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The Intelligent Image: Neurocinema or Quantum Cinema? (2003)

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From Machines of Motion to Machines of Vision

The nineteenth century was obsessed with motion – with illusions of motion, and with machines of motion. There were two kinds of machines of motion: the first tried to analyze motion, the second to synthesize motion. The analysis of motion was the task of the camera; the synthesis of motion was the task of the projector.

The evolution of cinema in the nineteenth century can be attributed to two major trends: firstly, to the progress in experimental physiology and psychology leading to the Gestalt psychology, and secondly, to the advances in machines attempting to adapt and transfer the physiological mechanism of perception into machines capable of the visual simulation of motion and – herein lies the problem – not into machines of perception.

Therefore, what we know as cinema today is in fact already a reduction of the nineteenth-century principle that began to investigate machines of vision, but finally reduced them to machines of motion. There is the moving-image industry with its motion pictures, that is to say: the Hollywood system. Its code is a legacy of the nineteenth century, and reduces the initial exploration of machines of vision to machines of motion. Only the avant-garde cinema of the 1920s, 1950s and 1960s maintained the original intention of creating machines of vision.

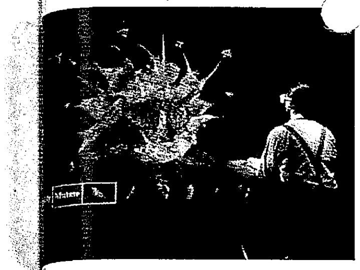
Classical cinema, therefore, already diminished the initial enterprise, which was about perception. Perception was reduced to the perception of motion, and remained on the retinal level because there was no pursuit of the question of how our brain perceives the world. People constructed machines with a kind of graphic notation – "la methode graphique" (Etienne-Jules Marey) – of motion. This method can be said to be still valid, tragically enough, today. What Marey did was to analyze, and deconstruct, motion with his famous graphical method. It made no difference whether a drawing machine was used or, as in the case of Eadweard Muybridge, a photographic machine. Both Muybridge and Marey soon realized that it is not enough to analyze motion, but many other machines had to be used in order to project, to synthesize, motion. We may conclude this interpretation with the fact that cinema was invented in the nineteenth century. The twentieth century merely turned the nineteenth-century inventions into standardized mass media – including television, which became a consumer apparatus. As a side-effect, we simultaneously turned this machinery not only into mass media, but also into art, an individual approach.

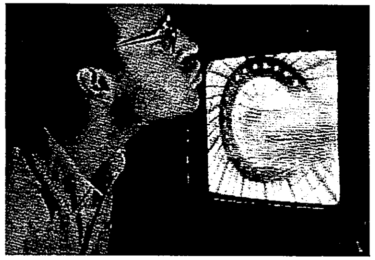
Cinema is a writing of motion (cinematography); it is just a machine that simulates motion for the eye. The avant-garde, from Dziga Vertov to Steina and Woody Vasulka, kept to the initial idea: machine vision – not machine motion. Vertov gave us the term *Kinoglaz*, the camera eye. With the advent of video (Latin: I see), it was clear that we had to make a paradigmatic shift from imitating and simulating motion to imitating and simulating vision with the help of machines. We had to change from cinematography (the writing of motion) to what I would call the writing of seeing: opsigraphy, from the Greek word *opsis* (as in "optics"). Or even to opsiscopy, the seeing of seeing – in other words, the observing of observing mechanisms. In cyberspace, for example, when you see yourself and your actions as an image, you are already in opsiscopic space. You are observing yourself in a picture that you observe; it is an observation of the second order. In fact, cyberspace is the beginning of opsiscopy: of machines that see how we see.

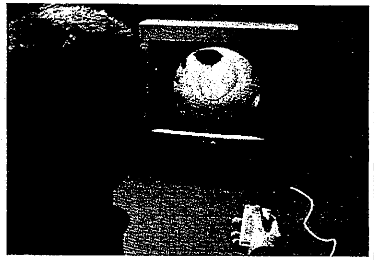
The Interactive Image

The technical apparatus so far used to create images representing reality imitated the organic technology of a natural apparatus, the sight organ. The possibility of imitating movement through pictures was a decisive step towards improving the representation of reality, and was the basis of the transformation of painting and photography into cinema, as a *trompe l'oeil* technology simulating motion. Image technology and its late-twentieth-century tendency to imitate life moved on from the simulation of movement (the motion picture) to the simulation of interaction: a responding and reacting image, the image as living system, the viable picture. The computer allowed the virtual storage of information as an electronic configuration. Information was no longer locked up magnetically or chemically as it had been on the filmstrip or videotape. The *virtuality of information storage* set information free and made it variable. The image became a picture field, its pixels became variables able to be altered at any time.

Willard Van Orman Quine's famous dictum "to be is to be the value of a (bound) variable," which founded a philosophy of ontological relativity, is perfectly applicable to the virtual image, to Virtual Reality.[1] This virtuality induced the *variability of the image content*. In some degree, the creation of an interface technology between observer and image was made necessary by the virtuality and the variability of the image; it enabled the observer to control with his own behavior that of the image. The picture field became an image system that reacted to the observer's movement. The observer became part of the system he observed. He became an internal observer – for the first time in history. In the real world, the observer is always part of the world he observes, always an internal observer. The external observer exists only in an idealized, non-existent world. Otto E. Rössler's work on "Endophysics"[2] opens up a new view of the universe and develops the physics of the internal observer. Classical cinema imitates this idealized world (of philosophy, mathematics, and classical physics). With their internal observers, Virtual Reality systems therefore simulate an aspect of reality, bringing interactive images one step closer to the imitation of life.



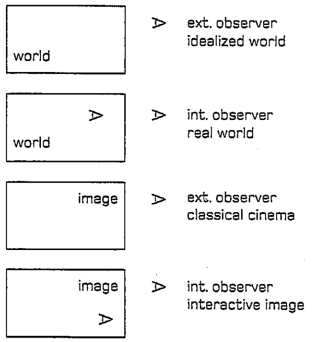




left
Bernd Lintermann,
Torsten Belschner
SonoMorphis
1998
interactive installation
mixed media
dimensions variable
installation view: ZKM |
Center for Art and Media
Karlsruhe, 1998
© Bernd Lintermann, Torsten Belschner

middle
Chris Dodge
The Winds that Wash the Seas
1994–1995
interactive installation
© Chris Dodge

right
Masaki Fujihata
Impalpability
1998
interactive CD-ROM
installation view
© Masaki Fujihata



Moving image and moving observer converged towards a new synthesis of image and observer: the interactive image, the most radical transformation ever of the image. Since artificial systems, whose behavior is similarly reactive to that of living systems, have been termed "viable" by Constructivist philosophers, the new image systems can also rightfully be called "viable." The *viability of image behavior* turns the moving image into a living image. Thus the computer is a decisive medium for perfectly simulating reality. Bernd Lintermann and Torsten Belschner's interactive computer-based installation *SonoMorphis* (1998) simulates the codes of evolution, the algorithms of growth of plants, giving the spectator the chance to create new species according to algorithms of recombination and mutation built on six offered optional organisms.

The Indexical Image

From these revolutions of image technology follows the technical and social deconstruction of the image. For this deconstruction of the technical apparatus of the image, the artist can enlist the help of a revolution in materials enabling a new physics of the image. See *Laserfilm* (2000) by Michael Schmid, Jörn Müller-Quade and Thomas Beth (on p.582) showing the change from the refractive optics of the past to the diffractive optics of the future. The important role of the index and the imprint in modern art (especially since the 1960s, as a result of a material-based artistic research) indicates that the indexical image (which is defined through a material and physical relationship between sign and object) will, as post-digital image, ultimately replace the illusionist world of computer-based 3-D simulations currently at the peak of their success. The indexical image is the beginning of a new culture of materiality of the image, beginning with nanotechnology, supramolecular chemistry and molecular engineering.[3] Major advances in chemistry and molecular technology have brought us new materials, including electrically active plastics, that may form the next generation of computer devices.

Chris Dodge's interactive installation *The Winds that Wash the Seas* (1994–95) allows the observer to blow against the monitor screen, and alter the image with the direction and force of his breath. A second observer can interact by moving his hand through water. Both observers transform the image. The interactive CD-ROM work *Impalpability* (1998) by Masaki Fujihata is also indexical in character, since the human hand manipulating the mouse again shows on the screen close-ups of a human hand. This new culture of materiality will be marked above all by the transition from electronic technology to nanotechnology, from microelectronics to nanoelectronics. This transition is supported by three stages in computer development. The mainframe era of computing saw a room-sized computer being used by several people. In the PC era, one person used one computer, hence the term personal computer. In the future era of calm technology and ubiquitous computing, one person is going to wear and use a lot of microcomputers. But what kind of computers will they be? Quantum computers, DNA computers,[4] molecular computers?

Cinema and Cybernetics

Gestalt psychology came into being around 1900, and peaked in 1930–1950. The "phi-phenomenon," a classical principle on which many 1960s filmmakers built their oeuvre, was formulated by Max Wertheimer in 1910. Gestalt psychology was followed by neurophysiology and cognitive science. If we follow this line, it becomes clear that whereas in the nineteenth century machinery was related to experimental physiology, the new machines of vision must come to be related to neuroscience and cognitive science. This leads us to the first group who gave us an idea for the next hundred years: the cyberneticists. From the calculating machine to the computer, they came up with machines that simulate thinking and seeing as well as motion. Machines were compared to the highest physical organ, the brain.[5] Finally, as early as 1950 they had the idea that we can build machines that also simulate life. An unknown but wonderful article by W. Grey Walter about a "Machina Speculatrix," a creative, vision-

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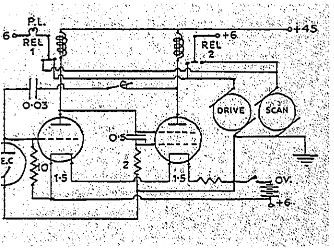
[1] Willard Van Orman Quine, *From a Logical Point of View*, Harvard University Press, Cambridge, MA, 1980.

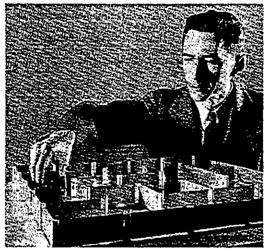
[2] Otto E. Rössler, *Endophysics. The World as an Interface*, World Scientific, Singapore, 1998

[3] "Ultimately we can arrange atoms the way we want." – Richard Feynman, "There's Plenty of Room at the Bottom" (1959), in *Feynman and Computation*, A. J. G. Hey (ed.), Perseus Books, Cambridge, MA, 1999, pp. 63–76; see also K. Eric Drexler, "Molecular engineering: an approach to the development of general capabilities for molecular manipulation" (1981), in *Proceedings of the National Academy of Science*, 78, 9, pp. 5275–5278; K. E. Drexler, *Nanosystems: Molecular Machinery, Manufacturing, and Computing*, Wiley & Sons, New York, 1992; Jean-Marie Lehn, *Supramolecular Chemistry*, VCH Verlag, Weinheim, 1995.

[4] Leonard Adleman, "On constructing a molecular computer, DNA Based Computers", in R. Lipton and E. Baum (eds), *DIMACS. series in Discrete Mathematics and Theoretical Computer Science*, American Mathematical Society, 1–21, 1996; Lila Kari, "DNA Computing: The Arrival of Biological Mathematics," in *The Mathematical Intelligencer*, 19 (2), 1997, pp. 1–22

[5] W. Ross Ashby, *Design for a brain*, Chapman & Hall, London, 1952; John von Neumann, *The Computer and the Brain*, Yale University Press, New Haven, 1958





left
W. Grey Walter
Circuit of M. Speculatrix
1950

right
Claude E. Shannon
Demonstration of a machine for solving the labyrinth problem
1951

ary machine, appeared under the accurate title "An Imitation of Life" in 1950.[6] In his book *The Living Brain*, he wrote:

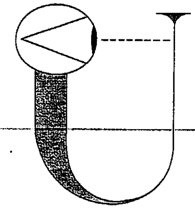
> "The first notion of constructing a free goal-seeking mechanism goes back to the psychologist Kenneth Craik. When he was engaged on a war job for the Government, he came to get the help of an automatic analyzer with some very complicated curves he had obtained, curves relating to the aiming errors of air gunners. Goal-seeking missiles were literally much in the air in those days; so were scanning mechanisms. Long before the home study was turned into a workshop, the two ideas, goal-seeking and scanning, had combined as the essential mechanical conception of a working model that would behave like a very simple animal. At the same time, this conception held promise of demonstrating, or at least testing the validity of, the theory that multiplicity of units is not so much responsible for the elaboration of cerebral functions, as the richness of their interconnection. With the minimum two elements there should be seven modes of existence. And there was another good reason, apart from the avoidance of unnecessary mechanical complications, for the utmost economy of design in *Machina Speculatrix*, inevitable name of the species for the discerning, though 'tortoise' to the profane; it would demonstrate the first of several principles exemplified in the mechanisms of most living creatures."[7]

To make the imitation of life possible, it was necessary to move on from the machine level and explore system theory. The cyberneticists realized that only systems can imitate living processes and life, and only systems can imitate the thinking process. Hence, system theory was the next step. In consequence, it is logical to think of the image as a system, too.

Cinema and System Theory: Interface Technology

How do we define a system? People realized that there has to be a border that distinguishes between system and environment. The axiom of system theory is "Construction: Draw a distinction."[8] We can see our borders: the skin, then a membrane. What was once called skin and membrane is now known as "interface technology." As the border that separates the system from the environment, interface technology differentiates the image from the real world. Naturally, this difference is not very clear; it is not a strict border like a wall, but more like foam.

We need a theory of border, a theory of interface technology, to separate a system from its environment, and to enable interchange between the two. I therefore refer to Ivan E. Sutherland and his 1963 article about man, machine and interface.[9] Here again, one sees the nineteenth-century relationship between man and m[illegible]e, but now a new concept states that there is something between man and machine, namely interface technology. An interface lies between the world and ourselves, between machines and ourselves. Maybe the world is only an interface. Maybe we can change the interface, if not the world. We can expand the interface: This is expanded cinema and VR technology. The important point is that the border – the interface – is permeable and variable. The border can be extended. Something that is now the environment can be part of the system in the next step. Something that is the system can be the environment for the sub-system. This means that if I am an external observer of one system, I can become part of the system for the next environment, an internal observer for another external observer. Normally, we believe our situation in the real world to be identical with that in classical cinema. We are external observers of the image; our observation has no effect on the image. But we have constructed systems where our observation is part of the system that we observe. Therefore, quantum theory with its effects of observation (from Heisenberg's "uncertainty principle," 1927, to John Archibald Wheeler's "participatory universe," 1983) becomes the role model for the observer-dependent media used in interactive image installations and systems. "To speak of the universe as a self-excited circuit is to imply once more a participatory universe."[10]



The universe viewed as a self-excited circuit. Starting small (thin U at "upper right"), it grows (loop U) and in times gives rise ("upper left") to observer participation – which in turn imparts "tangible reality" to even the earliest days of the universe.

We are compelled to see that the digital image is, for the first time, a real system. With its open-circuit installations where people enter the image by the observation of the camera, video came much closer than cinema to system theory. But even video magnetically sealed and imprisoned the information. Virtual information storage is necessary for an image as system. Virtual Reality is based on the virtuality of information storage in the computer. Today, information is just an electronic representation, which means you can change it immediately at any time. Thus, the image is a dynamic system of variables.

Cinema and Genetic Algorithms

My next point is that we define the variables of an image system as agents. The idea of agents has a long history, with roots going back to a mathematician, Axel Thue, who had a linguistic problem.[11] Say he had had a string of seven letters building an alphabet, he would write down a formula, say with four letters. He had two grammatical rules: A can always be transformed to B and A; and B can always be transformed to A. He was trying to discover a general method, an algorithm, that would decide whether a written formula (for example four letters) could be derived from the seven letters (the alphabet) by the two rules (the grammar). The general unsolv[illegible]of Thue's "word problem" was later made famous by Emil Leon Post.[12] Noam Chomsky, who used Semi-Thue systems, invented the first logical-mathematical models for natural language. On that basis, Backus and Naur developed another of all those programming languages, ALGOL (algorithmic language) in 1960.[13] Subsequently, the Belgian biologist Aristid Lindenmayer in 1967 invented the L-System (the Lindenmayer System), a programming language he called a "genetic algorithm" and which was a clear application of Thue's technique.[14] With the help of this mathematical-linguistic model, he was able to simulate the growth of plants![15] Neither geometry nor machines of vision but a programming language built on mathematics made it possible to simulate life processes like morphogenesis and growth of forms. The cinematic code of today is not to imitate motion, but to imitate growth, and even chaotic growth as an aspect of life. The image variables became autonomous agents, data with a life of its own.

After Lindenmayer, the best textbook about the genetic algorithm was written by John H. Holland. He came up with the next step: "complex adaptive systems" able to adapt to the environment. There was now an exchange between the previously separated system and environment. In his recently published *Hidden Order. How Adaptation Builds Complexity*,[16] he offers the seven concepts of aggregation, tagging, non-linearity, flows, diversity, internal models, and building blocks. All these mechanisms or properties of a system enable a sufficiently complex system to adapt to the environment.

Naturally, this adaptation is carried out by so-called software agents or autonomous agents. These software agents can make their own decisions to act within the algorithm, so that for the first time a system can adapt from within. I call this process of adaptation "intelligent behavior"; the system as a whole, after being virtual and variable, is becoming "viable." The image shows lifelike behavior – viability – and intelligence. When we turn the image into a system, it can behave like a living organism and possess artificial intelligence. The image can act on its own. The algorithmic image can imitate the evolution of life.

Wireless Communication and Non-Local, Distributed, Shared Cyberspace

In order to have intelligent images in the future, we must apply the idea of the Net, which means the observer is no longer part of a hierarchy. The so-called visual hierarchical pyramid applied to the classical image: One observer looked at one image. In the next decade we must try to make the image a system in which the observer is merely one node in the network of the image system. The no longer privileged observer will then be a peripheral interface machine like any other machine. And we must remember that cinema began with a single observer looking into one machine. The classical form was one observer, one film, one space. It was slowly transformed into a collective experience, but even in a movie theater there is one film, screened locally in one space at one time. The principle of unity still applies. The next step was television, with collective observation, but non-local, not in one space, dislocated, yet still restricted to the simultaneous viewing of one film. TV already has a network structure as its distribution model, and the next step is a simultaneous, dislocated and collective experience of different films seen at home from some kind of database.

Cyberspace, in its present form of the head-mounted display, is old-fashioned cinema: Again, you have one locally defined viewer of one movie in one place at one time. In the course of the next hundred years we must develop the cyberspace technology to meet our changed demands for collective experience in dislocated, distributed cyberspace. It must be simultaneous and it must be non-local – the image must be Net-based, built on information from non-local sources in the manner already demonstrated by online games with their thousands of inhabitants/ players. One century ago, people built railway lines, laid cables below and above ground and across the ocean beds. And now fiber optics must become the basis for collective experience of other visual codes. At present, a wire still leads to the computer from the head-mounted display. A future wireless technology might be based on neurophysiology: wireless neurocinema. The projector of the future is wireless usage of the Net, enabling the collective experience of non-local, visual and acoustic data.

Neurocinema

It was discovered in the nineteenth century that neurons use action potentials to signal over long distances. The all-or-none nature of the action potential means that it codes information by its presence or absence, not by its size or shape. In this respect, an action potential can be considered a pulse. How do action potentials represent sensory states and mental activities? How is information contained in the firing patterns of stored and retrieved action potentials? We owe the first images of neural networks to Ramón y Cajal.[17] They enabled the question of how the brain processes information to be put more precisely. Excitation and inhibition were known as attributes of the activities of neural networks since 1900. However, the excitatory and inhibitory effects of nerve pulses was first demonstrated by David Lloyd in 1946.[18]

This incipient knowledge of the structure and function of neural networks supported Leibniz and others in their ideas on the logical structure of the mind. Leibniz showed that logic can be reduced to arithmetic and that arithmetic can be expressed in a binary code (all numbers can be expressed by the digits 0 and 1). He conceived a logic machine that could calculate each computable number by the algebraic operations today known as algorithms. The English mathematician George Boole further developed this idea in his books *The Mathematical Analysis of Logic, Being an Essay Towards a Calculus of Deductive Reasoning* (1874) and *An Investigation of the Laws of Thought* (1854). Boole's Algebra, a symbolic method for logic relations, is a calculus of propositions whereby variables may be only 0 or 1. In 1938, Claude E. Shannon used Boole's Algebra to demonstrate that a perfect analogy exists between the calculus of propositions and the calculus for relay and switching circuits.[19] A theorem of the proposition calculus can also be interpreted as a valid theorem of switching circuits. The interpretation of a proposition as false can be interpreted as signifying that a circuit is closed, that a proposition is true as signifying that a circuit is open, and so forth.

The description of nervous activities accompanying thought processes can be turned into prescriptions for the design of machines that can think or (amounting to the same thing) the design of programs. One way to understand the laws of thought was to study carefully the brain and its nervous activ-

[6] W. Grey Walter, "An Imitation of Life," in *Scientific American*, 182, 5, 1950, pp. 42–45.

[7] W. Grey Walter, *The Living Brain*, Penguin, London, 1961, pp. 112–113. First published by Duckworth, 1953.

[8] G. Spencer Brown, *Laws of Form*, George Allan and Unwin, London, 1969.

[9] Ivan E. Sutherland, "Sketchpad – A Man-Machine Graphical Communication System," in *Proceedings of the Spring Joint Computer Conference*, Detroit, Michigan, May 1963, and *MIT Lincoln Laboratory Technical Report* #296, January 1963; Ivan E. Sutherland, "A Head-Mounted Three-Dimensional Display," in *AFIPS Conference Proceedings*, Vol. 33, Part I, 1968, pp. 757–764; Ivan E. Sutherland, "Facilitating the Man-Machine Interface," in *Purposive Systems: Proceedings of the First Annual Symposium of the American Society for Cybernetics*, Heinz Von Foester, J.D. White, L. J. Peterson, and J.K. Russell (eds), Spartan Books, New York, 1968, pp. 127–140.

[10] John Archibald Wheeler, "Law without Law", in *Quantum Theory and Measurement*, J. A Wheeler and W. H. Zurek (eds), Princeton University Press, Princeton, 1983, pp. 182–213.

[11] Axel Thue, *Probleme über Veränderungen von Zeichenreihen nach gegebenen Regeln*, Kristiania, Dybwad, 1914.

[12] Emil Leon Post, "Recursive unsolvability of a problem of Thue," in *Journal of Symbolic Logic*, 12, 1–11, 1947.

[13] J. W. Backus, Peter Naur and Wiliam Turanski, *Report on the Algorithmic Language Algol 60*, Danish Academy of Technical Sciences, Copenhagen, 1960.

[14] Aristid Lindenmayer, "Developmental systems without cellular interaction, their languages and grammars," in *Journal of Theoretical Biology*, 1971, pp. 455–484.

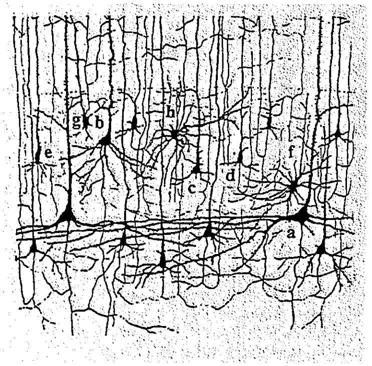
[15] Przemyslaw Prusinkiewicz and Aristid Lindenmayer, *The Algorithmic Beauty of Plants*, Springer, New York, 1990.

[16] John H. Holland, Heather Mimnaugh, *Hidden Order. How Adaptation Builds Complexity*, Perseus Books, Cambridge, MA, 1996.

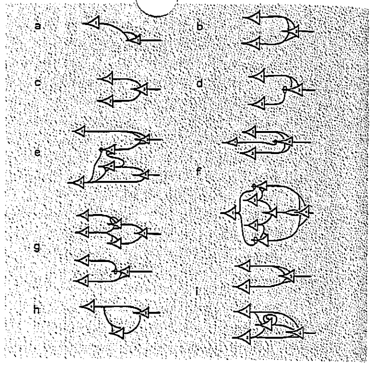
[17] Ramón y Cajal, *Histologie du système nerveux de l'homme et des vertébrés*, Paris, 1909–1910.

[18] David P. C. Lloyd, "Integrative patterns of excitation and inhibition in two-neuron reflex arcs," in *Journal of Neurophysiology*, 9, 1946, pp. 439–444.

[19] Claude E. Shannon, "A symbolic analysis of relay and switching circuits," in *Transactions of the American Institute of Electrical Engineers*, American Institute of Electrical Engineers, New York, 1938, p. 713.



This reproduction of a drawing by Ramón y Cajal shows a small proportion of the neurons in the cortex; in reality, the density of neurons is much higher. Cell b is a nice example of a pyramidal cell with a triangular cell body. Dendrites can be recognized by their rough surface. The axon extends downwards, with several branches to the left and right.



Warren S. McCulloch and Walter H. Pitts
A logical calculus of ideas immanent in nervous activity
1943

a) $N_2(t) . \equiv . N_1(t-1)$
b) $N_3(t) . \equiv . N_1(t-1) \vee N_2(t-1)$
c) $N_3(t) . \equiv . N_1(t-1) . N_2(t-1)$
d) $N_3(t) . \equiv . N_1(t-1) . \sim N_2(t-1)$
e) $N_3(t) :\equiv: N_1(t-1) . \vee . N_2(t-3) . \sim N_2(t-2)$
$N_3(t) . \equiv . N_2(t-2) . N_2(t-1)$
f) $N_4(t) :\equiv: \sim N_1(t-1) \vee N_2(t-1) \vee N_3(t-1) . \vee . N_1(t-1) . N_2(t-1) . N_3(t-1)$
$N_4(t) :\equiv: \sim N_1(t-2) \vee N_2(t-2) \vee N_3(t-2) . \vee . N_1(t-2) . N_2(t-2) . N_3(t-2)$
g) $N_3(t) . \equiv . N_2(t-2) . N_1(t-3)$
h) $N_2(t) . \equiv . N_1(t-1) . N_1(t-2)$
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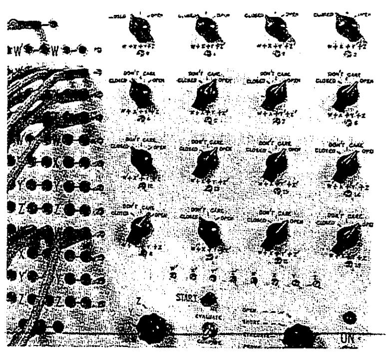


Claude E. Shannon
View of the front cover of the switching circuit analyzer
1938

ity. Since Ramón y Cajal's discovery that the cerebral cortex is composed of layers of cells tangential to the pial surface, the science of the brain has made enormous progress. We now have an atlas of the human brain[20] and considerable knowledge of conscious experience in the brain.[21] Beginning in the nineteenth century, the quest for an analogy between mathematics and the brain, between algebraic operations and nervous activities, between a calculus and deductive reasoning, had by the mid-twentieth century progressed to a stage where nervous activities representing ideas and thought processes could be described and formulated in mathematical terms. This quest led to machines that could think, constructed according to mathematical laws, for instance the propositional calculus. These machines can help us to understand reasoning and the brain. We therefore have a chain of analogies between nervous activity and mathematics, mathematics and machines, machines and nervous activities. Mentalism, mechanism and mathematics were seen as parallel worlds. [22] Symbolic or formal logic was used to design electrical circuits.[23] Electrical circuits were used to design a brain.[24]

Machines were supposed to do the work of the brain and mathematics, to turn thought processes into program processes. The turning point came in 1943 with the publication of three theoretical papers on what is now called cybernetics. Nobert Wiener, Arturo Rosenblueth and Julian H. Bigelow of MIT suggested ways of building goals and purposes into machines.[25] Warren S. McCulloch and Walter H. Pitts showed how machines might use concepts of logic and abstraction and how neural networks could be seen as parallel computers.[26] Kenneth J. W. Craik of Cambridge University proposed that machines could use models and analogies to solve problems.[27]

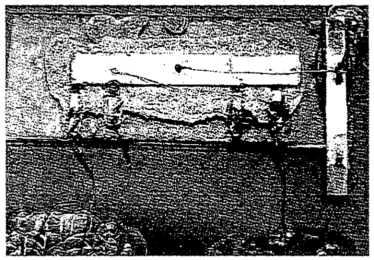
Warren McCulloch and Walter Pitts' formal theory of neural networks laid the foundations for automata theory and artificial intelligence. Due to the "all-or-nothing" character of nervous activity, a neuron can be seen as a binary logic device and neural events can be described by means of propositional logic derived from Rudolf Carnap's *The Logical Syntax of Language* (1937). Shannon demonstrated the analogy between the propositional calculus and switching circuits, McCulloch and Pitts showed the analogy between the propositional calculus and nervous activity. Neuronal networks, switching circuits and logic calculus became one, obeying the same laws. Electronic machines could therefore do the job of neuronal networks, and compute. McCulloch and Pitts' model of nervous activity and their proposal that neurons compute logic functions influenced John von Neumann's sketch of the architecture of future digital computers in a famous 1945 technical report. In 1947, Pitts and McCulloch gave a theoretical construction of neural networks for pattern recognition that showed how visual input could control motor output via the distributed activity of a layered neural network. In this remarkable paper entitled "How we know universals: The perception of auditory and visual forms,"[28] Pitts and McCulloch proposed a number of quite specific neural mechanisms that could be used to abstract important quantities from a neural representation. Between the papers of 1943 and 1947 a shift occurred from binary neuronal computing logic to specialized neural structures computing particular aspects of a sensory stimulus. S. C. Kleene's 1951 paper "Representation of Events in Nerve Nets and Finite Automata" marked, together with others, the beginning of abstract automata theory.[29]

19th century →		21st century	
eye cinema	trompe l'oeil eye technology	neurocinema	trompe le cerveau brain technology
medicine physiology	Roget Marey	cognitive science neurophysiology	Edelmann Kandel
physics optics mathematics	Faraday Stampfer Mach	nanotechnology quantum physics quantum computing	Feynman Bell Deutsch
macro-engineers	Lumière	molecular engineering	Drexler

The idea was born: With the aid of logic, events of the world could be represented in artificial neural networks. These networks could be simulated by switching circuits, following the same laws of symbolic logic as applied to the representation of events in neuronal networks. Automata built from these switching circuits, could simulate such nervous activities in the brain as thought processes, computing, and even seeing. Machine vision on a molecular scale is one possibility of the future cinematic imaginary. The McCulloch-Pitts model was based on binary units; many of the recent network models rely on continuous variables. Our perception of the world is driven by input from the sensory nerves. This input reaches the brain encoded as sequences of firing patterns of action potentials or spikes. The eye communicates chains of spikes to the brain. Information is coded by the firing of neurons, the timing of spikes codes the information. Neuronal networks are therefore pulse-coded. Vision is not a spatial representation in the brain through the retina. Vision is the brain's computing of temporal patterns. This pulse-based neuronal coding, created by the firing of neurons, delivers the basis of our perception. Biological neural networks, which communicate through pulses, use the timing of the pulse to transmit information. Pulsed neural networks[30] mean that vision is a temporal code.

Future cinema will be able to precisely simulate or stimulate those pulsed neural networks. Instead of *trompe l'oeil*, the next step might be *trompe le cerveau* – the cinematographic apparatus will deceive the brain, not the eye, will steer and govern precisely pulsed neural networks with the help of molecular machines. We would be able to imitate vision, to construct a cinematic experience without light and eyes, to create images without perception conveyed by the direct stimulation of neural networks. Thanks to pulse-based temporal codes that directly stimulate the brain with the help of neurochips or brain-chips, there would be perception without the senses, seeing without the eyes. Stimulation – artificial pulse-based representation of the world – would replace simulation. The brain, as opposed to the eye, would become the screen.[31]

In the twenty-first century, neurophysiology may be expected to assume the role played by physiology in the development of cinema in the nineteenth century. Advances in neurophysiology and cognitive science[32] give rise to the hope that future engineers will succeed in implementing these discoveries in neuronal and molecular machines that transform the technology of simulation to deceive the eye into a technology of stimulation that in turn deceives the brain.



Jack Kilby
The first "integrated circuit" or "chip"
1958

Instead of having to produce each component individually, the inventor accommodated a transistor, a capacitor and several resistors on the same slice of germanium.

Quantum Cinema

Scaling is a question of future cinema. Working on the level of supramolecular chemistry or nanotechnology, can we invent a cinematographic apparatus that enables us to manipulate not only singular neurons, cells and neuronal networks, but also particles smaller than neurons? If this is feasible, then we can learn from quantum theory, which teaches us that reality is observer-relative. Anything that is observed is also changed by the very act of observation. That means we must move from receptor technology (cameras) to effector technology. Up to now, we have developed only receptors: recording machines with which to record and represent the world. The decade-long crisis of representation will be resolved only when we develop a technology of effectors. The act of observation is changing not only the perception of reality and the image, but even the real world. This is a basic proposal of quantum theory. If in our case the observer is a machine, then our reality is not only observer-relative, but machine-relative, too. The new observing machines, from satellite TV to computers, are not only changing perception and simulating reality (simulating life) – they are constructing reality. Ultimately, even our status as subjects is being altered by this observer-relative, machine-relative, reality. While in the classical world it was valid to say "know yourself" or "express yourself," in the world being constructed with the help of these machines the subject must also be constructed. Like the machines that can construct what they, and we, see, all we can do is "construct ourselves."

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[23] Claude E. Shannon, "A symbolic analysis," op. cit.

[24] Ashby, op. cit.

[25] Nobert Wiener, Arturo Rosenblueth and Julian H. Bigelow, "Behaviour, Purpose, and Teleology," in *Philosophy of Science*, 10, 1943, pp. 18–24.

[26] Warren S. McCulloch and Walter H. Pitts, "A logical calculus of ideas immanent in nervous activity," in *Bulletin of Mathematical Biophysics*, 5, 1943, pp. 115–133.

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[28] W. Pitts, Warren S. McCulloch, "How we know universals; The perception of auditory and visual forms," in *Bulletin of Mathematical Biophysics*, University of Chicago Press, Chicago, 9, 1947, pp. 127–147.

[29] In Claude E. Shannon, John McCarthy, *Automata Studies*, Princeton University Press, Princeton, 1956.

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David Finkelstein[33] has shown that quantum physics can be considered a theoretical model for interactive media. Extending this idea further we can forecast the following relations:

Quantum Physics	**Media Theory**
quantum complementarity	computer interactivity
massive parallel computing (qubits, superposition)	massive parallel virtual worlds
entanglement (E. Schrödinger) teleportation of information (Zeilinger)	simulation of teleportation

Writing almost at the same time as Marey, the mathematician Josiah Gibbs in 1873 published an article entitled "A method of geometrical representation of the thermodynamic properties of substances by means of surfaces." It went unnoticed by the cultural world. The point was to find a method of geometrically representing the thermodynamic properties of living organisms. He did not want to represent motion, but energy. He realized that with the construction of surfaces you can get some idea how to represent a stream of energy. This article introduced the so-called "Gibbs phase state," which shows that space is not something continuous, but a statistical property.

Richard Feynman understood Gibbs' idea, and took it one step further. He saw that the viewpoint of an initial value has to be replaced by the state of a system. The state of a system is represented by a vector in its evolution time. Gibbs worked with geometry only; Feynman said we must also consider evolution time. Instead of considering the motion of a particle from a point A in space to a point B, we have to replace it with phase space. It has to be defined not as motion, but as transitions between different states. The idea is brilliant: No longer do we see in the manner of nineteenth-century recording machines that analyze motion in frames, but instead see motion as a dynamic system in which we must distinguish state transitions. If one state transition occurs, then the whole system changes to another phase state. This space can never really be measured; it can only be given a probabilistic value.

Many probabilities for possible paths exist. A path taken by one particle is merely a probabilistic average of (all) possible paths. Feynman introduced what is now called the "Feynman path integral": an integral of all potential paths. For makers of movies, of optical works, it means the observer has to be given the chance of choosing the possible paths. The tendency to give the observer an undefined field, a probabilistic of different paths, already exist. The Feynman integral of the probabilistic values is stored in the computer and the observer acts like a particle in selecting phase-state transitions.

If you recognize that the source of the image is a vast field of probabilities, you begin to realize how many people might be able to see different movies at the same time. My vision is that every member of a cinema audience would be able to watch a different movie. Impossible to put into practice with images on celluloid, the idea i[illegible]ible with virtual information storage in a quantum computer, which enables stochastic access to the information. Each viewer has a set of variables which, although finite, allows him to see a different movie resulting from the same stock of probabilistic values. This idea applies the Feynman integral to the optical field and needs the performance capabilities of the quantum computer,[34] which will replace electronic computers in the future. The new field of quantum information, with its strange attractions like superposition and entanglement,[35] permit the utopian vision of a totally new, cinematic imaginary with no local restrictions.

Kathryn Bigelow's admirable film *Strange Days* (1995, scenario by James Cameron and Jay Cockes) already sketches out such a quantum cinema of the future with extremely advanced interface technology involving the direct attachment of the brain, and shows a cinematic apparatus which substitutes all former historical cinematographic machines, a subjective camera-eye of a kind never seen before: one enabling us to see with one another's eyes. A cinematic apparatus called "Squid" (Superconducting Quantum Interference Device) built on the "Josephson junction" is the first example of quantum cinema. A similar visual apparatus appears in *Brainstorm*, 1983, by Douglas Trumbull.

Kathryn Bigelow
Strange Days
USA, 1995
color, sound
139 min
film still
© 20th Century Fox

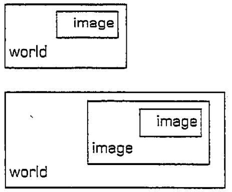
The new computer technology will enable the cinematographic code to develop from a 1:1 relationship (one viewer – one film – one place – one time) into a multi-user virtual environment (x viewers – x films – x places – x times). The Many-Worlds Interpretation of quantum mechanics[35] models a future of many virtual worlds, massively parallel computed and "entangled" (see *The Matrix*, 1999). In this dispersed Virtual Reality, hundreds of spectators will act not only in front of the screen but behind it, too. Net technology is already providing a new stage for communication, a new kind of projector. Just as the twentieth century standardized nineteenth-century image-technological inventions and turned them into a mass industry, the twenty-first century must make the advanced image technology of the twentieth century compatible with mass usage. Contemporary VR technology is strikingly reminiscent of the first nineteenth-century cinema, which was characterized by singular reception. The example of the Phenakistoscope enables us to grasp the principle of singular reception: one person watches one film in one place at one time. Projection made collective simultaneous perception possible: x people watch one film in one place at one time. Television brought about non-local perception: x people watch one film in x places at one time. Video and CD-ROM enable either singular or collective perception, simultaneous as well as non-simultaneous: x/one viewer(s) watch x/one film(s) in x/one places(s) at x/one time(s). In the late twentieth century, the digital image started from scratch.

	Viewer(s	[illegible]e(s)	Time(s)	Film(s)
19th century				
Phenakistoscope single spectator	1	1	1	1
Projector simultaneous collective perception	x	1	1	1
20th century				
TV simultaneously distributed non-local	x	x	1	1
Video, CD-ROM	x/1	x/1	x/1	x/1
Virtual Reality single spectator	1	1	1	1
21st century				
Distributed non-local Multi-User Virtual Environment (MUVE) anybody anywhere any time	x	x	x	x

X = any quantity

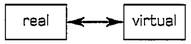
The head-mounted display of VR systems returned to the singular local reception of nineteenth-century cinema: one person sees one film in one place at one time. In order to survive, VR technology must appropriate the collective, non-simultaneous, non-local forms of perception already known from television and radio.

The sound tele-technology we know from mobile phones (compare wearable ubiquitous computing) will supply the music of the future, which will seize the tele-technology of the image as well. The image technologies of the future will allow anybody to see any movie in any place at any time. The formula for future image technology reads: anybody, anywhere, any time. However, the decisive point is that with this form of collective interaction (instead of the present-day individual interface technology) the observer does not remain an external observer, as in the case of film, but becomes an internal observer. He will participate in, and thereby change, the image-worlds. This entry into the image-world will trigger reactions in the sense of the co-variant model not only in multiple parallel image-worlds but also in the real world. The relation between image-world and reality will be multiple and reversible, and the observer himself will be the interface between an artificial virtual world and the real world. Controlled by the internal observer, events in the real world will affect the virtual world. Events in the virtual world, also controlled by the observer, will affect the real world and parallel virtual worlds.



massive parallel worlds

reversible



The observer will cut from one narrative to another. Instead of linear narration, multiple users will create instant multiple narratives. Interactions between the observer and the image world will become bi-directional. A cause in the real world will have an effect in the virtual world and, conversely, a cause in the virtual world will have an effect in another parallel virtual world or in the real world. Observer-controlled interactions between real and virtual worlds and between different parallel virtual worlds in computer or Net-based installations enable the spectator to be the new author, the new cameraman or camerawoman, the new cutter, the new narrator. In the multimedia installations of the future, the observer will be the narrator, either locally or, via the Net, by remote control. Through their navigation, the observers will create new forms of narration in Net- or computer-based installations.

The convergence of film, video, television and Internet offers a historic occasion to expand and revolutionize the cinematographic code. The horizon of the new digital image is already being built by multiple projections supporting multiple narration techniques, by immersive image technologies from CAVE to online games and other distributed VR technologies. Above all, however, image technology of the future will be shaped by massive parallel virtual worlds (MUVEs = multi-user virtual environments) which are tele-correlated or "entangled." The idea of wireless or online MUVEs is strongly supported by the strangest features of quantum physics: non-locality and entanglement. Einstein, following Newton, did not believe in "actions at a distance." Quantum theory predicted that pairs of photons behave identically in correlated measurements, and that is why the photons are said to be "entangled": it seems that measuring one instantly "influences" the outcome of a measurement of the other, no matter how far apart they are. Einstein called this behavior "spooky action at a distance." In 1964, John Bell showed that this behavior theoretically exists.[37] The apparent ability of quantum systems to act at a distance is known as nonlocality. Experiments by Clauser, Aspect and Zeilinger[38] confirmed the entangled, supercorrelated nature of the two-photon state, the possibility of interactions between remote measuring devices. In distributed or dislocated interactive virtual worlds, we will find the same inseparability. The interaction will not only be unidirectional from observer to image, from real to virtual, but also bi-directional – from the virtual back to the real, from the image back to the observer. Reversible computing will allow reversible relations between real space and image space. This interaction will not be locally bound (as was the case even with computer-assisted interaction), but correlative between distant virtual worlds, or between dislocated real and virtual worlds. The structure of non-local communication will be assisted by intelligent virtual agents or assistants, from GPS (Global Positioning Systems) to WAP mobile phones. These intelligent image systems will be a next step toward liberating humanity from the natural prison of space and time.

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