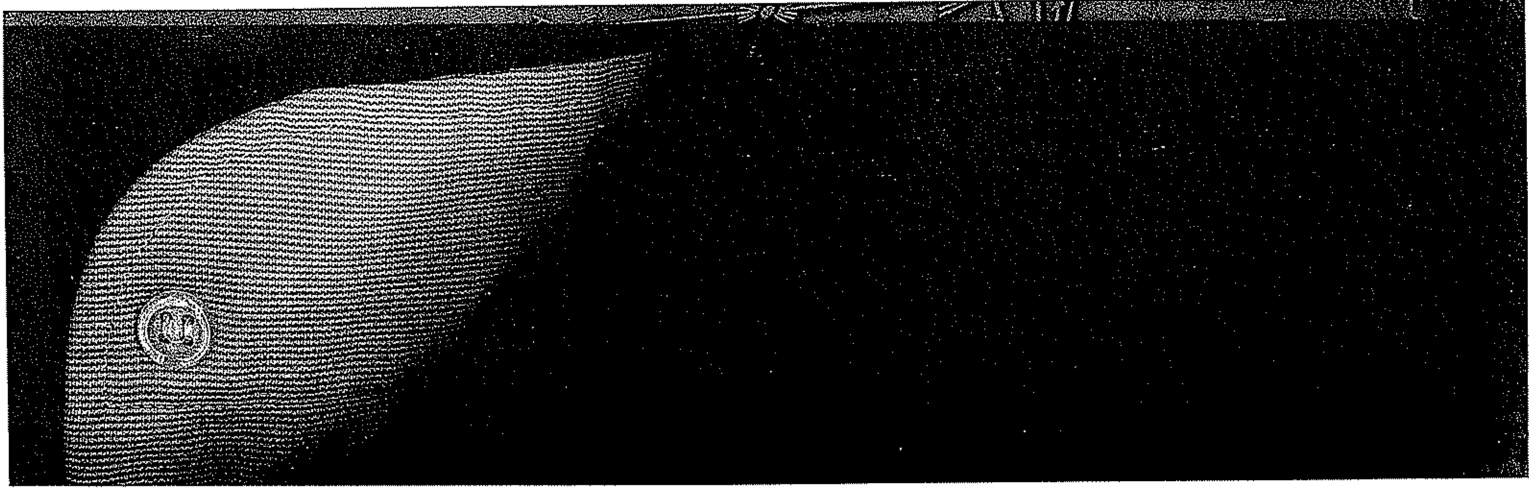
As was often the case throughout the twentieth century, countries other than the United States were first to critically engage with new technologies developed and deployed in the United States. There are a few ways to explain this phenomenon. Firstly, the speed with which new technologies are assimilated in the United States makes them "invisible" almost overnight: they become an assumed part of the everyday existence, something which does not seem to require much reflection. The slower speed of assimilation and the higher costs involved give other countries more time to reflect upon new technologies, as it was the case with new media and the Internet in the 1990s. In the case of the Internet, by the end of the 1990s it became as commonplace in the United States as the telephone, while in Europe the Internet still remained a phenomenon to reflect upon, both for economic reasons (U.S. subscribers would pay a very low monthly flat fee; in Europe they had to pay by the minute) and for cultural reasons (a more skeptical attitude towards new technologies in many European countries slowed down their assimilation). So when in the early 1990s the Soros Foundation set up contemporary art centers throughout the Eastern Europe, it wisely gave them a mandate to focus their activities on new media art, both in order to support younger artists who had difficulty getting around the more established "art mafia" in these countries and also in order to introduce the general public to the Internet.

Secondly, we can explain the slow U.S. engagement with new media art during the 1990s by the very minimal level of the public support for the arts there. In Europe, Japan, and Australia festivals for media and new media art such as the ones I mentioned above, commissions for artists to create such work, exhibition catalogs and other related cultural activities were funded by the governments. In the United States the lack of government funding for the arts left only two cultural players which economically could have supported creative work in new media: anti-intellectual, market- and cliché-driven commercial mass culture and equally commercial art culture (i.e., the art market). For different reasons, neither of these players would support new media art nor would foster intellectual discourse about it. Out of the two, commercial culture (in other words, culture designed for mass audiences) has played a more progressive role in adopting and experimenting with new media, even though for obvious reasons the content of commercial new media products has had severe limits. Yet without commercial culture we would not have computer games using artificial intelligence; network-based multimedia (including various Web plug-ins which enable distribution of music, moving images and 3-D environments over the Web); sophisticated 3-D modeling; animation and rendering tools; database-driven Web sites; CD-ROMs, DVDs, and other storage formats; and most other advanced new media technologies and forms.

The 1990s the U.S. art world proved to be the most conservative cultural force in contemporary society, lagging behind the rest of the cultural and social institutions in dealing with new media technologies. (In the 1990s a standard joke at new media festivals was that a new media piece requires two interfaces: one for art curators and one for everybody else.) This resistance is understandable given that the logic of the art world and the logic of new media are exact opposites. The first is based the romantic idea of authorship which assumes a single author, the notion of a one-of-a-kind art object, and the control over the distribution of such objects which takes place through a set of exclusive places: galleries, museums, auctions. The second privileges the existence of potentially numerous copies; infinitely many different states of the same work; author-user symbiosis (the user can change the work through interactivity); the collective; collaborative authorship; and network distribution (which bypasses the art system distribution channels). Moreover, exhibition of new media requires a level of technical sophistication and computer equipment which neither U.S. museums nor galleries were able to provide in the 1990s. In contrast, in Europe generous federal and regional funding allowed not only for mountings of sophisticated exhibitions but also for the development of a whole new form of art: the interactive computer installation. It is true that after many years of its existence, the U.S. art world learned how to deal with and in fact fully embraced video installation—but video installations require standardized equipment and don't demand constant monitoring. Neither is the case with interactive installations or even with Web pieces. While in Europe equipment-intensive forms of interactive installation have flourished throughout the 1990s, the U.S. art world has taken the easy way out by focusing on "net art," i.e., Web-based pieces whose exhibition does not require much resources beyond an off-the-shelf computer and a net connection.

All this started to change with increasing speed by the end of the 1990s. Various cultural institutions in the United States finally began to pay attention to new media. The first were education institutions. Around 1995 universities and art schools, particularly on the West Coast, began to initiate programs in new media art and design as well as open faculty positions in these areas; by the beginning of the new decade, practically every university and art school on the West Coast had both undergraduate and graduate programs in new media. A couple of years later museums such as Walker Art Center begun to mount a number of impressive online exhibitions and started to commission online projects. The 2000 Whitney Biannual included a room dedicated to net art (even though its presentation conceptually was ages behind the presentation of new media in such places as Ars Electronica Center in Linz, Intercommunication Center in Tokyo, or ZKM in Germany). Finally in 2001, both the Whitney Museum in New York and the San Francisco Museum of Modern art (SFMOMA) mounted large survey exhibitions of new media art (*Bitstreams* at the Whitney, *010101: Art in Technological Times* at SFMOMA). Add to this a constant flow of conferences and workshops mounted in such bastions of American Academia as the Institute for Advanced Studies in Princeton; fellowships in new media initiated by such prestigious funding bodies as the Rockefeller Foundation and Social Science Research Council (both begun in 2001); book series on new media published by such well-respected presses as the MIT Press. What ten years ago was a cultural underground became an established academic and artistic field; what has emerged from on-the-ground interactions of individual players has solidified, matured, and acquired institutional forms.

Paradoxically, at the same time as the new media field started to mature (the end of the 1990s), its very reason for existence came to be threatened. If all artists now, regardless of their preferred media, also routinely use digital computers to create, modify, and produce works, do we need to have a special field of new media art? As digital and network media rapidly become an omnipresent in our society, and as most artists came to routinely use these new media, the field is facing a danger of becoming a ghetto whose participants would be united by their fetishism of latest computer



technology, rather than by any deeper conceptual, ideological or aesthetic issues—a kind of local club for photo enthusiasts. I personally do think that the existence of a separate new media field now and in the future makes very good sense, but it does require a justification—something that I hope the rest of this text, by taking up more theoretical questions, will help to provide.

Software Design and Modern Art: Parallel Projects

Ten years after the appearance of the first cultural institutions solely focused on new media, the field has matured and solidified. But what exactly is new media? And what is new media art? Surprisingly, these questions remain not so easy to answer. The book you are now holding in your hands does provide very interesting answers to these questions; it also provides the most comprehensive foundation for the new media field, in the process redefining it in a very productive way. In short, this book is not just a map of the field as it already exists but a creative intervention into it.

The particular selections and their juxtaposition this book re-define new media as parallel tendencies in modern art and computing technology after the World War II. Although the editors of the anthology may not agree with this move, I would like to argue that eventually this parallelism changes the relationship between art and technology. In the last few decades of the twentieth century, modern computing and network technology materialized certain key projects of modern art developed approximately at the same time. In the process of this materialization, the technologies overtook art. That is, not only have new media technologies—computer programming, graphical human-computer interface, hypertext, computer multimedia, networking (both wired-based and wireless)—actualized the ideas behind projects by artists, they have also extended them much further than the artists originally imagined. As a result these technologies themselves have become the greatest art works of today. The greatest hypertext is the Web itself, because it is more complex, unpredictable and dynamic than any novel that could have been written by a single human writer, even James Joyce. The greatest interactive work is the interactive human-computer interface itself: the fact that the user can easily change everything which appears on her screen, in the process changing the internal state of a computer or even commanding reality outside of it. The greatest avant-garde film is software such as Final Cut Pro or After Effects which contains the possibilities of combining together thousands of separate tracks into a single movie, as well as setting various relationships between all these different tracks—and it thus it develops the avant-garde idea of a film as an abstract visual score to its logical end, and beyond. Which means that those computer scientists who invented these technologies—J. C. R. Licklider (◊05), Douglas Engelbart (◊08. ◊16), Ivan Sutherland (◊09), Ted Nelson (◊11, ◊21, ◊30), Seymour Papert (◊28), Tim Berners-Lee (◊54), and others—are the important artists of our time, maybe the only artists who are truly important and who will be remembered from this historical period.

To prove the existence of historical parallelism, *The New Media Reader* positions next to each of the key texts by modern artists that articulate certain ideas those key texts by modern computer scientists that articulate similar ideas in relation to software and hardware design. Thus we find next to each other a story by Jorge Luis Borges (1941) (◊01) and an article by Vannevar Bush (1945) (◊02) which both contain the idea of a massive branching structure as a better way to organize data and to represent human experience.

The parallelism between texts by artists and by computer scientists involves not only the ideas in the texts but also the form of the texts. In the twentieth century artists typically presented their ideas either by writing manifestos or by creating actual art works. In the case of computer scientists, we either have theoretical articles that develop plans for particular software and/or hardware designs or more descriptive articles about already created prototypes or the actual working systems. Structurally manifestos correspond to the theoretical programs of computer scientists, while completed artworks correspond to working prototypes or systems designed by scientists to see if their ideas do work and to demonstrate these ideas to colleagues, sponsors and clients. Therefore *The New Media Reader* to a large extent consists of these two types of texts: either theoretical presentations of new ideas and speculations about projects (or types of projects) that would follow from them; or the descriptions of the projects actually realized.

Institutions of modern culture that are responsible for selecting what makes it into the canon of our cultural memory and what is left behind are always behind the times. It may take a few decades or even longer for a new field which is making an important contribution to modern culture to "make it" into museums, books, and other official registers of cultural memory. In general, our official cultural histories tend to privilege art (understood in a romantic sense as individual products an individual artists) over mass industrial culture. For instance, while modern graphical and industrial designers do have some level of cultural visibility, their names, with the exception of a few contemporary celebrity designers such as Bruce Mau and Philip Stark, are generally not as known as the names of fine artists or fiction writers. Some examples of key contemporary fields that so far have not been given their due are music videos, cinematography, set design, and industrial design. But no cultural field so far has remained more unrecognized than computer science and, in particular, its specific branch of human-computer interaction, or HCI (also called human-computer interface design).

It is time that we treat the people who have articulated fundamental ideas of human-computer interaction as the major modern artists. Not only did they invent new ways to represent any data (and thus, by default, all data which has to do with "culture," i.e. the human experience in the world and the symbolic representations of this experience) but they have also radically redefined our interactions with all of old culture. As the window of a Web browser comes to supplement the cinema screen, museum space, CD player, book, and library, the new situation manifests itself: all culture, past and present, is being filtered through the computer, with its particular human-computer interface. Human-computer interface comes to act as a new form through which all older forms of cultural production are being mediated.

The New Media Reader contains essential articles by some of the key interface and software designers in the history of computing so far, from Engelbart to Berners-Lee. Thus in my view this book is not just an anthology of new media but also the first example of a radically new history of modern culture—a view from the future when more people will recognize that the true cultural innovators of the last decades of the twentieth century were interface designers, computer game designers, music video directors and DJs — rather than painters, filmmakers, or fiction writers, whose fields remained relatively stable during this historical period.

What Is New Media? Eight Propositions

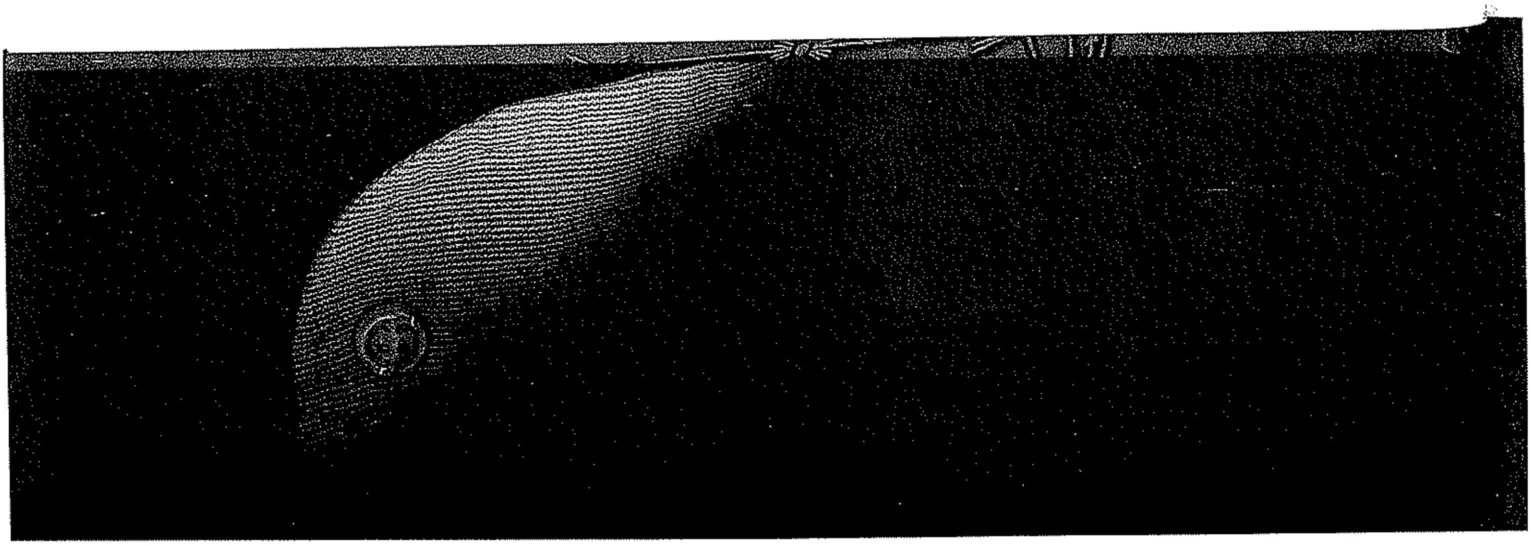
Having discussed the particular perspective adopted by *The New Media Reader* in relation to the larger cultural context we may want to place new media in—the notion of parallel developments in modern art and in computing—I now want to go through other possible concepts of new media and its histories (including a few proposed by the present author elsewhere). Here are eight answers; without a doubt, more can be invented if desired.

1 New Media versus Cyberculture

To begin with, we may distinguish between new media and cyberculture. In my view they represent two distinct fields of research. I would define cyberculture as the study of various social phenomena associated with the Internet and other new forms of network communication. Examples of what falls under cyberculture studies are online communities, online multi-player gaming, the issue of online identity, the sociology and the ethnography of email usage, cell phone usage in various communities, the issues of gender and ethnicity in Internet usage, and so on.[1] Notice that the emphasis is on the *social* phenomena; cyberculture does not directly deal with new cultural objects enabled by network communication technologies. The study of these objects is the domain of new media. In addition, new media is concerned with cultural objects and paradigms enabled by all forms of computing and not just by networking. To summarize: cyberculture is focused on the social and on networking; new media is focused on the cultural and computing.

2 New Media as Computer Technology Used as a Distribution Platform

What are these new cultural objects? Given that digital computing is now used in most areas of cultural production, from publishing and advertising to filmmaking and architecture, how can we single out the area of culture that specifically owes its existence to computing? In my *The Language of New Media* I begin the discussion of new media by invoking its definition which can be deduced from how the term is used in popular press: new media are the cultural objects which use digital computer technology for



distribution and exhibition.[2] Thus, Internet, Web sites, computer multimedia, computer games, CD-ROMs and DVDs, virtual reality, and computer-generated special effects all fall under new media. Other cultural objects which use computing for production and storage but not for final distribution—television programs, feature films, magazines, books and other paper-based publications, etc.—are not new media.

The problems with this definition are three-fold. Firstly, it has to be revised every few years, as yet another part of culture comes to rely on computing technology for distribution (for instance, the shift from analog to digital television; the shift from film-based to digital projection of feature films in movie theatres; e-books, and so on) Secondly, we may suspect that eventually most forms of culture will use computer distribution, and therefore the term "new media" defined in this way will lose any specificity. Thirdly, this definition does not tell us anything about the possible effects of computer-based distribution on the aesthetics of what is being distributed. In other words, do Web sites, computer multimedia, computer games, CD-ROMs, and virtual reality all have something in common because they are delivered to the user via a computer? Only if the answer is at least a partial yes does it makes sense to think about new media as a useful theoretical category.

3 New Media as Digital Data Controlled by Software

The Language of New Media is based on the assumption that, in fact, all cultural objects that rely on digital representation and computer-based delivery do share a number of common qualities. In the book I articulate a number of principles of new media: numerical representation, modularity, automation, variability, and transcoding. I do not assume that any computer-based cultural object will necessary be structured according to these principles today. Rather, these are tendencies of a culture undergoing computerization that gradually will manifest themselves more and more. For instance, the principle of variability states that a new media cultural object may exist in potentially infinitly many different states. Today the examples of variability are commercial Web sites programmed to customize Web pages for each user as she is accessing the site, or DJs remixes of already existing recordings; tomorrow the principle of variability may also structure a digital film which will similarly exist in multiple versions.

I deduce these principles, or tendencies, from the basic fact of digital representation of media. New media is reduced to digital data that can be manipulated by software as any other data. This allows automating many media operations, to generate multiple versions of the same object, etc. For instance, once an image is represented as a matrix of numbers, it can be manipulated or even generated automatically by running various algorithms, such as sharpen, blue, colorize, change contrast, etc.

More generally, extending what I proposed in my book, I could say that two basic ways in which computers model reality—through data structures and algorithms—can also be applied to media once it is represented digitally. In other words, given that new media is digital data controlled by particular "cultural" software, it make sense to think of any new media object in terms of particular data structures and/or particular algorithms it embodies.[3] Here are examples of data structures: an image can be thought of as a two-dimensional array (x, y), while a movie can be thought of as a three-dimensional array (x, y, t). Thinking about digital media in terms of algorithms, we discover that many of these algorithms can be applied to any media (such as copy, cut, paste, compress, find, match) while some still retain media specificity. For instance, one can easily search for a particular text string in a text but not for a particular object in an image. Conversely, one can composite a number of still or moving images together but not different texts. These differences have to do with different semiotic logics of different media in our culture: for example, we are ready to read practically any image or a composite of images as being meaningful, while for a text string to be meaningful we require that it obey the laws of grammar. On the other hand, language has a priori discrete structure (a sentence consists of words which consist if morphemes, and so on) that makes it very easily to automate various operations on it (such as search, match, replace, index), while digital representation of images does not by itself allow for automation of semantic operations.

4 New Media as the Mix Between Existing Cultural Conventions and the Conventions of Software

As a particular type of media is turned into digital data controlled by software, we may expect that eventually it will fully obey the principles of modularity, variability, and automation. However, in practice these processes may take a long time and they do not proceed in a linear fashion—rather, we witness "uneven development." For instance, today some media are already totally automated while in other cases this automation hardly exists—even though technologically it can be easily implemented.

Let us take as the example contemporary Hollywood film production. Logically we could have expected something like the following scenario. An individual viewer receives a customized version of the film that takes into account her/his previous viewing preferences, current preferences, and marketing profile. The film is completely assembled on the fly by AI software using pre-defined script schemas. The software also generates, again on the fly, characters, dialog, and sets (this makes product placement particularly easy) that are taken from a massive "assets" database.

The reality today is quite different. Software is used in some areas of film production but not in others. While some visuals may be created using computer animation, cinema still centers on the system of human stars whose salaries account for a large percent of a film budget. Similarly, script writing (and countless re-writing) is also trusted to humans. In short, the computer is kept out of the key "creative" decisions, and is delegated to the position of a technician.

If we look at another type of contemporary media—computer games—we will discover that they follow the principle of automation much more thoroughly. Game characters are modeled in 3D; they move and speak under software control. Software also decides what happens next in the game, generating new characters, spaces, and scenarios in response to user's behavior. It is not hard to understand why automation in computer games is much more advanced than in cinema. Computer games are one of the few cultural forms "native" to computers; they began as singular computer programs (before turning into a complex multimedia productions which they are today)—rather than being an already established medium (such as cinema) which is now slowly undergoing computerization.

Given that the principles of modularity, automation, variability and transcoding are tendencies that slowly and unevenly manifest themselves, is there a more precise way to describe new media, as it exists today? *The Language of New Media* analyzes the language of contemporary new media (or, to put this differently, "early new media") as the mix (we can also use software metaphors of "morph" or "composite") between two different sets of cultural forces, or cultural conventions: on the one hand, the conventions of already mature cultural forms (such as a page, a rectangular frame, a mobile point of view) and, on the other hand, the conventions of computer software and, in particular, of HCI, as they have developed until now.

Let me illustrate this idea with two examples. In modern visual culture a representational image was something one gazed at, rather than interacted with. An image was also one continuous representational field, i.e. a single scene. In the 1980s the graphical user interface (GUI) redefined an image as a figure-ground opposition between a non-interactive, passive ground (typically a desktop pattern) and active icons and hyperlinks (such as the icons of documents and applications appearing on the desktop). The treatment of representational images in new media represents a mix between these two very different conventions. An image retains its representational function while at the same time is treated as a set of hot spots ("image-map"). This is the standard convention in interactive multimedia, computer games, and Web pages. So while visually an image still appears as a single continuous field, in fact it is broken into a number of regions with hyperlinks connected to these regions, so clicking on a region opens a new page, or re-starts the game narrative, etc.

This example illustrates how a HCI convention is "superimposed" (in this case, both metaphorically and literally, as a designer places hot spots over an existing image) over an older representational convention. Another way to think about this is to say that a technique normally used for control and data management is mixed with a technique of fictional representation and fictional narration. I will use another example to illustrate the opposite process: how a cultural convention normally used for fictional representation and narration is "superimposed" over software techniques of data management and presentation.

The cultural convention in this example is the mobile camera model borrowed from cinema. In *The Language of New Media* I analyze how it became a generic interface used to access any type of data:

> Originally developed as part of 3D computer graphics technology for such applications as computer-aided design, flight simulators, and computer movie making, during the 1980s and 1990s the camera model became as much of an interface convention as scrollable windows or cut and paste operations. It became an accepted way for interacting with any data which is represented in three dimensions—which, in a computer culture, means literally anything and everything: the results of a physical simulation, an architectural site, design of a new molecule, statistical data, the structure of a computer network and so on. As computer culture is gradually spatializing all representations and experiences, they become subjected to the camera's particular grammar of data access. Zoom, tilt, pan, and track: we now use these operations to interact with data spaces, models, objects and bodies.[4]

To sum up: new media today can be understood as the mix between older cultural conventions for data representation, access, and manipulation and newer conventions of data representation, access, and manipulation. The "old" data are representations of visual reality and human experience, i.e., images, text-based and audio-visual narratives—what we normally understand by "culture." The "new" data is numerical data.

As a result of this mix, we get such strange hybrids as clickable "image-maps," navigable landscapes of financial data, QuickTime (which was defined as the format to represent any time-based data but which in practice is used exclusively for digital video), animated icons—a kind of micro-movies of computer culture—and so on.

As can be seen, this particular approach to new media assumes the existence of historically particular aesthetics that characterize new media, or "early new media," today. (We may also call it the "aesthetics of early information culture.") This aesthetics results from the convergence of historically particular cultural forces: already existing cultural conventions and the conventions of HCI. Therefore, it could not have existed in the past and it unlikely to stay without changes for a long time. But we can also define new media in the opposite way: as specific aesthetic features which keep re-appearing at an early stage of deployment of every new modern media and telecommunication technology.

5 New Media as the Aesthetics that Accompanies the Early Stage of Every New Modern Media and Communication Technology

Rather than reserving the term "new media" to refer to the cultural uses of current computer and computer-based network technologies, some authors have suggested that every modern media and telecommunication technology passes through its "new media stage." In other words, at some point photography, telephones, cinema, and television each were "new media." This perspective redirects our research efforts: rather than trying to identify what is unique about digital computers functioning as media creation, media distribution and telecommunication devices, we may instead look for certain aesthetic techniques and ideological tropes which accompany every new modern media and telecommunication technology at the initial stage of their introduction and dissemination. Here are a few examples of such ideological tropes: new technology will allow for "better democracy;" it will give us a better access to the "real" (by offering "more immediacy" and/or the possibility "to represent what before could not be represented"); it will contribute to "the erosion of moral values"; it will destroy the "natural relationship between humans and the world" by "eliminating the distance" between the observer and the observed.

And here are two examples of aesthetic strategies that seem to often accompany the appearance of a new media and telecommunication technology (not surprisingly, these aesthetic strategies are directly related to ideological tropes I just mentioned). In the mid 1990s a number of filmmakers started to use inexpensive digital cameras (DV) to create films characterized by a documentary style (for instance, *Timecode, Celebration, Mifune*). Rather than treating live action as a raw material to be later re-arranged in post-production, these filmmakers placed premier importance on the authenticity of the actors' performances. DV equipment is small enough to allow a filmmaker to literally be inside the action as it unfolds. In addition to adopting a more intimate filmic approach, a filmmaker can keep shooting for a whole duration of a 60 or 120 minute DV tape as opposed to the standard ten-minute film roll. This gives the filmmaker and the actors more freedom to improvise around a theme, rather than being shackled to the tightly scripted short shots of traditional filmmaking. (In fact the length of *Timecode* exactly corresponds to the length of a standard DV tape.)

These aesthetic strategies for representing the real, which at first may appear to be unique to digital revolution in cinema, are in fact not unique. DV-style filmmaking has a predecessor in an international filmmaking movement that begun in the late 1950s and unfolded throughout the 1960s. Called "direct cinema," "candid" cinema, "uncontrolled" cinema, "observational" cinema, or *cinéma vérité* ("cinema truth"), it also involved filmmakers using lighter and more mobile (in comparison to what was available before) equipment. Like today's "DV realists," the 1960s "direct cinema" proponents avoided tight staging and scripting, preferring to let events unfold naturally. Both then and now, the filmmakers used new filmmaking technology to revolt against the existing cinema conventions that were perceived as being too artificial. Both then and now, the key word of this revolt was the same: "immediacy."

My second example of similar aesthetic strategies re-appearing deals with the development of moving image technology throughout the nineteenth century and the development of digital technologies to display moving images on a computer desktop during the 1990s. In the first part of the 1990s, as computers' speed kept gradually increasing, CD-ROM designers were able to go from a slide show format to the superimposition of small moving elements over static backgrounds and finally to full-frame moving images. This evolution repeats the nineteenth century progression: from sequences of still images (magic lantern slides presentations) to moving characters over static backgrounds (for instance, in Reynaud's Praxinoscope Theater) to full motion (the Lumieres' cinematograph). Moreover, the introduction of QuickTime by Apple in 1991 can be compared to the introduction of the Kinetoscope in 1892: both were used to present short loops, both featured the images approximately two by three inches in size, both called for private viewing rather than collective exhibition. Culturally, the two technologies also functioned similarly: as the latest technological "marvel." If in the early 1890s the public patronized Kinetoscope parlors where peep-hole machines presented them with the latest invention—tiny moving photographs arranged in short loops; exactly a hundred years later, computer users were equally fascinated with tiny QuickTime movies that turned a computer in a film projector, however imperfect. Finally, the Lumieres' first film screenings of 1895 which shocked their audiences with huge moving images found their parallel in 1995 CD-ROM titles where the moving image finally fills the entire computer screen (for instance, in the *Johnny Mnemonic* computer game, based on the film by the same title). Thus, exactly a hundred years after cinema was officially "born," it was reinvented on a computer screen.

Interesting as they are, these two examples also illustrate the limitations of thinking about new media in terms of historically recurrent aesthetic strategies and ideological tropes. While ideological tropes indeed seem to be reappearing rather regularly, many aesthetic strategies may only reappear two or three times. Moreover, some strategies and/or tropes can be already found in the first part of the nineteenth century while others only made their first appearance much more recently.[5] In order for this approach to be truly useful it would be insufficient to simply name the strategies and tropes and to record the moments of their appearance; instead, we would have to develop a much more comprehensive analysis which would correlate the history of technology with social, political, and economical histories of the modern period.

So far my definitions of new media have focused on technology; the next three definitions will consider new media as material re-articulation, or encoding, of purely cultural tendencies—in short, as ideas rather than technologies.

6 New Media as Faster Execution of Algorithms Previously Executed Manually or through Other Technologies

A modern digital computer is a programmable machine. This simply means that the same computer can execute different algorithms. An algorithm is a sequence of steps that need to be followed to accomplish a task. Digital computers execute most algorithms very quickly—however in principle an algorithm, since it is just a sequence of simple steps, can also be executed by a human, although much more slowly. For instance, a human can sort files in a particular order, or count the number of words in a text, or cut a part of an image and paste it in a different place.

This realization gives us a new way to think about both digital computing, in general, and new media in particular as a massive speed-up of various manual techniques that all have already existed. Consider, for instance, the computer's ability to represent objects in linear perspective and to animate such representations. When you move your character through the world in a first person shooter computer game (such as *Quake*), or when you move your viewpoint around a 3D architectural model, a computer re-calculates perspectival views for all the objects in the frame many times every second (in the case of current desktop hardware, frame rates of 80 frames a second are not uncommon). But we should remember that the algorithm itself was codified during the Renaissance in Italy, and that, before digital computers came along (that is, for about five hundred years) it was executed by human draftsmen. Similarly, behind many other new media techniques there is an algorithm that, before computing, was executed manually. (Of course since art has always involved some technology—even as simple as a stylus for making marks on stone—what I mean by "manually" is that a human had to systematically go through every step of an algorithm himself, even if he was assisted by some image making tools.) Consider, for instance, another very popular new media technique: making a composite from different photographs. Soon after photography was invented, such nineteenth century photographers as Henry Peach Robinson and Oscar G. Rejlander were already creating smooth "combination prints" by putting together multiple photographs.

While this approach to thinking about new media takes us away from thinking about it purely in technological terms, it has a number of problems of its own. Substantially speeding up the execution of an algorithm by implementing this algorithm in software does not just leave things as they are. The basic point of dialectics is that a substantial change in quantity (i.e., in speed of execution in this case) leads to the emergence of qualitatively new phenomena. The example of automation of linear perspective is a case in point. Dramatically speeding up the execution of a perspectival algorithm makes possible previously non-existent representational technique: smooth movement through a perspectival space. In other words, we get not only quickly produced perspectival drawings but also computer-generated movies and interactive computer graphics.

The technological shifts in the history of "combination prints" also illustrate the cultural dialectics of transformation of quantity into quality. In the nineteenth century, painstakingly crafted "combination prints" represented an exception rather than the norm. In the twentieth century, new photographic technologies made possible photomontage that quickly became one of the basic representational techniques of modern visual culture. And finally the arrival of digital photography via software like Photoshop as well as scanners and digital cameras, in the late 1980s and 1990s, not only made photomontage much more omnipresent than before but it also fundamentally altered its visual characteristics. In place of graphic and hard-edge compositions pioneered by Moholy-Nagy and Rodchenko we now have smooth multi-image composites which use transparency, blur, colorization, and other easily available digital manipulations and which often incorporate typography that is subjected to exactly the same manipulations (thus in post-Photoshop visual culture the type becomes a subset of a photo-based image). To see this dramatic change, it is enough to compare a typical music video from 1985 and a typical music video from 1995: within ten years, the visual aesthetics of photomontage had undergone a fundamental change.

Finally, thinking about new media as speeding up of algorithms which previously were executed by hand foregrounds the use of computers for fast algorithm execution, but ignores two other essential uses: real-time network communication and real-time control. The abilities to interact with or control remotely located data in real time, to communicate with other human beings in real time, and control various technologies (sensors, motors, other computers) in real time constitute the very foundation of our information society—phone communications, Internet, financial networking, industrial control, the use of micro-controllers in numerous modern machines and devices, and so on. They also make possible many forms of new media art and culture: interactive net art, interactive computer installations, interactive multimedia, computer games, real-time music synthesis.

While non-real-time media generation and manipulation via digital computers can be thought of as speeding up of previously existing artistic techniques, *real-time* networking and control seem to constitute qualitatively new phenomena.

When we use Photoshop to quickly combine photographs together, or when we compose a text using a Microsoft Word, we simply do much faster what before we were doing either completely manually or assisted by some technologies (such as a typewriter). However, in the cases when a computer interprets or synthesizes human speech in real time, monitors sensors and modifies programs based on their input in real-time, or controls other devices, again in real-time, this is something which simply could not be done before. So while it is important to remember that, on one level, a modern digital computer is just a faster calculator, we should not ignore its other identity: that of a cybernetic control device. To put this in different way, while new media theory should pay tributes to Alan Turing (◊03), it should not forget about its other conceptual father—Norbert Wiener (◊04).

7 New Media as the Encoding of Modernist Avant-Garde; New Media as Metamedia

The approach to new media just discussed does not foreground any particular cultural period as the source of algorithms that are eventually encoded in computer software. In my article "Avant-Garde as Software" I have proposed that, in fact, a particular historical period is more relevant to new media than any other—that of the 1920s (more precisely, the years between 1915 and 1928).[6] During this period the avant-garde artists and designers invented a whole new set of visual and spatial languages and communication techniques that we still use today. According to my hypothesis,

> With new media, 1920s communication techniques acquire a new status. Thus new media does represent a new stage of the avant-garde. The techniques invented by the 1920s Left artists became embedded in the commands and interface metaphors of computer software. In short, the avant-garde vision became materialized in a computer. All the strategies developed to awaken audiences from a dream-existence of bourgeois society (constructivist design, New Typography, avant-garde cinematography and film editing, photo-montage, etc.) now define the basic routine of a post-industrial society: the interaction with a computer. For example, the avant-garde strategy of collage reemerged as a "cut and paste" command, the most basic operation one can perform on any computer data. In another example, the dynamic windows, pull-down menus, and HTML tables all allow a computer user to simultaneously work with practically unrestricted amount of information despite the limited surface of the computer screen. This strategy can be traced to Lissitzky's use of movable frames in his 1926 exhibition design for the International Art Exhibition in Dresden.

The encoding of the 1920s avant-garde techniques in software does not mean that new media simply quantitatively extends the techniques which already existed. Just as it is the case with the phenomenon of real-time computation that I discussed above, tracing new media heritage in the 1920s avant-garde reveals a qualitative change as well. The modernist avant-garde was concerned with "filtering" visible reality in new ways. The artists were concerned with representing the outside world, with "seeing" it in as many different ways as possible. Of course some artists already began to react to the emerging media environment by making collages and photo-montages consisting of newspaper clippings, existing photographs, pieces of posters, and so on; yet these practices of manipulating existing media were not yet central. But a number of decades later they have moved to the foreground of cultural production. To put this differently, after a century and a half of media culture, already existing media records (or "media assets," to use the Hollywood term) become the new raw material for software-based cultural production and artistic practice. Many decades of analog media production resulted in a huge media archive and it is the contents of this archive—television programs, films, audio recordings, etc.—which became the raw data to be processed, re-articulated, mined and re-packaged through digital software—rather than raw reality. In my article I formulate this as follows:

> New media indeed represents the new avant-garde, and its innovations are at least as radical as the formal innovations of the 1920s. But if we are to look for these innovations in the realm of forms, this traditional area of cultural evolution, we will not find them there. For the new avant-garde is radically different from the old:
>
> 1. The old media avant-garde of the 1920s came up with new forms, new ways to represent reality and new ways to see the world. The new media avant-garde is about new ways of accessing and manipulating information. Its techniques are

hypermedia, databases, search engines, data mining, image processing, visualization, and simulation.

2. The new avant-garde is no longer concerned with seeing or representing the world in new ways but rather with accessing and using in new ways previously accumulated media. In this respect new media is post-media or meta-media, as it uses old media as its primary material.

My concept of "meta-media" is related to a more familiar notion of "postmodernism"—the recognition that by the 1980s the culture became more concerned with reworking already existing content, idioms and style, rather than genially creating new ones. What I would like to stress (and what I think the original theorists of post-modernism in the 1980s have not stressed enough) is the key role played by the material factors in the shift towards postmodernist aesthetics: the accumulation of huge media assets and the arrival of new electronic and digital tools which made it very easy to access and re-work these assets. This is another example of quantity changing into quality in media history: the gradual accumulation of media records and the gradual automation of media management and manipulation techniques eventually recoded modernist aesthetics into a very different postmodern aesthetics.

8 New Media as Parallel Articulation of Similar Ideas in Post-WWII Art and Modern Computing

Along with the 1920s, we can think of other cultural periods that generated ideas and sensibilities particularly relevant to new media. In the 1980s a number of writers looked at the connections between Baroque and post-modern sensibilities; given the close link between post-modernism and new media I just briefly discussed, it would be logical if parallels between the Baroque and new media can also be established.[7] It can also be argued that in many ways new media returns us to a pre-modernist cultural logic of the eighteenth century: consider for instance, the parallel between eighteenth-century communities of readers who were also all writers and participants in Internet newsgroups and mailing lists who are also both readers and writers.

In the twentieth century, along with the 1920s, which for me represents the cultural peak of this century (because during this period more radically new aesthetic techniques were prototyped than in any other period of similar duration), the second cultural peak—the 1960s—also seems to contain many of new media's genes. A number of writers such as Söke Dinkla have argued that interactive computer art (from the 1980s on) further develops ideas already contained in the new art of the 1960s (happenings, performances, installation): active participation of the audience, an artwork as a temporal process rather than as a fixed object, an artwork as an open system.[8] This connection makes even more sense when we remember that some of the most influential figures in new media art (Jeffrey Shaw, Roy Ascott (◊10)) started their art careers in the 1960s and only later moved to computing and networking technologies. For instance, at the end of the 1960s Jeffrey Shaw was working on inflatable structures for film projections and performances which were big enough to contain a small audience inside—something which he later came back to in many of his VR installations, and even more directly in the EVE project.[9]

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There is another aesthetic project of the 1960s that also can be linked to new media not only conceptually but also historically, since the artists who pursued this project with computers (such as Manfred Mohr) knew of minimalist artists who during the same decade pursued the same project "manually" (most notably, Sol LeWitt).[10] This project can be called "combinatorics."[11] It involves creating images and/or objects by systematically varying a single parameter or by systematically creating all possible combinations of a small number of elements.[12] "Combinatorics" in computer art and minimalist art of the 1960s led to the creation of remarkably similar images and spatial structures; it illustrates well that the algorithms, this essential part of new media, do not depend on technology but can be executed by humans.

Four Decades of New Media

Along with the ones I already mentioned, more connections between 1960s cultural imaginations and new media exist. As with another recent important anthology on new media (Randall Packer and Ken Jordan's *Multimedia: From Wagner to Virtual Reality*), *The New Media Reader* contains a number of important texts by the radical artists and writers from the 1960s which have conceptual affinity to the logic of computing technology: those of Allan Kaprow (◊06), William Burroughs (◊07); the Oulipo (◊12) (whose members pursued the combinatorics project in relation to literature), Nam June Paik (◊15) and others. Section I, "The Complex, the

Changing, and the Intermediate" and section II, "Collective Media, Personal Media," present what is to date the most ◊05 73 comprehensive set of cultural texts from the 1960s. These ideas particularly resonate with the developments in ◊08 93 computing in the same period.

Although modern computing has many conceptual fathers ◊09 109 and mothers, from Leibniz to Ada Lovelace, and its prehistory spans many centuries, I would argue that the ◊11 133 paradigm that still defines our understanding and usage of computing was defined in the 1960s. During the 1960s the principles of the modern interactive GUI were given clear articulation (although the practical implementation and ◊16 231 refinement of these ideas took place later, in the 1970s at Xerox PARC). The articles by Licklider (◊05), Sutherland (◊09), Nelson (◊11, ◊21, ◊30), and Engelbart (◊08, ◊17) from the 1960s included in the reader are the essential documents of our time; one day the historians of culture will ◊21 301 rate them on the same scale of importance as texts by Marx, Freud, and Saussure. (Other key developments that also took place in the 1960s and early 1970s were the Internet, Unix, and object-oriented programming. A number of other ◊26 391 essential ideas of modern computing such as networking itself, the use of computers for real-time control, and the ◊29 433 graphical interactive display were articulated earlier, in the ◊30 441 second part of the 1940s and the first part of the 1950s.)[13]

The first two sections of the reader take us into the end of ◊33 485 the 1970s; during the time period covered in section II the key principles of modern computing and the GUI had already ◊34 499 been practically implemented and refined by the developers ◊34 515 at Xerox PARC but they were not yet commercially available to consumers. The third section, "Design, Activity, and ◊38 563 Action," runs from the end of the 1970s into the 1980s. Near the end of this period the Macintosh (released in 1984) popularized the GUI; it also shipped with a simple drawing and painting programs which emphasized the new role of a computer as a creative tool; finally, it was the first inexpensive computer which came with a bit-mapped display. Atari computers made computer-based sound manipulation affordable; computer games achieved a new level of popularity; cinema started to use computers for special effects (*Tron*, released by Disney in 1982, contained seventeen minutes of 3-D computer generated scenes); towards the very end of the decade, Photoshop, which can be called the key software application of postmodernism, was finally released. All these developments of the 1980s created a new set of roles for the modern digital computer: a manipulator of existing media (Photoshop); a media synthesizer (film special effects, sound software); and a new medium (or rather, more than one new media) in its own right (computer games). *The New Media Reader* collects essential articles by computer scientists from the 1980s that articulate ideas behind these new roles of a computer (Bolt (◊29), Shneiderman (◊33), Laurel (◊38) and others).

As computing left the strict realm of big business, the military, the government, and the university and entered society at large, cultural theorists begin to think about its effects, and it is appropriate that *The New Media Reader* also reprints key theoretical statements from the 1980s (e.g., Sherry Turkle (◊34), Donna Haraway (◊35)). I should note here that European cultural theorists reacted to computerization earlier than the Americans: both Jean-François Lyotard's *The Post-Modern Condition* (1979) and Jean Baudrillard's *Simulacra and Simulations* (1981) contain detailed discussions of computing, something which their 1980s American admirers did not seem to notice.

The last section of the reader, "Revolution, Resistance, and the Launch of the Web" continues to weave texts by computer scientists, social researchers, cultural theorists, and critics from the end of the 1980s onward; it also takes us into the early 1990s when the rise of the Web redefined computing one again. If the 1980s gradually made visible the new role of a computer as a media manipulator and an interface to media—the developments which eventually were codified around 1990 in the term "new media"—in the 1990s another role of a digital computer (which was already present since the late 1940s) came to the foreground: that of a foundation for real-time multimedia networking, available not just for selected researchers and the military (as it was for decades) but for millions of people.

In the 1960s we can find strong conceptual connections between computing and radical art of the period, but with the sole exception of Ted Nelson (the conceptual father of hypertext) no computer scientist was directly applying radical political ideas of the times to computer design. In fact these ideas had a strong effect on the field, but it was delayed until the 1970s when Alan Kay (◊26) and his colleagues at Xerox PARC pursued the vision of personal computer workstation that would empower an individual rather than a big organization. In the late 1980s and early 1990s, however, we seem to witness a different kind of parallel between social changes and computer design. Although causally unrelated, conceptually it makes sense that the end of Cold War and the design of the Web took place at exactly the same time. The first development ended the separation of the world into parts closed off from each other, making it a single global system; the second development connected world's computers into a single network. The early Web (i.e., before it came to be dominated by big commercial portals towards the end of the 1990s) also practically implemented a radically horizontal, non-hierarchical model of human existence in which no idea, no ideology, and no value system can dominate the rest—thus providing a perfect metaphor for a new post–Cold-War sensibility.

The emergence of new media studies as a field testifies to our recognition of the key cultural role played by digital computers and computer-enabled networking in our global society. For a field in its infancy, we are very lucky to now have such a comprehensive record of its origins as the one provided by *The New Media Reader*; I believe that its readers will continue to think about both the ideas in its individual texts and the endless connections which can be found between different texts for many years to come.

1. For a good example of cyberculture paradigm, see the Resource Center for Cyberculture Studies, <http://www.com.washington.edu/rccs/>

2. Lev Manovich, *The Language of New Media* (Cambridge: MIT Press, 2001).

3. I don't mean here the actual data structures and algorithms which may be used by particular software—rather, I am thinking of them in a more abstract way: what is the structure of a cultural object and what kind of operations it enables for the user.

4. Manovich, *The Language of New Media*, 80.

5. I believe that the same problems apply to Erkki Huhtamo's very interesting theory of media archeology which is close to the approach presented here and which advocates the study of tropes which accompany the history of modern media technology, both the ones which were realized and the ones which were only imagined.

6. Lev Manovich, "Avant-Garde as Software," in *Ostranenie*, edited by Stephen Kovats (Frankfurt: Campus Verlag, 1999). <http://www.manovich.net/docs/avantgarde_as_software.doc> (Quotations are from the online text.)

7. Norman Klein is currently completing a book entitled *From Vatican to Las Vegas: A History of Special Effects* that is discussing in detail the connections between the treatment of space in the Baroque and in cyberculture.

8. See for instance Söke Dinkla, "From Participation to Interaction: Towards the Origins of Interactive Art," in *Clicking In: Hots Links to a Digital Culture*, edited by Lynn Herhman Leeson (Seattle: Bay Press, 1996).

9. Jeffrey Shaw, ed., *Jeffrey Shaw—A User's Manual* (DAP, 1997).

10. Information on Manfred Mohr can be found online at <http://www.emohr.com/>.

11. Frank Dietrich has used the term "combinatorics"to talk about a particular direction in the early computer art of the 1960s. See Dietrich, Frank, "Visual Intelligence: The First Decade of Computer Art," Computer Graphics, 1985.

12. It is interesting that Sol LeWitt was able to produce works "by hand" which often consisted of more systematic variations of the same elements than similar works done by other artists who used computers. In other words, we can say that Sol LeWitt was better in executing certain minimalist algorithms than the computers of the time.

13. See Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge: MIT Press, 1997).

01. [Introduction] The Garden of Forking Paths

Many of new media's important ideas and influences first appeared in unexpected contexts. Artists and writers have often presaged developments in new media that were invisible to the most esteemed technologists. Ted Nelson and Doug Engelbart; who devised many of new media's most important concepts, have spent most of their careers on the periphery of the field. The Web, the one system that has created the greatest public interest and involvement in new media so far, was initially rejected by the new media community as a giant backward leap both conceptually and technologically. Thus it is fitting to begin this anthology not with some journal article from an established scientist but with the following detective story, written by an Argentine librarian.

To say that Jorge Luis Borges was a librarian, of course, is like saying Wallace Stevens was an insurance executive. It is true but particularly misleading. Borges did head Argentina's National Library for some time, and books and libraries figure prominently in his writing. Borges also may have been the most important figure in Spanish-language literature since Cervantes. But whatever his particular literary rank, he was clearly of tremendous influence, writing intricate poems, short stories, and essays that instantiated concepts of dizzying power.

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Another important predecessor to new media literature is seen in the work of the Oulipo (◊12), a group that constrained their writing processes with algorithms.

The concept Borges described in "The Garden of Forking Paths"—in several layers of the story, but most directly in the combination book and maze of Ts'ui Pen—is that of a novel that can be read in multiple ways, a hypertext novel. Borges described this in 1941, prior to the invention (or at least the public disclosure) of the electromechanical digital computer. Not only did he invent the hypertext novel—Borges went on to describe a theory of the universe based upon the structure of such a novel. Then he sketched out, in the actions of the protagonist, one particular existential philosophy which motivates action within this universe, a universe in which everything that is possible does indeed occur in some branch of reality. These matters are all handled in the story alongside issues of race, war, espionage, ancestry, and even the nature of academic discourse about history.

The term "hypertext" was coined by Ted Nelson; his essay (◊11) defines the term.

Borges did not ever write a hypertext novel. In fact, although Carlos Fuentes has stated that today's Latin American novel would not exist without Borges, he never wrote a novel at all. He found it sufficient to encode ideas rich enough for treatment in a novel in a format which was smaller than the typical short story, a format he called a "fiction." A hypertext novel (in codex form) was in fact written by another Argentine author, Julio Cortázar. His *Hopscotch*, which has several "expendable" chapters and which invites the reader to read in two different ways, was written in Paris and published in 1963. (It was soon afterwards read by Robert Coover, and led him to experiment with punch-card literature.) Although Cortázar and Borges held different political views, wrote in different styles, and lived far apart, the author of *Hopscotch* was certainly acquainted with Borges's writing. Borges, as editor of *El Sur*, published Cortázar's first story in 1946.

Robert Coover (◊49) became the major advocate for hypertext and electronic literature among authors of literary fiction in print.

Writers using the computer as a medium have found many types of inspiration in the work of Borges. In structuring works, they have looked not only to "The Garden of Forking Paths" but also to combinatorial ideas and notions of textual infinity found in "The Library of Babel" and "The Book of Sand." Many writers have also found the metafictional workings of Borges's stories, and his symbology (which includes chessboards, mirrors, and mazes) to be inspiring. Not only did Stuart Moulthrop create a hypertextual version of "The Garden of Forking Paths" in 1987 ⊗; he also gave his important hypertext novel set during the Gulf War a title that refers to both American wartime efforts and to Borges: *Victory Garden*.

Moulthrop's "Forking Paths" ⊗, although never published, is known through discussion in academic literature. Also see Moulthrop's essay (◊48).

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For new media to exist, a great deal of experimentation and programming had to be undertaken, much of it at a very low level and requiring great technical skill and effort. Borges was no hacker; nor did he specify the hypertext novel in perfect detail. But computers do not function as they do today *only* because of the playful labor of hackers or because of planned-out projects to program, develop, and reconfigure systems. Our use of computers is also based on the visions of those who, like Borges—pronouncing this story from the growing dark of his blindness—saw those courses that future artists, scientists, and hackers might take.

—NM

Further Reading

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Cortazar, Julio. *Hopscotch*. Trans. Gregory Rabassa. New York: Pantheon, 1966. From the Spanish *Rayuela*. Buenos Aires: Editorial Sudamericana, 1963.

Original Publication

Trans. Donald A. Yates. *Labyrinths: Selected Stories & Other Writings*, 19–29. Ed. Donald A. Yates and James E. Irby. New York: New Directions, 1964. From the Spanish "El jardin de senderos que se bifurcan," first published in *El jardin de senderos que se bifurcan*. Buenos Aires: Sur, 1941.

The Garden of Forking Paths

Jorge Luis Borges

For Victoria Ocampo

On page 22 of Liddell Hart's *History of World War I* you will read that an attack against the Serre-Montauban line by thirteen British divisions (supported by 1,400 artillery pieces), planned for the 24th of July, 1916, had to be postponed until the morning of the 29th. The torrential rains, Captain Liddell Hart comments, caused this delay, an insignificant one, to be sure.

The following statement, dictated, reread and signed by Dr. Yu Tsun, former professor of English at the *Hochschule* at Tsingtao, throws an unsuspected light over the whole affair. The first two pages of the document are missing.

"... and I hung up the receiver. Immediately afterwards, I recognized the voice that had answered in German. It was that of Captain Richard Madden. Madden's presence in Viktor Runeberg's apartment meant the end of our anxieties and—but this seemed, *or should have seemed*, very secondary to me—also the end of our lives. It meant that Runeberg had been arrested or murdered.[1] Before the sun set on that day, I would encounter the same fate. Madden was implacable. Or rather, he was obliged to be so. An Irishman at the service of England, a man accused of laxity and perhaps of treason, how could he fail to seize and be thankful for such a miraculous opportunity: the discovery, capture, maybe even the death of two agents of the German Reich? I went up to my room; absurdly I locked the door and threw myself on my back on the narrow iron cot. Through the window I saw the familiar roofs and the cloud-shaded six o'clock sun. It seemed incredible to me that that day without premonitions or symbols should be the one of my inexorable death. In spite of my dead father, in spite of having been a child in a symmetrical garden of Hai Feng, was I—now—going to die? Then I reflected that everything happens to a man precisely, precisely *now*. Centuries of centuries and only in the present do things happen; countless men in the air, on the face of the earth and the sea, and all that really is happening is happening to me. ... The almost intolerable recollection of Madden's horselike face banished these wanderings. In the midst of my hatred and terror (it means nothing to me now to speak of terror, now that I have mocked Richard Madden, now that my throat yearns for the noose) it occurred to me that that tumultuous and doubtless happy warrior did not suspect that I possessed the Secret. The name of the exact location of the new British artillery park on the River Ancre. A bird streaked across the gray sky and blindly I translated it into an airplane and that airplane into many (against the French sky) annihilating the artillery station with vertical bombs. If only my mouth, before a bullet shattered it, could cry out that secret name so it could be heard in Germany. ... My human voice was very weak. How might I make it carry to the ear of the Chief? To the ear of that sick and hateful man who knew nothing of Runeberg and me save that we were in Staffordshire and who was waiting in vain for our report in his arid office in Berlin, endlessly examining newspapers. ... I said out loud: *I must flee*. I sat up noiselessly, in a useless perfection of silence, as if Madden were already lying in wait for me. Something—perhaps the mere vain ostentation of proving my resources were nil—made me look through my pockets. I found what I knew I would find. The American watch, the nickel chain and the square coin, the key ring with the incriminating useless keys to Runeberg's apartment, the notebook, a letter which I resolved to destroy immediately (and which I did not destroy), a crown, two shillings and a few pence, the red and blue pencil, the handkerchief, the revolver with one bullet. Absurdly, I took it in my hand and weighed it in order to inspire courage within myself. Vaguely I thought that a pistol report can be heard at a great distance. In ten minutes my plan was perfected. The telephone book listed the name of the only person capable of transmitting the message; he lived in a suburb of Fenton, less than a half hour's train ride away.

I am a cowardly man. I say it now, now that I have carried to its end a plan whose perilous nature no one can deny. I know its execution was terrible. I didn't do it for Germany, no. I care nothing for a barbarous country which imposed upon me the abjection of being a spy. Besides, I know of a man from England—a modest man—who for me is no less great than Goethe. I talked with him for scarcely an hour, but during that hour he was Goethe.... I did it because I sensed that the Chief somehow feared people of my race—for the innumerable ancestors who merge within me. I wanted to prove to him that a yellow man could save his armies. Besides, I had to flee from Captain Madden. His hands and his voice could call at my door at any moment. I dressed silently, bade farewell to myself in the mirror, went downstairs, scrutinized the peaceful street and went out. The station was not far from my home, but I judged it wise to take a cab. I argued that in this way I ran less risk of being recognized; the fact is that in the deserted street I felt myself visible and vulnerable, infinitely so. I remember that I told the cab driver to stop a short distance before the main entrance. I got out with voluntary, almost painful slowness; I was going to the village of Ashgrove but I bought a ticket for a more distant station. The train left within a very few minutes, at eight-fifty. I hurried; the next one would leave at nine-thirty. There was hardly a soul on the platform. I went through the coaches; I remember a few farmers, a woman dressed in mourning, a young boy who was reading with fervor the *Annals* of Tacitus, a wounded and happy soldier. The coaches jerked forward at last. A man whom I recognized ran in vain to the end of the platform. It was Captain Richard Madden. Shattered, trembling, I shrank into the far corner of the seat, away from the dreaded window.

From this broken state I passed into an almost abject felicity. I told myself that the duel had already begun and that I had won the first encounter by frustrating, even if for forty minutes, even if by a stroke of fate, the attack of my adversary. I argued that this slightest of victories foreshadowed a total victory. I argued (no less fallaciously) that my cowardly felicity proved that I was a man capable of carrying out the adventure successfully. From this weakness I took strength that did not abandon me. I foresee that man will resign himself each day to more atrocious undertakings; soon there will be no one but warriors and brigands; I give them this counsel: *The author of an atrocious undertaking ought to imagine that he has already accomplished it, ought to impose upon himself a future as irrevocable as the past.* Thus I proceeded as my eyes of a man already dead registered the elapsing of that day, which was perhaps the last, and the diffusion of the night. The train ran gently along, amid ash trees. It stopped, almost in the middle of the fields. No one announced the name of the station. "Ashgrove?" I asked a few lads on the platform. "Ashgrove," they replied. I got off.

1. An hypothesis both hateful and odd. The Prussian spy Hans Rabener, alias Viktor Runeberg, attacked with drawn automatic the bearer of the warrant for his arrest, Captain Richard Madden. The latter, in self-defense, inflicted the wound which brought about Runeberg's death. (Editor's note.)

A lamp enlightened the platform but the faces of the boys were in shadow. One questioned me, "Are you going to Dr. Stephen Albert's house?" Without waiting for my answer, another said, "The house is a long way from here, but you won't get lost if you take this road to the left and at every crossroads turn again to your left." I tossed them a coin (my last), descended a few stone steps and started down the solitary road. It went downhill, slowly. It was of elemental earth; overhead the banches were tangled; the low, full moon seemed to accompany me.

For an instant, I thought that Richard Madden in some way had penetrated my desperate plan. Very quickly, I understood that that was impossible. The instructions to turn always to the left reminded me that such was the common procedure for discovering the central point of certain labyrinths. I have some understanding of labyrinths:

not for nothing am I the great grandson of that Ts'ui Pên who was governor of Yunnan and who renounced worldly power in order to write a novel that might be even more populous than the *Hung Lu Meng* and to construct a labyrinth in which all men would become lost. Thirteen years he dedicated to these heterogeneous tasks, but the hand of a stranger murdered him—and his novel was incoherent and no one found the labyrinth. Beneath English trees I meditated on that lost maze: I imagined it inviolate and perfect at the secret crest of a mountain; I imagined it erased by rice fields or beneath the water; I imagined it infinite, no longer composed of octagonal kiosks and returning paths, but of rivers and provinces and kingdoms.... I thought of a labyrinth of labyrinths, of one sinuous spreading labyrinth that would encompass the past and the future and in some way involve the stars. Absorbed in these illusory images, I forgot my destiny of one pursued. I felt myself to be, for an unknown period of time, an abstract perceiver of the world. The vague, living countryside, the moon, the remains of the day worked on me, as well as the slope of the road which eliminated any possibility of weariness. The afternoon was intimate, infinite. The road descended and forked among the now confused meadows. A high-pitched, almost syllabic music approached and receded in the shifting of the wind, dimmed by leaves and distance. I thought that a man can be an enemy of other men, of the moments of other men, but not of a country: not of fireflies, words, gardens, streams of water, sunsets. Thus I arrived before a tall, rusty gate. Between the iron bars I made out a poplar grove and a pavilion. I understood suddenly two things, the first trivial, the second almost unbelievable: the music came from the pavilion, and the music was Chinese. For precisely that reason I had openly accepted it without paying it any heed. I do not remember whether there was a bell or whether I knocked with my hand. The sparkling of the music continued.

From the rear of the house within a lantern approached: a lantern that the trees sometimes striped and sometimes eclipsed, a paper lantern that had the form of a drum and the color of the moon. A tall man bore it. I didn't see his face for the light blinded me. He opened the door and said slowly, in my own language: "I see that the pious Hsi P'êng persists in correcting my solitude. You no doubt wish to see the garden?"

I recognized the name of one of our consuls and I replied, disconcerted, "The garden?"

"The garden of forking paths."

Something stirred in my memory and I uttered with incomprehensible certainty, "The garden of my ancestor Ts'ui Pên."

"Your ancestor? Your illustrious ancestor? Come in."

The damp path zigzagged like those of my childhood. We came to a library of Eastern and Western books. I recognized bound in yellow silk several volumes of the Lost Encyclopedia, edited by the Third Emperor of the Luminous Dynasty but never printed. The record on the phonograph revolved next to a bronze phoenix. I also recall a *famille rose* vase and another, many centuries older, of that shade of blue which our craftsmen copied from the potters of Persia . . .

Stephen Albert observed me with a smile. He was, as I have said, very tall, sharp-featured, with gray eyes and a gray beard. He told me that he had been a missionary in Tientsin "before aspiring to become a Sinologist."

We sat down—I on a long, low divan, he with his back to the window and a tall circular clock. I calculated that my pursuer, Richard Madden, could not arrive for at least an hour. My irrevocable determination could wait.

"An astounding fate, that of Ts'ui Pên," Stephen Albert said. "Governor of his native province, learned in astronomy, in astrology and in the tireless interpretation of the canonical books, chess player, famous poet and calligrapher—he abandoned all this in order to compose a book and a maze. He renounced the pleasures of both tyranny and justice, of his populous couch, of his banquets and even of erudition—all to close himself up for thirteen years in the Pavilion of the Limpid Solitude. When he died, his heirs found nothing save chaotic manuscripts. His family, as you may be aware, wished to condemn them to the fire; but his executor—a Taoist or Buddhist monk—insisted on their publication."

"We descendants of Ts'ui Pên," I replied, "continue to curse that monk. Their publication was senseless. The book is an indeterminate heap of contradictory drafts. I examined it once: in the third chapter the hero dies, in the fourth he is alive. As for the other undertaking of Ts'ui Pên, his labyrinth . . ."

"Here is Ts'ui Pên's labyrinth," he said, indicating a tall lacquered desk.

"An ivory labyrinth!" I exclaimed. "A minimum labyrinth."

"A labyrinth of symbols," he corrected. "An invisible labyrinth of time. To me, a barbarous Englishman, has been entrusted the revelation of this diaphanous mystery. After more than a hundred years, the details are irretrievable; but it is not hard to conjecture what happened. Ts'ui Pên must have said once: *I am withdrawing to write a book.* And another time: *I am withdrawing to construct a labyrinth.* Every one imagined two works; to no one did it occur that the book and the maze were one and the same thing. The Pavilion of the Limpid Solitude stood in the center of a garden that was perhaps intricate; that circumstance could have suggested to the heirs a physical labyrinth. Hs'ui Pên died; no one in the vast territories that were his came upon the labyrinth; the confusion of the novel suggested to me that *it* was the maze. Two circumstances gave me the correct solution of the problem. One: the curious legend that Ts'ui Pên had planned to create a labyrinth which would be strictly infinite. The other: a fragment of a letter I discovered."

Albert rose. He turned his back on me for a moment; he opened a drawer of the black and gold desk. He faced me and in his hands he held a sheet of paper that had once been crimson, but was now pink and tenuous and cross-sectioned. The fame of Ts'ui Pên as a calligrapher had been justly won. I read, uncomprehendingly and with fervor, these words written with a minute brush by a man of my blood: *I leave to the various futures (not to all) my garden of forking paths.* Wordlessly, I returned the sheet. Albert continued:

"Before unearthing this letter, I had questioned myself about the ways in which a book can be infinite. I could think of nothing other than a cyclic volume, a circular one. A book whose last page was identical with the first, a book which had the possibility of continuing indefinitely. I remembered too that night which is at the middle of *The Thousand and One Nights* when Scheherazade (through a magical oversight of the copyist) begins to relate word for word the story of *The Thousand and One Nights,* establishing the risk of coming once again to the night when she must repeat it, and thus on to infinity. I imagined as well a Platonic, hereditary work, transmitted from father to son, in which each new individual adds a chapter or corrects with pious care the pages of his elders. These conjectures diverted me; but none seemed to correspond, not even remotely, to the contradictory chapters of Ts'ui Pên. In the midst of this perplexity, I received from Oxford the manuscript you have examined. I lingered, naturally, on the sentence: *I leave to the various futures (not to all) my garden of forking paths.* Almost instantly, I understood: 'the garden of forking paths' was the chaotic novel; the phrase 'the various futures (not to all)' suggested to me the forking in time, not in space. A broad rereading of the work confirmed the theory. In all fictional works, each time a man is confronted with several alternatives, he chooses one and eliminates the others; in the fiction of Ts'ui Pên, he chooses—simultaneously—all of them. *He creates,* in this way, diverse futures, diverse times which themselves also proliferate and fork. Here, then, is the explanation of the novel's contradictions. Fang, let us say, has a secret; a stranger calls at his door; Fang resolves to kill him. Naturally, there are several possible outcomes: Fang can kill the intruder, the intruder can kill Fang, they both can escape, they both can die, and so forth. In the work of Ts'ui Pên, all possible outcomes occur; each one is the point of departure for other forkings. Sometimes, the paths of this labyrinth converge: for example, you arrive at this house, but in one of the possible pasts you are my enemy, in another, my friend. If you will resign yourself to my incurable pronunciation, we shall read a few pages."

His face, within the vivid circle of the lamplight, was unquestionably that of an old man, but with something unalterable about it, even immortal. He read with slow precision two versions of the same epic chapter. In the first, an army marches to a battle across a lonely mountain; the horror of the rocks and shadows makes the men undervalue their lives and they gain an easy victory. In the second, the same army traverses a palace where a great festival is taking place; the resplendent battle seems to them a continuation of the celebration and they win the victory. I listened with proper veneration to these ancient narratives, perhaps less admirable in themselves than the fact that they had been created by my blood and were being restored to me by a man of a remote empire, in the course of a desperate adventure, on a Western isle. I remember the last words, repeated in each version like a secret commandment: *Thus fought the heroes, tranquil their admirable hearts, violent their swords, resigned to kill and to die.*

From that moment on, I felt about me and within my dark body an invisible, intangible swarming. Not the swarming of the divergent, parallel and finally coalescent armies, but a more inaccessible, more intimate agitation that they in some manner prefigured. Stephen Albert continued:

"I don't believe that your illustrious ancestor played idly with these variations. I don't consider it credible that he would sacrifice thirteen years to the infinite execution of a rhetorical experiment. In your country, the novel is a subsidiary form of literature; in Ts'ui Pên's time it was a despicable form. Ts'ui Pên was a brilliant novelist, but he was also a man of letters who doubtless did not consider himself a mere novelist. The testimony of his contemporaries proclaims—and his life fully confirms—his metaphysical and mystical interests. Philosophic controversy usurps a good part of the novel. I know that of all problems, none disturbed him so greatly nor worked upon him so much as the abysmal problem of time. Now then, the latter is the only problem that does not figure in the pages of the *Garden*. He does not even use the word that signifies *time*. How do you explain this voluntary omission?"

I proposed several solutions—all unsatisfactory. We discussed them. Finally, Stephen Albert said to me:

"In a riddle whose answer is chess, what is the only prohibited word?"

I thought a moment and replied, "The word *chess*."

"Precisely," said Albert. "*The Garden of Forking Paths* is an enormous riddle, or parable, whose theme is time; this recondite cause prohibits its mention. To omit a word always, to resort to inept metaphors and obvious periphrases, is perhaps the most emphatic way of stressing it. That is the tortuous method preferred, in each of the meanderings of his indefatigable novel, by the oblique Ts'ui Pên. I have compared hundreds of manuscripts, I have corrected the errors that the negligence of the copyists has introduced, I have guessed the plan of this chaos, I have re-established—I believe I have re-established—the primordial organization, I have translated the entire work: it is clear to me that not once does he employ the word 'time.' The explanation is obvious: *The Garden of Forking Paths* is an incomplete, but not false, image of the universe as Ts'ui Pên conceived it. In contrast to Newton and Schopenhauer, your ancestor did not believe in a uniform, absolute time. He believed in an infinite series of times, in a growing, dizzying net of divergent, convergent and parallel times. This network of times which approached one another, forked, broke off, or were unaware of one another for centuries, embraces *all* possibilities of time. We do not exist in the majority of these times; in some you exist, and not I; in others I, and not you; in others, both of us. In the present one, which a favorable fate has granted me, you have arrived at my house; in another, while crossing the garden, you found me dead; in still another, I utter these same words, but I am a mistake, a ghost."

"In every one," I pronounced, not without a tremble to my voice, "I am grateful to you and revere you for your re-creation of the garden of Ts'ui Pên."

"Not in all," he murmured with a smile. "Time forks perpetually toward innumerable futures. In one of them I am your enemy."

Once again I felt the swarming sensation of which I have spoken. It seemed to me that the humid garden that surrounded the house was infinitely saturated with invisible persons. Those persons were Albert and I, secret, busy and multiform in other dimensions of time. I raised my eyes and the tenuous nightmare dissolved. In the yellow and black garden there was only one man; but this man was as strong as a statue . . . this man was approaching along the path and he was Captain Richard Madden.

"The future already exists," I replied, "but I am your friend. Could I see the letter again?"

Albert rose. Standing tall, he opened the drawer of the tall desk; for the moment his back was to me. I had readied the revolver. I fired with extreme caution. Albert fell uncomplainingly, immediately. I swear his death was instantaneous—a lightning stroke.

The rest is unreal, insignificant. Madden broke in, arrested me. I have been condemned to the gallows. I have won out abominably; I have communicated to Berlin the secret name of the city they must attack. They bombed it yesterday; I read it in the same papers that offered to England the mystery of the learned Sinologist Stephen Albert who was murdered by a stranger, one Yu Tsun. The Chief had deciphered this mystery. He knew my problem was to indicate (through the uproar of the war) the city called Albert, and that I had found no other means to do so than to kill a man of that name. He does not know (no one can know) my innumerable contrition and weariness.

02. [Introduction] As We May Think

The blasts that leveled Hiroshima and Nagasaki were produced by one of the most powerful forces of the 20th century: the U.S. military-industrial complex. Vannevar Bush was arguably the man that put this force in motion, and was a primary organizer of the Manhattan Project that produced the bombs themselves. Yet Bush was also deeply troubled by later developments in the Cold War arms race. His vision of how technology could lead toward understanding and away from destruction was a primary inspiration for the postwar research that lead to the development of new media.

Before the war, Bush had been the architect of groundbreaking analog computing projects at MIT. In June 1940 he convinced Franklin Delano Roosevelt to give him funding and political support to create a new kind of collaborative relationship between the military, industry, and academic researchers—without congressional, or nearly any other, oversight. His influence, and the size of this new collaboration, grew phenomenally over the next five years. The result was named the "military-industrial complex" by Dwight Eisenhower, but this structure is perhaps more aptly called the "iron triangle" of self-perpetuating military, industrial, and academic relationships. The iron triangle had a decisive role in the history of new media (funding and shaping many important projects) as well as in Bush's personal history.

004 65

As part of the war effort, Bush's organization provided funding for Norbert Wiener to investigate new models for anti-aircraft guns. During this research Wiener formulated his initial thoughts on feedback loops, and began down an intellectual path that eventually led him to coin the term "cybernetics." See Wiener's speech (004).

"As We May Think" was published twice in 1945—in the *Atlantic Monthly* and *Life*—first shortly before, and then just after, the U.S. nuclear attacks on Japan. On one level, the technologies it describes now seem amusingly antiquated, as if they could sit alongside ray guns and food pills. But read in a different light, the article seems remarkably cutting-edge. It describes voice interaction, wearable information devices, and wireless data connections that are still part of our near-future vision today. These descriptions, however, are only the preparation for Bush's most famous proposal: the "memex," a "future device for individual use . . . a sort of mechanized private file and library" in the shape of a desk. The memex, as described, uses methods such as microfilm storage, dry photography, and analog computing to give postwar scholars access to a huge, indexed repository of knowledge—any section of which can be called up with a few keystrokes.

The field of information retrieval has been inspired by Bush's vision of simple, elegant information access. New media, however, has been inspired by a different aspect of Bush's vision: the scholar creating links and pathways through this information—associative connections that attempt to partially reflect the "intricate web of trails carried by the cells of the brain." The trails envisioned freely interconnect all the contents of the memex, which include both public documents and personal notes, diagrams, and photographs. Given a memex, a scholar could create her own knowledge tools as connections within reams of information, share these tools, and use complexes of tools to create yet more sophisticated knowledge that could in turn be deployed toward this work. The memex has been envisioned as a means of turning an *information explosion* into a *knowledge explosion*. This remains one of the defining dreams of new media.

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Toward the close of the article, Bush also discusses direct connections between human and machinic electrical systems, a basis for more recent cyborg visions. See Donna Haraway's "Cyborg Manifesto" (035).

Shortly after "As We May Think" was first published, Doug Engelbart, a young radar technician, came across it in a Red Cross library for U.S. soldiers in the Philippines. Later, with the memex in mind, Engelbart began work that would result in the invention of the mouse, the word processor, the hyperlink, and concepts of new media for which these groundbreaking inventions were merely enabling technologies. Another history-making moment of inspiration is likely to have taken place at the dinner table of Ted Nelson's grandfather, who regularly read aloud from the *Atlantic Monthly*. Nelson, later, couldn't place exactly his first encounter with Bush's essay. He knew, however, that it was a major influence as he made his discovery of the hyperlink (independent of Engelbart's discovery of it), coined the terms "hypertext" and "hypermedia," and wrote books that envisioned personal computing and network publishing (of a more sophisticated sort than now provided by Web technologies) before the first personal computer was even available.

Bush's is the first of many essays in *The New Media Reader* that look not toward but beyond the Web. The documents presented in this volume are useful not only because they contain ideas that were influential. These documents are also useful because they contain ideas that, to many users and producers of new media, are in fact still *new*. Bush's trails are an example of this. Nothing quite like them yet exists on the Web, or in other common new media systems. In addition to one-jump, one-way links, wouldn't it be a pleasure to have trails; capable of connecting through a series of information places in order to help construct a more nuanced map of connections in the reader's mind?

◊08 93 ◊11 133 ◊16 231

Selections by Doug Engelbart from 1962 and 1968 are included in this book (◊08 and ◊16). A more complete version of his memex story is reported in *A History of Personal Workstations*, edited by Adele Goldberg, ACM Press History Series, 1988.

◊21 301 ◊30 441

See the 1965, 1974, and 1981 selections by Ted Nelson (◊11, ◊21, ◊30).

Bush concluded his article by expressing the hope that the applications of science, which had recently been used to "throw masses of people against one another with cruel weapons," could also help the human race "encompass the great record and to grow in the wisdom of race experience." Bush had already helped to speed the world toward both outcomes. Toward the first, by playing an instrumental role in initiating a massive worldwide arms race, whose dangers he saw clearly—he said, shortly after the dropping of the first hydrogen bomb, that it "was a turning point when we entered into the grim world that we are entering right now" (*Endless Frontier*, 364). Toward the second, by fostering and inspiring the research community that would contribute so notably to the "great record" in wartime and postwar years.

—NWF

Bush's wartime efforts had tremendous and lasting outcomes. As Paul Edwards writes in *The Closed World*, "It would be almost impossible to overstate the long-term effects of this enormous undertaking on American science and engineering. The vast interdisciplinary effort profoundly restructured scientific research communities. It solidified the trend to science-based industries—already entrenched in the interwar years—but it added the new ingredient of massive government funding and military direction." (p. 47)

Further Reading

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As We May Think

Vannevar Bush

As Director of the Office of Scientific Research and Development, Dr. Vannevar Bush has coordinated the activities of some six thousand leading American scientists in the application of science to warfare. In this significant article he holds up an incentive for scientists when the fighting has ceased. He urges that men of science should then turn to the massive task of making more accessible our bewildering store of knowledge. For years inventions have extended man's physical powers rather than the powers of his mind. Trip hammers that multiply the fists, microscopes that sharpen the eye, and engines of destruction and detection are new results, but not the end results, of modern science. Now, says Dr. Bush, instruments are at hand which, if properly developed, will give man access to and command over the inherited knowledge of the ages. The perfection of these pacific instruments should be the first objective of our scientists as they emerge from their war work. Like Emerson's famous address of 1837 on "The American Scholar," this paper by Dr. Bush calls for a new relationship between thinking man and the sum of our knowledge.
—THE EDITOR [*The Atlantic Monthly*]

This has not been a scientist's war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. Now, for many, this appears to be approaching an end. What are the scientists to do next?

For the biologists, and particularly for the medical scientists, there can be little indecision, for their war has hardly required them to leave the old paths. Many indeed have been able to carry on their war research in their familiar peacetime laboratories. Their objectives remain much the same.

It is the physicists who have been thrown most violently off stride, who have left academic pursuits for the making of strange destructive gadgets, who have had to devise new methods for their unanticipated assignments. They have done their part on the devices that made it possible to turn back the enemy, have worked in combined effort with the physicists of our allies. They have felt within themselves the stir of achievement. They have been part of a great team. Now, as peace approaches, one asks where they will find objectives worthy of their best.

1

Of what lasting benefit has been man's use of science and of the new instruments which his research brought into existence? First, they have increased his control of his material environment. They have improved his food, his clothing, his shelter; they have increased his security and released him partly from the bondage of bare existence. They have given him increased knowledge of his own biological processes so that he has had a progressive freedom from disease and an increased span of life. They are illuminating the interactions of his physiological and psychological functions, giving the promise of an improved mental health.

Science has provided the swiftest communication between individuals; it has provided a record of ideas and has enabled man to manipulate and to make extracts from that record so that knowledge evolves and endures throughout the life of a race rather than that of an individual.

There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends. The investigator is staggered by the findings and conclusions of thousands of other workers—conclusions which he cannot find time to grasp, much less to remember, as they appear. Yet specialization becomes increasingly necessary for progress, and the effort to bridge between disciplines is correspondingly superficial.

Professionally our methods of transmitting and reviewing the results of research are generations old and by now are totally inadequate for their purpose. If the aggregate time spent in writing scholarly works and in reading them could be evaluated, the ratio between these amounts of time might well be startling. Those who conscientiously attempt to keep abreast of current thought, even in restricted fields, by close and continuous reading might well shy away from an examination calculated to show how much of the previous month's efforts could be produced on call. Mendel's concept of the laws of genetics was lost to the world for a generation because his publication did not reach the few who were capable of grasping and extending it; and this sort of catastrophe is undoubtedly being repeated all about us, as truly significant attainments become lost in the mass of the inconsequential.

The difficulty seems to be, not so much that we publish unduly in view of the extent and variety of present day interests, but rather that publication has been extended far beyond our present ability to make real use of the record. The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.

But there are signs of a change as new and powerful instrumentalities come into use. Photocells capable of seeing things in a physical sense, advanced photography which can record what is seen or even what is not, thermionic tubes capable of controlling potent forces under the guidance of less power than a mosquito uses to vibrate his wings, cathode ray tubes rendering visible an occurrence so brief that by comparison a microsecond is a long time, relay combinations which will carry out involved sequences of movements more reliably than any human operator and thousands of times as fast—there are plenty of mechanical aids with which to effect a transformation in scientific records.

Two centuries ago Leibnitz invented a calculating machine which embodied most of the essential features of recent keyboard devices, but it could not then come into use. The economics of the situation were against it: the labor involved in constructing it, before the days of mass production, exceeded the labor to be saved by its use, since all it could accomplish could be duplicated by sufficient use of pencil and paper. Moreover, it would have been subject to frequent breakdown, so that it could not have been depended upon; for at that time and long after, complexity and unreliability were synonymous.

Babbage, even with remarkably generous support for his time, could not produce his great arithmetical machine. His idea was sound enough, but construction and maintenance costs were then too heavy. Had a Pharaoh been given detailed and explicit designs of an automobile, and had he understood them completely, it would have taxed the resources of his kingdom to have fashioned the thousands of parts for a single car, and that car would have broken down on the first trip to Giza.

Machines with interchangeable parts can now be constructed with great economy of effort. In spite of much complexity, they perform reliably. Witness the humble typewriter, or the movie camera, or the automobile. Electrical contacts have ceased to stick when thoroughly understood. Note the automatic telephone exchange, which has hundreds of thousands of such contacts, and yet is reliable. A spider web of metal, sealed in a thin glass container, a wire heated to brilliant glow, in short, the thermionic tube of radio sets, is made by the hundred million, tossed about in packages, plugged into sockets—and it works! Its gossamer parts, the precise location and alignment involved in its construction, would have occupied a master craftsman of the guild for months; now it is built for thirty cents. The world has arrived at an age of cheap complex devices of great reliability; and something is bound to come of it.

2

A record if it is to be useful to science, must be continuously extended, it must be stored, and above all it must be consulted. Today we make the record conventionally by writing and photography, followed by printing; but we also record on film, on wax disks, and on magnetic wires. Even if utterly new recording procedures do not appear, these present ones are certainly in the process of modification and extension.

Certainly progress in photography is not going to stop. Faster material and lenses, more automatic cameras, finer-grained sensitive compounds to allow an extension of the minicamera idea, are all imminent. Let us project this trend ahead to a logical, if not inevitable, outcome. The camera hound of the future wears on his forehead a lump a little larger than a walnut. It takes pictures 3 millimeters square, later to be projected or enlarged, which after all involves only a factor of 10 beyond present practice. The lens is of universal focus, down to any distance accommodated by the unaided eye, simply because it is of short focal length. There is a built-in photocell on the walnut such as we now have on at least one camera, which automatically adjusts exposure for a wide range of illumination. There is film in the walnut for a hundred exposures, and the spring for operating its shutter and shifting its film is wound once for all when the film clip is inserted. It produces its result in full color. It may well be stereoscopic, and record with two spaced glass eyes, for striking improvements in stereoscopic technique are just around the corner.

The cord which trips its shutter may reach down a man's sleeve within easy reach of his fingers. A quick squeeze, and the picture is taken. On a pair of ordinary glasses is a square of fine lines near the top of one lens, where it is out of the way of ordinary vision. When an object appears in that square, it is lined up for its picture. As the scientist of the future moves about the laboratory or the field, every time he looks at something worthy of the record, he trips the shutter and in it goes, without even an audible click. Is this all fantastic? The only fantastic thing about it is the idea of making as many pictures as would result from its use.

Will there be dry photography? It is already here in two forms. When Brady made his Civil War pictures, the plate had to be wet at the time of exposure. Now it has to be wet during development instead. In the future perhaps it need not be wetted at all. There have long been films impregnated with diazo dyes which form a picture without development, so that it is already there as soon as the camera has been operated. An exposure to ammonia gas destroys the unexposed dye, and the picture can then be taken out into the light and examined. The process is now slow, but someone may speed it up, and it has no grain difficulties such as now keep photographic researchers busy. Often it would be advantageous to be able to snap the camera and to look at the picture immediately.

Another process now in use is also slow, and more or less clumsy. For fifty years impregnated papers have been used which turn dark at every point where an electrical contact touches them, by reason of the chemical change thus produced in an iodine compound included in the paper. They have been used to make records, for a pointer moving across them can leave a trail behind. If the electrical potential on the pointer is varied as it moves, the line becomes light or dark in accordance with the potential.

This scheme is now used in facsimile transmission. The pointer draws a set of closely spaced lines across the paper one after another. As it moves, its potential is varied in accordance with a varying current received over wires from a distant station, where these variations are produced by a photocell which is similarly scanning a picture. At every instant the darkness of the line being drawn is made equal to the darkness of the point on the picture being observed by the photocell. Thus, when the whole picture has been covered, a replica appears at the receiving end.

A scene itself can be just as well looked over line by line by the photocell in this way as can a photograph of the scene. This whole apparatus constitutes a camera, with the added feature, which can be dispensed with if desired, of making its picture at a distance. It is slow, and the picture is poor in detail. Still, it does give another process of dry photography, in which the picture is finished as soon as it is taken.

It would be a brave man who would predict that such a process will always remain clumsy, slow, and faulty in detail. Television equipment today transmits sixteen reasonably good pictures a second, and it involves only two essential differences from the process described above. For one, the record is made by a moving beam of electrons rather than a moving pointer, for the reason that an electron beam can sweep across the picture very rapidly indeed. The other difference involves merely the use of a screen which glows momentarily when the electrons hit, rather than a chemically treated paper or film which is permanently altered. This speed is necessary in television, for motion pictures rather than stills are the object.

Use chemically treated film in place of the glowing screen, allow the apparatus to transmit one picture only rather than a succession, and a rapid camera for dry photography results. The treated film needs to be far faster in action than present examples, but it probably could be.

More serious is the objection that this scheme would involve putting the film inside a vacuum chamber, for electron beams behave normally only in such a rarefied environment. This difficulty could be avoided by allowing the electron beam to play on one side of a partition, and by pressing the film against the other side, if this partition were such as to allow the electrons to go through perpendicular to its surface, and to prevent them from spreading out sideways. Such partitions, in crude form, could certainly be constructed, and they will hardly hold up the general development.

Like dry photography, microphotography still has a long way to go. The basic scheme of reducing the size of the record, and examining it by projection rather than directly, has possibilities too great to be ignored. The combination of optical projection and photographic reduction is already producing some results in microfilm for scholarly purposes, and the potentialities are highly suggestive. Today, with microfilm, reductions by a linear factor of 20 can be employed and still produce full clarity when the material is re-enlarged for examination. The limits are set by the graininess of the film, the excellence of the optical system, and the efficiency of the light sources employed. All of these are rapidly improving.

Assume a linear ratio of 100 for future use. Consider film of the same thickness as paper, although thinner film will certainly be usable. Even under these conditions there would be a total factor of 10,000 between the bulk of the ordinary record on books, and its microfilm replica. The Encyclopoedia Britannica could be reduced to the volume of a matchbox. A

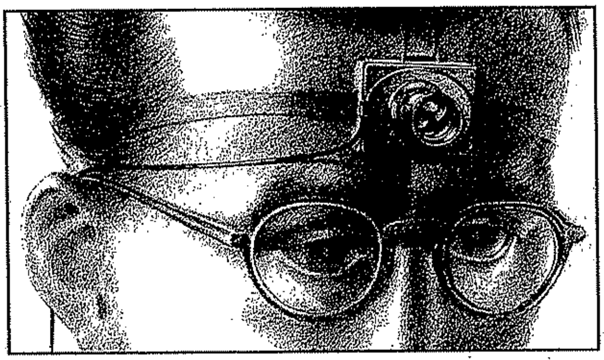

Figure 2.1. A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*Life* 19(11), p. 112).

library of a million volumes could be compressed into one end of a desk. If the human race has produced since the invention of movable type a total record, in the form of magazines, newspapers, books, tracts, advertising blurbs, correspondence, having a volume corresponding to a billion books, the whole affair, assembled and compressed, could be lugged off in a moving van. Mere compression, of course, is not enough; one needs not only to make and store a record but also be able to consult it, and this aspect of the matter comes later. Even the modern great library is not generally consulted; it is nibbled at by a few.

Compression is important, however, when it comes to costs. The material for the microfilm Britannica would cost a nickel, and it could be mailed anywhere for a cent. What would it cost to print a million copies? To print a sheet of newspaper, in a large edition, costs a small fraction of a cent. The entire material of the Britannica in reduced microfilm form would go on a sheet eight and one-half by eleven inches. Once it is available, with the photographic reproduction methods of the future, duplicates in large quantities could probably be turned out for a cent apiece beyond the cost of materials. The preparation of the original copy? That introduces the next aspect of the subject.

3

To make the record, we now push a pencil or tap a typewriter. Then comes the process of digestion and correction, followed by an intricate process of typesetting, printing, and distribution. To consider the first stage of the procedure, will the author of the future cease writing by hand or typewriter and talk directly to the record? He does so indirectly, by talking to a stenographer or a wax cylinder; but the elements are all present if he wishes to have his talk directly produce a typed record. All he needs to do is to take advantage of existing mechanisms and to alter his language.

At a recent World Fair a machine called a Voder was shown. A girl stroked its keys and it emitted recognizable speech. No human vocal chords entered into the procedure at any point; the keys simply combined some electrically produced vibrations and passed these on to a loud-speaker. In the Bell Laboratories there is the converse of this machine, called a Vocoder. The loudspeaker is replaced by a microphone, which picks up sound. Speak to it, and the corresponding keys move. This may be one element of the postulated system.

The other element is found in the stenotype, that somewhat disconcerting device encountered usually at public meetings. A girl strokes its keys languidly and looks about the room and sometimes at the speaker with a disquieting gaze. From it emerges a typed strip which records in a phonetically simplified language a record of what the speaker is supposed to have said. Later this strip is retyped into ordinary language, for in its nascent form it is intelligible only to the initiated. Combine these two elements, let the Vocoder run the stenotype, and the result is a machine which types when talked to.

Our present languages are not especially adapted to this sort of mechanization, it is true.

It is strange that the inventors of universal languages have not seized upon the idea of producing one which better fitted the technique for transmitting and recording speech. Mechanization may yet force the issue, especially in the scientific field; whereupon scientific jargon would become still less intelligible to the layman.

One can now picture a future investigator in his laboratory. His hands are free, and he is not anchored. As he moves about and observes, he photographs and comments. Time is automatically recorded to tie the two records together. If he goes into the field, he may be connected by radio to his recorder. As he ponders over his notes in the evening, he again talks his comments into the record. His typed record, as well as his photographs, may both be in miniature, so that he projects them for examination.

Much needs to occur, however, between the collection of data and observations, the extraction of parallel material from the existing record, and the final insertion of new material into the general body of the common record. For mature thought there is no mechanical substitute. But creative thought and essentially repetitive thought are very different things. For the latter there are, and may be, powerful mechanical aids.

Adding a column of figures is a repetitive thought process, and it was long ago properly relegated to the machine. True, the machine is sometimes controlled by a keyboard, and thought of a sort enters in reading the figures and poking the corresponding keys, but even this is avoidable. Machines have been made which will read typed figures by photocells and then depress the corresponding keys; these are combinations of photocells for scanning the type, electric circuits for sorting the consequent variations, and relay circuits for interpreting the result into the action of solenoids to pull the keys down.

All this complication is needed because of the clumsy way in which we have learned to write figures. If we recorded them positionally, simply by the configuration of a set of dots on a card, the automatic reading mechanism would become comparatively simple. In fact if the dots are holes, we have the punched-card machine long ago produced by Hollorith for the purposes of the census, and now used throughout business. Some types of complex businesses could hardly operate without these machines.

Adding is only one operation. To perform arithmetical computation involves also subtraction, multiplication, and division, and in addition some method for temporary storage of results, removal from storage for further manipulation, and recording of final results by printing. Machines for these purposes are now of two types: keyboard machines for accounting and the like, manually controlled for the insertion of data, and usually automatically controlled as far as the sequence of operations is concerned; and punched-card machines in which separate operations are usually delegated to a series of machines, and the cards then transferred bodily from one to another. Both forms are very useful; but as far as complex computations are concerned, both are still in embryo.

Rapid electrical counting appeared soon after the physicists found it desirable to count cosmic rays. For their own purposes the physicists promptly constructed thermionic-tube equipment capable of counting electrical impulses at the rate of 100,000 a second. The advanced arithmetical machines of the future will be electrical in nature, and they will perform at 100 times present speeds, or more.

Moreover, they will be far more versatile than present commercial machines, so that they may readily be adapted for a wide variety of operations. They will be controlled by a control card or film, they will select their own data and manipulate it in accordance with the instructions thus inserted, they will perform complex arithmetical computations at exceedingly high speeds, and they will record results in such form as to be readily available for distribution or for later further manipulation. Such machines will have enormous appetites. One of them will take instructions and data from a whole roomful of girls armed with simple key board punches, and will deliver sheets of computed results every few minutes. There will always be plenty of things to compute in the detailed affairs of millions of people doing complicated things.

4

The repetitive processes of thought are not confined however, to matters of arithmetic and statistics. In fact, every time one combines and records facts in accordance with established logical processes, the creative aspect of thinking is concerned only with the selection of the data and the process to be employed and the manipulation thereafter is repetitive in nature and hence a fit matter to be relegated to the machine. Not so much has been done along these lines, beyond the bounds of arithmetic, as might be done, primarily because of the economics of the situation. The needs of business and the extensive market obviously waiting, assured the advent of mass-produced arithmetical machines just as soon as production methods were sufficiently advanced.

With machines for advanced analysis no such situation existed; for there was and is no extensive market; the users of advanced methods of manipulating data are a very small part of the population. There are, however, machines for solving differential equations—and functional and integral equations, for that matter. There are many special machines, such as the harmonic synthesizer which predicts the tides. There will be many more, appearing certainly first in the hands of the scientist and in small numbers.

If scientific reasoning were limited to the logical processes of arithmetic, we should not get far in our understanding of the physical world. One might as well attempt to grasp the game of poker entirely by the use of the mathematics of probability. The abacus, with its beads strung on parallel wires, led the Arabs to positional numeration and the concept of zero many centuries before the rest of the world; and it was a useful tool—so useful that it still exists.

It is a far cry from the abacus to the modern keyboard accounting machine. It will be an equal step to the arithmetical machine of the future. But even this new machine will not take the scientist where he needs to go. Relief must be secured from laborious detailed manipulation of higher mathematics as well, if the users of it are to free their brains for something more than repetitive detailed transformations in accordance with established rules. A mathematician is not a man who can readily manipulate figures; often he cannot. He is not even a man who can readily perform the transformations of equations by the use of calculus. He is primarily an individual who is skilled in the use of symbolic logic on a high plane, and especially he is a man of intuitive judgment in the choice of the manipulative processes he employs.

All else he should be able to turn over to his mechanism, just as confidently as he turns over the propelling of his car to the intricate mechanism under the hood. Only then will mathematics be practically effective in bringing the growing knowledge of atomistics to the useful solution of the advanced problems of chemistry, metallurgy, and biology. For this reason there still come more machines to handle advanced mathematics for the scientist. Some of them will be sufficiently bizarre to suit the most fastidious connoisseur of the present artifacts of civilization.

5

The scientist, however, is not the only person who manipulates data and examines the world about him by the use of logical processes, although he sometimes preserves this appearance by adopting into the fold anyone who becomes logical, much in the manner in which a British labor leader is elevated to knighthood. Whenever logical processes of thought are employed—that is, whenever thought for a time runs along an accepted groove—there is an opportunity for the machine. Formal logic used to be a keen instrument in the hands of the teacher in his trying of students' souls. It is readily possible to construct a machine which will manipulate premises in accordance with formal logic, simply by the clever use of relay circuits. Put a set of premises into such a device and turn the crank, and it will readily pass out conclusion after conclusion, all in accordance with logical law, and with no more slips than would be expected of a keyboard adding machine.

Logic can become enormously difficult, and it would undoubtedly be well to produce more assurance in its use. The machines for higher analysis have usually been equation solvers. Ideas are beginning to appear for equation transformers, which will rearrange the relationship expressed by an equation in accordance with strict and rather advanced logic. Progress is inhibited by the exceedingly crude way in which mathematicians express their relationships. They employ a symbolism which grew like Topsy and has little consistency; a strange fact in that most logical field.

A new symbolism, probably positional, must apparently precede the reduction of mathematical transformations to machine processes. Then, on beyond the strict logic of the mathematician, lies the application of logic in everyday affairs. We may some day click off arguments on a machine with the same assurance that we now enter sales on a cash register. But the machine of logic will not look like a cash register, even of the streamlined model.

So much for the manipulation of ideas and their insertion into the record. Thus far we seem to be worse off than before—for we can enormously extend the record; yet even in its present bulk we can hardly consult it. This is a much larger matter than merely the extraction of data for the purposes of scientific research; it involves the entire process by which man profits by his inheritance of acquired knowledge. The prime action of use is selection, and here we are halting indeed. There may be millions of fine thoughts, and the account of the experience on which they are based, all encased within stone walls of acceptable architectural form; but if the scholar can get at only one a week by diligent search, his syntheses are not likely to keep up with the current scene.

Selection, in this broad sense, is a stone adze in the hands of a cabinetmaker. Yet, in a narrow sense and in other areas, something has already been done mechanically on selection. The personnel officer of a factory drops a stack of a few thousand employee cards into a selecting machine, sets a code in accordance with an established convention, and produces in a short time a list of all employees who live in Trenton and know Spanish. Even such devices are much too slow when it comes, for example, to matching a set of fingerprints with one of five million on file. Selection devices of this sort will soon be speeded up from their present rate of reviewing data at a few hundred a minute.

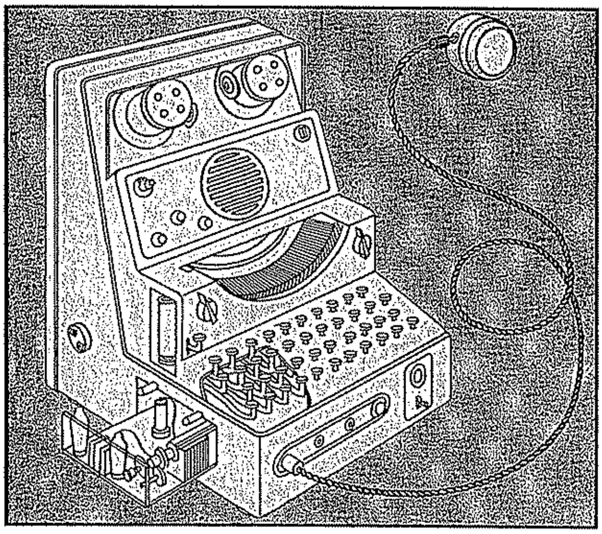

Figure 2.2. Supersecretary of the coming age, the machine contemplated here would take dictation, type it automatically and even talk back if the author wanted to review what he had just said. It is somewhat similar to the Voder seen at the New York World's Fair. Like all machines suggested by the diagrams in this article, it is not yet in existence (*Life* 19(11), p. 114).

By the use of photocells and microfilm they will survey items at the rate of a thousand a second, and will print out duplicates of those selected.

This process, however, is simple selection: it proceeds by examining in turn every one of a large set of items, and by picking out those which have certain specified characteristics. There is another form of selection best illustrated by the automatic telephone exchange. You dial a number and the machine selects and connects just one of a million possible stations. It does not run over them all. It pays attention only to a class given by a first digit, then only to a subclass of this given by the second digit, and so on; and thus proceeds rapidly and almost unerringly to the selected station. It requires a few seconds to make the selection, although the process could be speeded up if increased speed were economically warranted. If necessary, it could be made extremely fast by substituting thermionic-tube switching for mechanical switching, so that the full selection could be made in one one-hundredth of a second. No one would wish to spend the money necessary to make this change in the telephone system, but the general idea is applicable elsewhere.

Take the prosaic problem of the great department store. Every time a charge sale is made, there are a number of things to be done. The inventory needs to be revised, the salesman needs to be given credit for the sale, the general accounts need an entry, and, most important, the customer needs to be charged. A central records device has been developed in which much of this work is done conveniently. The salesman places on a stand the customer's identification card, his own card, and the card taken from the article sold—all punched cards. When he pulls a lever, contacts are made through the holes, machinery at a central point makes the necessary computations and entries, and the proper receipt is printed for the salesman to pass to the customer.

But there may be ten thousand charge customers doing business with the store, and before the full operation can be completed someone has to select the right card and insert it at the central office. Now rapid selection can slide just the proper card into position in an instant or two, and return it afterward. Another difficulty occurs, however. Someone must read a total on the card, so that the machine can add its computed item to it. Conceivably the cards might be of the dry photography type I have described. Existing totals could then be read by photocell, and the new total entered by an electron beam.

The cards may be in miniature, so that they occupy little space. They must move quickly. They need not be transferred far, but merely into position so that the photocell and recorder can operate on them. Positional dots can enter the data. At the end of the month a machine can readily be made to read these and to print an ordinary bill. With tube selection, in which no mechanical parts are involved in the switches, little time need be occupied in bringing the correct card into use—a second should suffice for the entire operation. The whole record on the card may be made by magnetic dots on a steel sheet if desired, instead of dots to be observed optically, following the scheme by which Poulsen long ago put speech on a magnetic wire. This method has the advantage of simplicity and ease of erasure. By using photography, however one can arrange to project the record in enlarged form and at a distance by using the process common in television equipment.

One can consider rapid selection of this form, and distant projection for other purposes. To be able to key one sheet of a million before an operator in a second or two, with the possibility of then adding notes thereto, is suggestive in many ways. It might even be of use in libraries, but that is another story. At any rate, there are now some interesting combinations possible. One might, for example, speak to a microphone, in the manner described in connection with the speech controlled typewriter, and thus make his selections. It would certainly beat the usual file clerk.

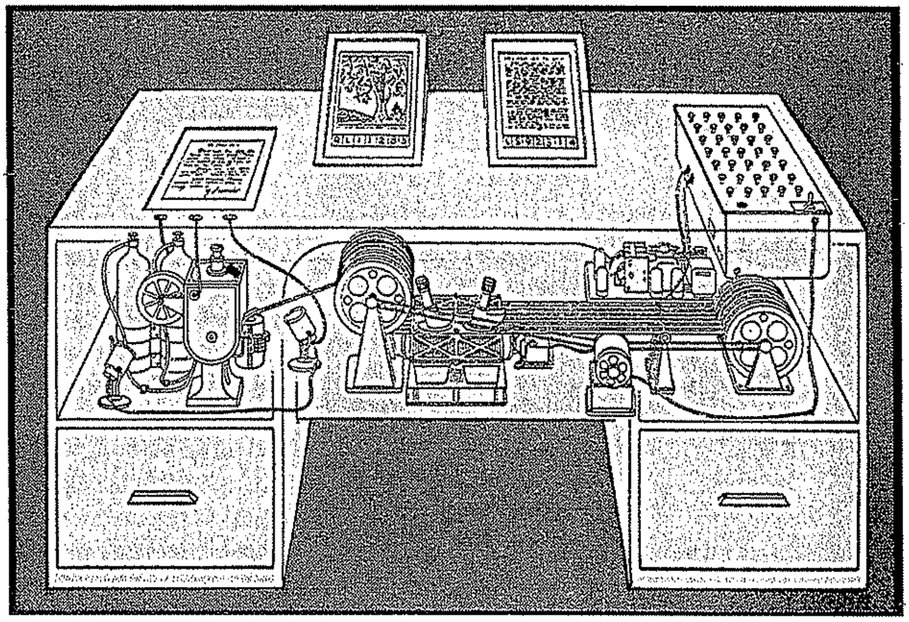

Figure 2.3. Memex in the form of a desk would instantly bring files and material on any subject to the operator's fingertips. Slanting translucent viewing screens magnify supermicrofilm filed by code numbers. At left is a mechanism which automatically photographs longhand notes, pictures and letters, then files them in the desk for future reference (*Life* 19(11), p. 123).

6

The real heart of the matter of selection, however, goes deeper than a lag in the adoption of mechanisms by libraries, or a lack of development of devices for their use. Our ineptitude in getting at the record is largely caused by the artificiality of systems of indexing. When data of any sort are placed in storage, they are filed alphabetically or numerically, and information is found (when it is) by tracing it down from subclass to subclass. It can be in only one place, unless duplicates are used; one has to have rules as to which path will locate it, and the rules are cumbersome. Having found one item, moreover, one has to emerge from the system and re-enter on a new path.

The human mind does not work that way. It operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. It has other characteristics, of course; trails that are not frequently followed are prone to fade, items are not fully permanent, memory is transitory. Yet the speed of action, the intricacy of trails, the detail of mental pictures, is awe-inspiring beyond all else in nature.

Man cannot hope fully to duplicate this mental process artificially, but he certainly ought to be able to learn from it. In minor ways he may even improve, for his records have relative permanency. The first idea, however, to be drawn from the analogy concerns selection. Selection by association, rather than indexing, may yet be mechanized. One cannot hope thus to equal the speed and flexibility with which the mind follows an associative trail, but it should be possible to beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage.

Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and, to coin one at random, "memex" will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

It consists of a desk, and while it can presumably be operated from a distance, it is primarily the piece of furniture at which he works. On the top are slanting translucent screens, on which material can be projected for convenient reading.

There is a keyboard, and sets of buttons and levers. Otherwise it looks like an ordinary desk.

In one end is the stored material. The matter of bulk is well taken care of by improved microfilm. Only a small part of the interior of the memex is devoted to storage, the rest to mechanism. Yet if the user inserted 5000 pages of material a day it would take him hundreds of years to fill the repository, so he can be profligate and enter material freely.

Most of the memex contents are purchased on microfilm ready for insertion. Books of all sorts, pictures, current periodicals, newspapers, are thus obtained and dropped into place. Business correspondence takes the same path. And there is provision for direct entry. On the top of the memex is a transparent platen. On this are placed longhand notes, photographs, memoranda, all sorts of things. When one is in place, the depression of a lever causes it to be photographed onto the next blank space in a section of the memex film, dry photography being employed.

There is, of course, provision for consultation of the record by the usual scheme of indexing. If the user wishes to consult a certain book, he taps its code on the keyboard, and the title page of the book promptly appears before him, projected onto one of his viewing positions. Frequently-used codes are mnemonic, so that he seldom consults his code book; but when he does, a single tap of a key projects it for his use. Moreover, he has supplemental levers. On deflecting one of these levers to the right he runs through the book before him, each page in turn being projected at a speed which just allows a recognizing glance at each. If he deflects it further to the right, he steps through the book 10 pages at a time; still further at 100 pages at a time. Deflection to the left gives him the same control backwards.

A special button transfers him immediately to the first page of the index. Any given book of his library can thus be called up and consulted with far greater facility than if it were taken from a shelf. As he has several projection positions, he can leave one item in position while he calls up another. He can add marginal notes and comments, taking advantage of one possible type of dry photography, and it could even be arranged so that he can do this by a stylus scheme, such as is now employed in the telautograph seen in railroad waiting rooms, just as though he had the physical page before him.

7

All this is conventional, except for the projection forward of present-day mechanisms and gadgetry. It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing.

When the user is building a trail, he names it, inserts the name in his code book, and taps it out on his keyboard. Before him are the two items to be joined, projected onto adjacent viewing positions. At the bottom of each there are a number of blank code spaces, and a pointer is set to indicate one of these on each item. The user taps a single key, and the items are permanently joined. In each code space appears the code word. Out of view, but also in the code space, is inserted a set of dots for photocell viewing; and on each item these dots by their positions designate the index number of the other item.

Thereafter, at any time, when one of these items is in view, the other can be instantly recalled merely by tapping a button below the corresponding code space. Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book. It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book. It is more than this, for any item can be joined into numerous trails.

The owner of the memex, let us say, is interested in the origin and properties of the bow and arrow. Specifically he is studying why the short Turkish bow was apparently superior to the English long bow in the skirmishes of the Crusades.

He has dozens of possibly pertinent books and articles in his memex. First he runs through an encyclopedia, finds an interesting but sketchy article, leaves it projected. Next, in a history, he finds another pertinent item, and ties the two together. Thus he goes, building a trail of many items. Occasionally he inserts a comment of his own, either linking it into the main trail or joining it by a side trail to a particular item. When it becomes evident that the elastic properties of available materials had a great deal to do with the bow, he branches off on a side trail which takes him through textbooks on elasticity and tables of physical constants. He inserts a page of longhand analysis of his own.

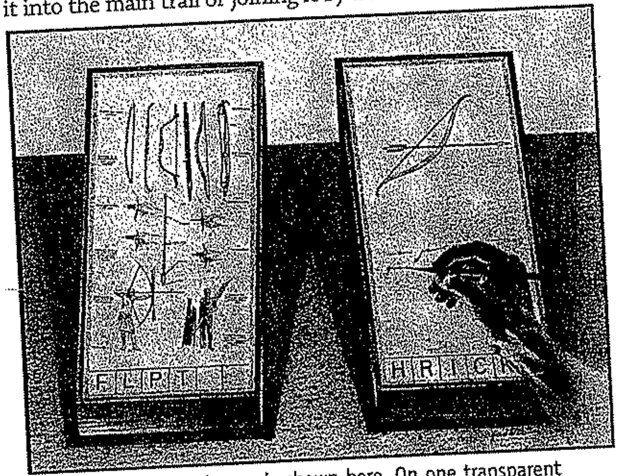

Figure 2.4. Memex in use is shown here. On one transparent screen the operator of the future writes notes and commentary dealing with reference material which is projected on the screen at left. Insertion of the proper code symbols at the bottom of right-hand screen will tie the new item to the earlier one after notes are photographed on supermicrofilm (*Life* 19(11), p. 124).

Thus he builds a trail of his interest through the maze of materials available to him.

And his trails do not fade. Several years later, his talk with a friend turns to the queer ways in which a people resist innovations, even of vital interest. He has an example, in the fact that the outraged Europeans still failed to adopt the Turkish bow.

In fact he has a trail on it. A touch brings up the code book. Tapping a few keys projects the head of the trail. A lever runs through it at will, stopping at interesting items, going off on side excursions. It is an interesting trail, pertinent to the discussion. So he sets a reproducer in action, photographs the whole trail out, and passes it to his friend for insertion in his own memex, there to be linked into the more general trail.

8

Wholly new forms of encyclopedias will appear, ready made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified. The lawyer has at his touch the associated opinions and decisions of his whole experience, and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, and side trails to their physical and chemical behavior. The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only on the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find delight in the task of establishing useful trails through the enormous mass of the common record. The inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected.

Thus science may implement the ways in which man produces, stores, and consults the record of the race. It might be striking to outline the instrumentalities of the future more spectacularly, rather than to stick closely to methods and elements now known and undergoing rapid development, as has been done here. Technical difficulties of all sorts have been ignored, certainly, but also ignored are means as yet unknown which may come any day to accelerate technical progress as violently as did the advent of the thermionic tube. In order that the picture may not be too commonplace, by reason of sticking to present-day patterns, it may be well to mention one such possibility, not to prophesy but merely to suggest, for prophecy based on extension of the known has substance, while prophecy founded on the unknown is only a doubly involved guess.

All our steps in creating or absorbing material of the record proceed through one of the senses—the tactile when we touch keys, the oral when we speak or listen, the visual when we read. Is it not possible that some day the path may be established more directly?

We know that when the eye sees, all the consequent information is transmitted to the brain by means of electrical vibrations in the channel of the optic nerve. This is an exact analogy with the electrical vibrations which occur in the cable of a television set: they convey the picture from the photocells which see it to the radio transmitter from which it is broadcast. We know further that if we can approach that cable with the proper instruments, we do not need to touch it; we can pick up those vibrations by electrical induction and thus discover and reproduce the scene which is being transmitted, just as a telephone wire may be tapped for its message.

The impulses which flow in the arm nerves of a typist convey to her fingers the translated information which reaches her eye or ear, in order that the fingers may be caused to strike the proper keys. Might not these currents be intercepted, either in the original form in which information is conveyed to the brain, or in the marvelously metamorphosed form in which they then proceed to the hand?

By bone conduction we already introduce sounds: into the nerve channels of the deaf in order that they may hear. Is it not possible that we may learn to introduce them without the present cumbersomeness of first transforming electrical vibrations to mechanical ones, which the human mechanism promptly transforms back to the electrical form? With a couple of electrodes on the skull the encephalograph now produces pen-and-ink traces which bear some relation to the electrical phenomena going on in the brain itself. True, the record is unintelligible, except as it points out certain gross misfunctioning of the cerebral mechanism; but who would now place bounds on where such a thing may lead? In the outside world, all forms of intelligence whether of sound or sight, have been reduced to the form of varying currents in an electric circuit in order that they may be transmitted. Inside the human frame exactly the same sort of process occurs. Must we always transform to mechanical movements in order to proceed from one electrical phenomenon to another? It is a suggestive thought, but it hardly warrants prediction without losing touch with reality and immediateness.

Presumably man's spirit should be elevated if he can better review his shady past and analyze more completely and objectively his present problems. He has built a civilization so complex that he needs to mechanize his records more fully if he is to push his experiment to its logcal conclusion and not merely become bogged down part way there by overtaxing his limited memory. His excursions may be more enjoyable if he can reacquire the privilege of forgetting the manifold things he does not need to have immediately at hand, with some assurance that he can find them again if they prove important.

The applications of science have built man a well-supplied house, and are teaching him to live healthily therein. They have enabled him to throw masses of people against one another with cruel weapons. They may yet allow him truly to encompass the great record and to grow in the wisdom of race experience. He may perish in conflict before he learns to wield that record for his true good. Yet, in the application of science to the needs and desires of man, it would seem to be a singularly unfortunate stage at which to terminate the process, or to lose hope as to the outcome.