Artificial Intelligence, Architectural Intelligence: The Computer in Architecture, 1960–80

A dissertation proposal by Molly Wright Steenson

Dissertation committee

Prof. M. Christine Boyer (advisor)
Prof. Edward Eigen (reader)
Prof. Axel Kilian (reader)

Abstract

With the advent of the information age, architects in the 1960s and 70s found themselves contending with more complex design problems than they had in the past. In response to these changes, the architectural profession began to turn to computers and computer-related sciences including cybernetics and artificial intelligence (AI), and to ways to solve and represent problems using the computer. The computational shift promoted design process over formal object, moved the architect out of a central role in the design process, and generated architectural solutions beyond the capabilities of machine or architect alone. This dissertation will examine the work of three architects: Christopher Alexander (b. 1936), Nicholas Negroponte (b. 1943) and Cedric Price (1934–2003) and the influence of, and their collaborations with, key figures in cybernetics and artificial intelligence. The period from 1960 to 1980 is significant because it marks the introduction of computing paradigms to architecture and the beginning of the mainstream of computers in architectural practice. Throughout, this dissertation will develop the notion of generative systems in architecture; that is, systems that incorporate models of intelligence, interact with and respond to both designer and end user, and adapt and evolve over time.

Artificial Intelligence, Architectural Intelligence: The Computer in Architecture, 1960–80

In the 1960s and 70s, architects began to face increased complexity within their profession, raising a major issue within the architectural purview: the role of the architect in an informationally complex world. While architecture could be defined as "the constructable end product of the architect," as Royston Landau wrote in 1968, "the ex-craftsman's designer is faced with a new, multi-variable world in which the old delineations of his activity are no longer applicable."[1] With what Landau called the "accelerating growth of information and knowledge" came "an increase in doubt,"[2] One response to the conditions Landau described was architecture's turn to computation: to computers, conceptually and practically, and toward disciplines like cybernetics[3] and artificial intelligence (AI).[4] This dissertation will address the computational shift in architecture, one that privileged the design process over the final representation, altered the centrality of the role of the architect and generated architectural solutions beyond the capabilities of machine or architect alone. In particular, it will examine Christopher Alexander (b. 1936), Nicholas Negroponte (b. 1943) and Cedric Price (1934–2003) and the influence of, and their collaborations with, key figures in cybernetics and artificial intelligence. Throughout, this dissertation will develop the notion of generative systems in architecture; that is, systems that incorporate models of intelligence, interact with and respond to both designer and end user, and adapt and evolve over time. The period from 1960 to 1980 is significant because it marks the introduction of computing paradigms to architecture and ends with the early mainstreaming of computers in architectural practice.

Alexander, Negroponte and Price were similar in that they responded to a common impetus by using computing and concepts of machine intelligence in their work. All challenged the traditional role of the architect, with Negroponte and Price going so far as to explicitly call themselves "anti-architect" and with Alexander railing against the "genius" role of the architect.[5]

---

[1] Royston Landau, *New Directions in British Architecture* (New York,: G. Braziller, 1968), 11.

[2] Landau cites both Karl Popper and Bertrand Russell in footnotes in this passage, underscoring the positivistic aspect of the argument. Ibid., 12.

[3] The term "cybernetics" refers to the study of communication and control within systems, a term that Norbert Wiener (1894–1964) derived from Greek word for steersman in 1948. Cybernetics examines how actors within a system exchange messages of information and receive feedback on the success of their transmissions. It situates the exchange of information as the raison d'être of any organism, whether living being, built circuit or societal construct. This approach to system dynamics influenced a wide range of fields, including engineering, computer science, biology, philosophy, and social organization.

[4] Artificial intelligence (AI) refers to the study of machines that "exhibit and simulate intelligent behaviour." *O.E.D.,* "artificial intelligence." It is the notion, wrote John McCarthy, who coined the term "artificial intelligence" in 1955, "that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it." John McCarthy et al., "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," (1955). AI sought to use information theory to model the brain, examining how computers could learn, problem-solve and use natural language. Where cybernetics creates a universal system of part-to-whole interaction, AI does not operate on so broad a scale—it is a set of models and methods on how intelligence works. While many of the ideas that they had were not scalable or achievable until recently—and still sometimes not by today's standards—contemporary AI uses a framework set forth by Marvin Minsky in 1961: Search, pattern-recognition, learning, induction and planning. Marvin Minsky, "Steps toward Artificial Intelligence," *Proceedings of the I.R.E.* 49, no. 1 (1961).

[5] Price called himself anti-architect in regards to the Fun Palace; Negroponte referred to himself as "antiarchitect," distinguishing from that being an anti-architectural stance, and while Alexander did not call himself anti-architect, he

Although they did not collaborate with one another, they based their notions of generative machines on work by many of the same figures in technology, including W. Ross Ashby,[6] Gordon Pask,[7] Marvin Minsky,[8] Douglas Engelbart[9] and J.C.R. Licklider.[10] However, the manner in which Alexander, Negroponte and Price approached technology differed. Alexander sought to use computers for data processing and problem solving in the early 1960s, only to shift the computer to the periphery in his 1977 book *A Pattern Language*. Negroponte, on the other hand, only reinforced the importance of the computer in the concept of what he called an "architecture machine," one that would develop a symbiotic, conversational relationship with the user and use ever more sophisticated interfaces for input or output, and that would become so sophisticated, it would ultimately develop a notion of agency. Unlike Negroponte and Alexander, Price did not start with the computer as his central interest but instead turned to technology to provide unexpected interactions that supported his interest in "indeterminacy."[12]

While Alexander, Negroponte, and Price were key figures in the development of intelligent systems for architecture, they were by no means the only architects who were active in this regard. Throughout the 1960s, a number of conferences and publications addressed the implications of computing and architecture, including *Architecture and the Computer* at the Boston Architectural Center in 1964, *Computer Graphics in Architecture and Design* at the Yale School of Art and Architecture in 1968, and the *Design Quarterly* double issue, "Design and the Computer" in 1966. Such confluences brought together representatives from architecture, urban planning, engineering and computer science. The events and publications took place within mainstream of architectural education and knowledge and included such participants as Walter Gropius, Charles Moore, and Louis Kahn, in addition to up and coming architects and technologists working at the nexus of computing and architecture. Studying these events will help to historicize the changes they reflected in the field of architecture.

In this dissertation, I will engage sources from both architectural history and the history of technology to trace the development of the generative, intelligent systems at the center of

frequently and explicitly challenged the role of the architect, as early as in *Notes on the Synthesis of Form*. See Stanley Mathews, "An Architecture for the New Britain: The Social Vision of Cedric Price's Fun Palace and Potteries Thinkbelt" (Columbia University, 2003), 73., Nicholas Negroponte, *Soft Architecture Machines* (Cambridge, Mass.,: The MIT Press, 1975), 1. Serge Chermayeff and Christopher Alexander, *Community and Privacy; toward a New Architecture of Humanism*, 1st ed. (Garden City, N.Y.,: Doubleday, 1963), 116.

[6] W. Ross Ashby (1903-1972), British psychiatrist and cybernetician

[7] Gordon Pask (1928-1996), British psychology and cybernetician, especially known for second-order cybernetics and Conversation Theory.

[8] Marvin Minsky (1927-). Electrical engineer, cognitive psychologist and artificial intelligence pioneer. Founder of the Artificial Intelligence Laboratory at MIT.

[9] Douglas Engelbart (1925-). Electrical engineer, inventor of the computer mouse, former lab director at Stanford Research Institute.

[10] J.C.R. Licklider (1915-1990). Computer scientist who coined the term "man-computer symbiosis" and invented time-sharing (multiple users logging into a mainframe computer).

[12] While the word "indeterminate" is used frequently to describe Price's work, especially by Stanley Mathews and Gonçalo Furtado, neither author provides the source for its use. The word "indeterminacy" in regard to Price is used by Royston Landau in 1968 in *New Directions in British Architecture*. Gordon Pask uses it in a 1962 article. It would be possible that Pask article introduced the notion of indeterminacy to Price, something that likely would have occurred during their collaboration on the Fun Palace. See Gordon Pask, "Comments on an indeterminacy that characterizes a self-organising system." *Cybernetics of Neural Processes*, Consiglio Nazionale delle Richerche (1965):1-30.

Alexander, Negroponte and Price's work. My research will examine closely the technological sources that influenced the key figures of the dissertation, the computational capabilities in use at the key sites in the dissertation (especially MIT), and the reciprocal collaborations and influences between the architects and the technologists. By synthesizing both architectural and technological material, the dissertation will probe how Alexander, Negroponte and Price challenged traditional architectural design and form-making processes, creating systems that generated architectural solutions in a unique human-computer symbiosis. Ultimately, the dissertation will seek to draw a clear picture of generative systems, the way they changed architectural method, knowledge and practice in the period of study, and the implications for contemporary architecture, computing and interactivity.

Technological backdrop

Systems of intelligence and responsiveness assume a set of technological requirements. While it may seem obvious, architectural computing presumes something very basic: that an architect could even use a computer at all. Computers in the 1960s were rare and expensive, belonging mostly to major educational institutions, firms that serviced military contracts, or to large businesses (including Skidmore Owings and Merrill). MIT proved very important in this regard because it offered computing resources to its own students, faculty and researchers, as well as to other universities and firms in the Boston area.[19]

Architects first used computers in two ways: in what I will call quantitative problem solving and in representation. Quantitative problem solving provided the greatest return given the expense of computing. It referred to writing functional requirements, analyzing data, performing engineering calculations, providing metadata for projects and calculating costs.[20] The second category, representation, included the means for architects to draw and manipulate images: computer graphics, computer-aided design and data visualization tools. For much of the 1960s, these three types of representational tools were developed in different domains, separately from one another. Early computer graphics were developed as a static means to display an image on a cathode ray tube, constructed from mechanical engineering data.[21] Computer-aided design referred to the manipulation and abstraction of computer images. [22] Data visualization referred to

[19] This was especially the case with the 1963 invention of time-sharing, which allowed multiple people to access a mainframe computer at the same time from separate terminals.

[20] These include Skidmore Owings & Merrill's computerized specification system, engineering calculations for the John Hancock Tower in Chicago, and Bolt, Beranek and Newman's programming of hospital space using a computer. This includes the concept of "automatic data processing (ADP)." Boston Architectural Center., *Architecture and the Computer*, First Boston Architectural Center Conference (Boston: Boston Architectural Center, 1964).

[21] The term "computer graphics" was coined by William Fetter at Boeing in 1960.William Fetter, "Computer Graphics," *Design Quarterly* 66/67, no. Design and the Computer (1966): 15. At MIT, the Air Force funded computer graphics and computer-aided design research. Boston Architectural Center., *Architecture and the Computer*, 26.

[22] Notably, Ivan Sutherland developed Sketchpad, a two-dimensional computer-aided design program, as his dissertation advised by Claude Shannon in 1962. Sketchpad's console consisted of a large number of dials, buttons, toggle switches, knobs and a light pen for drawing and manipulating shapes on a screen. Steven Coons, director of the Computer-Aided Design Project at MIT supervised the three-dimensional design program Sketchpad 3, developed in 1964 by Timothy Johnson after Sutherland left MIT for ARPANET; he worked closely with architects at MIT on computer-aided design programs for architecture. Steven A. Coons, "Computer-Aided Design," *Design Quarterly* 66/67(1966): 8.

the creation of visual relationships and mapping of statistical data. Developers of such systems combined input devices like light pens, keyboards, tablets and the computer mouse, and output devices that displayed graphic forms on screens or that drew them with plotters.

Christopher Alexander: From Problem-Solving to Pattern-Generating

An explicit and implicit computational approach to architecture underscored Christopher Alexander's work throughout the 1960s and 70s. He began his career wanting to use computers for architectural purposes: indeed, he was one of the only architects in the early 1960s with the mathematical expertise to program and use a computer.[23] Over the next 15 years, however, the computer as a processing device would cease to occupy so central a position in his work. Instead, he applied the logic and structure of computing problems in patterns and pattern languages, a codification of a solution for a design problem that repeats in the environment (*A Pattern Language).*[24]

Alexander applied cybernetics and AI to architecture in an attempt to address the growing complexity of design problems. He noted the difficulty of designing for intermeshing systems, even when the designed object itself (whether something as big as a village or as small as a teapot[25]) seemed uncomplicated. "In spite of their superficial simplicity, even these problems have a background of needs and activities which is becoming too complex to grasp intuitively," he wrote in his dissertation, published as *Notes on the Synthesis of Form* in 1964.[26] The design process he described in *Notes* required a computer to analyze complex sets of data to define "misfits"—design requirements—that the designer ameliorated by creating a form that solved the problem.[27] *Notes* presented a logical, quantitative model of architectural computing influenced by such texts as Ashby's 1952 *Design for a Brain,*[28] Minsky's 1961 "Steps Toward Artificial Intelligence," and D'Arcy Wentworth Thompson's 1917 *On Growth and Form*.[29]

---

[23] From his undergraduate studies onward, Christopher Alexander expressed an interest in both mathematical analysis and design. He completed two bachelor's degrees at the University of Cambridge: the first in mathematics, the second in architecture in the program led by Leslie Martin (1908–1999). He moved to the United States and continued his studies in the doctoral program at Harvard starting in 1958. Sean Keller, "Systems Aesthetics: Architectural Theory at the University of Cambridge, 1960-75" (Harvard University, 2005), 64.

[24] Christopher Alexander, Sara Ishikawa, and Murray Silverstein, *A Pattern Language : Towns, Buildings, Construction* (New York: Oxford University Press, 1977), x.

[25] Christopher Alexander, *Notes on the Synthesis of Form* (Cambridge,: Harvard University Press, 1964), 3.

[26] Ibid.

[27] This is a direct interpretation of Thomspon's "diagram of forces," in which forces within and without an organism determines its outward form. " The form is a part of the world over which we have control, and which we decide to shape while leaving the rest of the world as it is. The context is that part of the world which puts demands on this form; anything in the world that makes demands of the form is context. Fitness is a relation of mutual acceptability between these two." Ibid., 15, 18-19.

[28] W. Ross Ashby, a cybernetician, became chair of the University of Illinois Champaign-Urbana Electrical Engineering department at the request of Heinz von Foerster and Stafford Beer, both prominent cyberneticians. Heinz von Foerster parented the notion of second-order cybernetics. Stafford Beer would work with the Allende government in Chile in the application of cybernetics to political processes and personal control. Beer would work with Cedric Price on the Fun Palace, serving as the lead on the cybernetics committee in the early 1960s.

[29] It is similar to a set of highway design projects he conducted with Marvin Manheim in the Civil Engineering Laboratory at MIT in 1963. See Christopher Alexander and Marvin L. Manheim, *Hidecs 2: A Computer Program for the Hierarchical Decomposition of a Set Which Has an Associated Linear Graph* (Cambridge,: School of Engineering, Massachusetts Institute of Technology, 1962).

"Systems Generating Systems," a 1968 article by Alexander, situated architectural systems in more abstract terms than *Notes*. He wrote, "In order to speak of something as a system, we must be able to state clearly: 1) the holistic behaviour which we are focusing on; 2) the parts within the thing, and the interactions among these parts, which cause the holistic behaviour we have defined 3) the way in which this interaction, among these parts, causes the holistic behaviour defined."[30] He emphasized that systems represent a recursive, repeating set of abstractions that give rise to—or more precisely, that generate—other systems. These conceptual notions of system intelligence undergirded the Center for Environmental Structure (CES). The CES developed the notion of the pattern language for seven years, publishing three books between 1975 and 1979: *The Timeless Way of Building, The Oregon Experiment* and *A Pattern Language*. *A Pattern Language* provided 253 plain language patterns that addressed possibilities for building on any scale, putting a grammar into place that anybody could use to design one's own environments without the help of an architect. Alexander and his colleagues viewed them as scientific hypotheses, on one hand, or even poetry, on the other, because language offered a wide range of interpretations.[31] The CES imagined that it would store patterns in a computerized catalog and offer them to subscribers—what we would today call a digital pattern library.[32] Not only did the pattern language concept enjoy success among the general public, it became a model for system architectures, computer languages and contemporary interfaces. *A Pattern Language* became a generative architectural system in Alexander's very definition of the term.

Nicholas Negroponte: "Architecture Machines"

While Nicholas Negroponte[35] is best known today as a technology guru and founder of the MIT Media Lab, this dissertation is interested in his architectural background and the notion of "architecture machines"— evolving systems that worked in "symbiosis" with designer and resident that Negroponte thought would change the making of architecture.[36] As director of the Architecture Machine Group at MIT, founded in 1968, he assembled a theory of how such systems would work in the 1970 book *The Architecture Machine* (dedicated "to the first machine that can appreciate the gesture"[37]) and the 1975 book *Soft Architecture Machines*, and a series of computer-aided design tools and programs throughout the 1970s.

[30] Christopher Alexander, "Systems Generating Systems," *AD* 38(1968): 607. The ideas in "Systems Generating Systems" call to mind a precedent to artificial intelligence: the self-reproducing systems that Claude Shannon predicted in "Computers and Automata" in 1953.

[31] Alexander, Ishikawa, and Silverstein, *A Pattern Language : Towns, Buildings, Construction*, xv, xli.

[32] Christopher Alexander, Sara Ishikawa, and Murray Silverstein, Pattern Manual, ed. Center for Environmental Structure (Berkeley1967), 3.

[35] Negroponte was first introduced to computer-aided design as a student at MIT. He joined the MIT faculty in 1966, founded the Architecture Machine Group in 1968, and the MIT Media Lab in 1985. His later work also proved popular: his 1995 *Being Digital* was a bestseller for a year and was translated into 40 languages.

[36] Nicholas Negroponte, *The Architecture Machine* (Cambridge, Mass.,: M.I.T. Press, 1970), 11-12. The term "symbiosis" originated in J.C.R. Licklider's 1960 article, "Man-Machine Symbiosis" but was also a favorite word of Steven Coons, computer-aided design pioneer and mechanical engineering professor at MIT. J. C. R. Licklider, "Man-Computer Symbiosis," *IRE Transactions on Human Factors in Electronics* HFE-1, no. 1 (1960). See also Boston Architectural Center., *Architecture and the Computer*, 26.

[37] Negroponte, *The Architecture Machine*.

An architecture machine, in Negroponte's estimation, would turn the design process into a dialogue that would alter the traditional human-machine dynamic. He wrote, "The dialogue would be so intimate—even exclusive—that only mutual persuasion and compromise would bring about ideas, ideas unrealizable by either conversant alone. No doubt, in such a symbiosis it would not be solely the human designer who would decide when the machine is relevant."[38] In order to achieve the design goals and close relationship with the user the machine would have to incorporate artificial intelligence, he wrote, "because any design procedure, set of rules, or truism is tenuous, if not subversive, when used out of context or regardless of context."[39] Intelligence for Negroponte is thus not a passive quality but an active one, expressed through behavior, and improved over time.

However, building a successful architecture machine proved a much more difficult concept in practice because of the quality of interaction they achieved and their designer's overall fascination with bells and whistles. The URBAN5 (1967) program was Negroponte's first, major computer-aided design program that sought to use his ideas about conversation, dialogue and intelligence. In his own judgment, it failed because it could not adapt and its dialogue was too primitive.[40] The shortcomings of URBAN5 led the Architecture Machine Group to develop "The Architecture Machine"—a time-sharing computer that in addition to typical peripherals, had a camera interface on wheels (GROPE), robot arm (SEEK),[41] tablet-based sketching stations and "an assemblage of software."[42] Negroponte wrote, " he prognostications of hardware enumerated in wanton fantasy have been achieved and even superseded in the actual Architecture Machine of 1974. All too often we spend our time making better operating systems, fancier computer graphics, and more reliable hardware, yet begging the major issues of understanding either the making of architecture or the makings of intelligence."[43] "The Architecture Machine" was perhaps a failure of its own success.

The work of the Architecture Machine Group illustrates the difficulty in building generative systems that deliver on the promise of contextual intelligence and responsiveness. An "architecture machine" expresses its intelligence by watching and learning from a user, and doing the right thing at the right time. Not surprisingly, cybernetics and artificial intelligence grappled with the same kinds of issues: the technology was simply not advanced enough to deliver on the ideas and the models of the theorists.

---

[38] Ibid., 11-12.
[39] Ibid., 1. Here, Negroponte refers to and cites Avery Johnson, "Organizaiton, Perception and Control in Living Systems," *Industrial Management Review* 10, no. 2 (1969): 12.
[40] Negroponte, *The Architecture Machine*, 95-6.
[41] SEEK was featured in the *Software* show at the Jewish Museum in Boston in 1970 and Smithsonian in 1971.
[42] Negroponte, *Soft Architecture Machines*, 157-71.
[43] Ibid., 1.

Cedric Price: Buildings with "Minds of their Own"

Cedric Price (1934–2003) designed architectural systems in which the act of engaging and interacting with the architecture would change the user. He incorporated cybernetics and communication technology in his work as a means of enabling new types of social interaction. The result was a series of prescient architectural projects, such as the Fun Palace, Potteries Thinkbelt and Generator. Price's philosophy was an "enabling" one, as Landau described it. "He [Price] looks to technologies which can expose inadequacies in the conventional wisdom of architecture while at the same time celebrating the possibilities of thoughtful supportive environments."[45] For Price, technology provided a means for architecture to increase choice and flexibility. In literal and more figurative ways, "the 'hardware' of architectural form became secondary to the 'software of human activity," Stanley Mathews wrote in his dissertation on Price.[46] As Landau pointed out in *New Directions in British Architecture,* Price's projects had to do with "problem-understanding and question-asking (besides being a physical or antiphysical, technological or nontechnological, solution) is necessary if it is to be understood."[47] He noted that Price tightly defined the context of his projects, but pursued "indeterminacy" in the hopes of enabling the users of his projects to adapt them to their needs.[48]

Price designed Generator (1976-79, unbuilt) to create conditions for shifting personal interaction in a reconfigurable and responsive environment.[49] It would be "intelligent—it should have a mind of its own," wrote programmer-architects John and Julia Frazer, with whom Price collaborated.[50] He developed a scheme of 150 12' by 12' mobile, recombinable cubes constructed with off-the-shelf infill panels, glazing and sliding glass doors. To this kit of parts, he added catwalks; screens and boardwalks, all of which could be moved by mobile crane as desired by users to support whatever activities they had in mind. When the Frazers joined the Generator project two years after its start, they concocted interventions for Generator that would surprise its users. "The whole intention of the project is to create an architecture sufficiently responsive to the making of a change of mind constructively pleasurable," Price wrote in a letter to the Frazers.[51] "If you kick a system, the very least that you would expect it to do is kick you back," they replied.[52] The Frazers proposed four programs that would use input from sensors attached to Generator's components: a drawing program, an inventory program, a modeling and prototyping interface,

[45] Royston Landau, "A Philosophy of Enabling," in *The Square Book*, ed. Cedric Price (London: Architectural Association, 1984), 11.
[46] Mathews, "An Architecture for the New Britain: The Social Vision of Cedric Price's Fun Palace and Potteries Thinkbelt", 9.
[47] Landau, *New Directions in British Architecture*, 76.
[48] Ibid.
[49] It was to serve as a retreat and activity center for small groups of visitors (1 to 100) to the White Oak Plantation on the coastal Georgia-Florida border. The client was Howard Gilman, CEO of Gilman Paper Company, a generous arts patron.
[50] Ibid.
[51] John Frazer, Letter to Cedric Price (January 11, 1979). Generator document folio DR1995:0280:65 5/5, Cedric Price Archives (Montreal: Canadian Centre for Architecture).
[52] Ibid.

and the intriguingly-named boredom program.[53] "In the event of the site not being re-organized or changed for some time the computer starts generating unsolicited plans and improvements," the Frazers wrote.[54]

While Price did not have the computer programming skills that Negroponte and Alexander did, he continually returned to the possibilities of computers and technology to enable new interactions within his architecture. Doing so promoted indeterminacy, as Landau termed it, without requiring a static form to represent the choice of the user. The Fun Palace, Potteries Thinkbelt, Inter-Action Centre and Generator offer better-known examples of the interconnection of cybernetics, communication technologies and architecture, but this dissertation also seeks to uncover other projects of Price's projects that incorporated technology and chance as a way of creating different types of engagement with his work.

Archives and positioning of dissertation

Admittedly, a number of contemporary projects address architectural history and technology in the 1960s and 70s, although none as specifically about architecture and computing as this dissertation aims to do. The connections between cybernetics and art and architecture have recently been documented in a number of dissertations, books and articles. These bodies of work, however, do not elucidate the connection between artificial intelligence and architecture. They do not consider Alexander, Negroponte and Price in comparison to one another, nor do they provide a close reading of technological paradigms in use by architects. Several dissertations have been completed or are in progress on the work of Cedric Price but tend toward a monographic approach.[55] Furthermore, only one architectural history dissertation exists on Christopher Alexander (on his surprising common background with Peter Eisenman); others explore the use of pattern languages in non-architectural fields.[56] And while one dissertation provided a literature and architectural theory review of computation in architecture from 1960–80 in support of a PhD in design and computation in architecture, it only offers cursory detail about the parties it traces.[57] Finally, not a single dissertation has been completed that focuses on Negroponte's Architecture Machine Group or that uses archival material on the subject.

---

53 Ibid.
54 Ibid.
55 Dissertations completed include Mathews, "An Architecture for the New Britain: The Social Vision of Cedric Price's Fun Palace and Potteries Thinkbelt". Gonçalo Furtado, "Envisioning an Evolving Architecture: The Encounters of Gordon Pask, Cedric Price and John Frazer" (University College London, 2008). Tanja Herdt, "The Concept of Micropolitics in the Work of Cedric Price 1961-1984" (ETH, In progress). Articles Mary Louise Lobsigner, "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace," in *Anxious Modernisms: Experimentation in Postwar Architectural Culture*, ed. Sarah William Goldhagen and Re□jean Legault (Cambridge, MA: MIT Press, 2000). Stanley Mathews, "The Fun Palace as Virtual Architecture: Cedric Price and the Practices of Indeterminacy," *Journal of architectural education* 59, no. 3 (2006).
56 Keller, "Systems Aesthetics: Architectural Theory at the University of Cambridge, 1960-75".
57 Altin João de Magalhães Rocha, "Architecture Theory 1960-1980. Emergence of a Computational Perspective" (Massachusetts Institute of Technology, 2004).

This dissertation will draw upon both written and design work, published and unpublished, from Alexander, Negroponte and Price, in an analysis and close reading of their projects. Archives to visit include:

Architecture archives:

- Nicholas Negroponte's personal archives, Cambridge, MA
- Cedric Price Archive, Canadian Centre for Architecture, Montreal
- Serge Chermayeff Archive (Christopher Alexander), Avery Library, New York
- Center for Environmental Structure material, University of California, Berkeley
- Archigram Archive (online)
- ICA Archive, British Center for Art, Yale University, New Haven
- Boston Architectural Center (*Architecture and the Computer*)
- Yale Archives (*Computer Graphics in Architecture and Design)*

Technology archives

- MIT Institutional Archives
- Charles Babbage Institute, University of Minnesota-Twin Cities
- Computer History Museum, San Jose, CA
- Stanford Archives (Stanford Research Institute and Stanford Artificial Intelligence Lab)
- Gordon Pask Archive, Vienna

Contribution

Through a close reading of architectural projects and technological influences upon them, this dissertation seeks to understand how information technology and computing changed architectural practice in the 1960s and 70s. By rigorously examining the terminology and arguments that Alexander, Negroponte and Price used and tracing back their references, I hope to derive a clearer understanding than currently exists of their systems, processes and projects. In so doing, I seek to question the implications of intelligent systems and the agency and ethics that they embody. Moreover, this study will analyze the effect on architectural practice of decentralizing the role of the architect and examine the shift toward the creation of process, not form, as the designer's métier. Finally, by approaching architectural history through the lens of technology, and by approaching the architectural components of human-computer interaction and the history of computing in the 1960s and 70s, I hope to bring to light the vital importance that intelligent, generative systems played in architectural method and knowledge of that time and explore their contemporary legacy.

Bibliography

Architecture & technology

Primary sources

Anderson, Stanford. "Problem-Solving and Problem-Worrying." Architectural Association, London, March 1966; ACSA, Cranbrook Academy of Art, Bloomfield Hills, MI, June 6, 1966.

Banham, Reyner. *Theory and Design in the First Machine Age*. New York,: Praeger, 1960.

———. "The History of the Immediate Future." *The Journal of the Royal Institute of British Architects* 68.7 (1961): 252–266.

———. *The New Brutalism: Ethic or Aesthetic?* New York,: Reinhold, 1966.

Colquhoun, Alan. "Frames to Frameworks." *Encounter* 48 (1977): 41.

Cook, Peter, and Archigram. *Archigram*. New York: Princeton Architectural Press, 1999.

Giedion, Sigfried. *Space, Time and Architecture; the Growth of a New Tradition*, The Charles Eliot Norton Lectures for 1938-1939. Cambridge, MA: Harvard University Press, 1941.

———. *Mechanization Takes Command: A Contribution to Anonymous History*. Oxford University Press, 1948.

———. *Building in France, Building in Iron, Building in Ferroconcrete*, Texts & Documents. Santa Monica, CA: Getty Center for the History of Art and the Humanities, 1995 [1927].

Jencks, Charles. Jencks, Charles. *Architecture 2000; Predictions and Methods*. London,: Studio Vista, 1971.

———. *Modern Movements in Architecture*. New York: Anchor/Doubleday, 1973.

Landau, Royston. *New Directions in British Architecture*. New York,: G. Braziller, 1968.

———. "Toward a Structure for Architectural Ideas." *Arena*, June 1965.

March, Lionel. "Modern Movement to Vitruvius: Themes of Education and Research." *Royal Institute of British Architects Journal* 81 (1972).

Martin, Leslie. "Royal Institute of British Architects Conference on Architectural Education." 1958.

Meier, Richard L. *A Communications Theory of Urban Growth*: Published for the Joint Center for Urban Studies of the Massachusetts Institute of Technology and Harvard University by MIT Press, 1962.

Mumford, Lewis. *Technics and civilization*. New York: Harcourt, Brace and Company, 1934.

Reichardt, Jasia. *The Computer in Art*. London, New York,: Studio Vista, Van Nostrand Reinhold, 1971.

Thompson, D'Arcy Wentworth. *On Growth and Form*. Cambridge, UK: University Press, 1917.

Venturi, Robert, and Museum of Modern Art (New York N.Y.). *Complexity and Contradiction in Architecture*. New York: Museum of Modern Art, 1966.

Secondary sources

Brown, Paul. *White Heat Cold Logic : British Computer Art 1960-1980*, Leonardo. Cambridge, Mass.: MIT Press, 2008.

Constant, M. Catherine de Zegher, and Mark Wigley, eds. *The Activist Drawing: Retracing Situationist Architectures from Constant's New Babylon to Beyond*. New York, Cambridge, MA.: Drawing Center, MIT Press, 2001.

De Magalhães Rocha, Altin João. "Architecture Theory 1960-1980. Emergence of a Computational Perspective." PhD diss., Massachusetts Institute of Technology, 2004.

Goodyear, Anne Collins. "The Relationship of Art to Science and Technology in the United States, 1957-1971: Five Case Studies." PhD diss., University of Texas at Austin, 2002.

———. "Gyorgy Kepes, Billy Klüver, and American Art of the 1960s: Defining Attitudes Toward Science and Technology." *Science in Context* 17:4 (2004): 611-35.

Graham, Stephen, and Simon Marvin. *Splintering Urbanism : Networked Infrastructures, Technological Mobilities and the Urban Condition*. New York: Routledge, 2001.

Harwood, John. "The White Room: Eliot Noyes and the Logic of the Information Age Interior." *Grey Room* 12 (2003): 5–31.

———. "The redesign of design: Multinational corporations, computers and design logic, 1945—1976." PhD diss., Columbia University, 2006.

Hays, K. Michael. *Architecture Theory since 1968*. Cambridge, Mass ; London: The MIT Press, 1998.

Higgott, Andrew. *Mediating Modernism : Architectural Cultures in Britain*. London ; New York: Routledge, 2007.

Keller, Sean. "Systems Aesthetics: Architectural Theory at the University of Cambridge, 1960-75." PhD diss., Harvard University, 2005.

———. "Fenland Tech: Architectural Science in Postwar Cambridge." *Grey Room* 23 (2006): 40-65.

Martin, Reinhold. *The Organizational Complex : Architecture, Media, and Corporate Space*. Cambridge, Mass.: MIT Press, 2003.

Massey, Anne. *The Independent Group: Modernism and Mass Culture in Britain, 1945-59*. Manchester, UK: Manchester University Press, 1995.

Medina, Eden. "Democratic Socialism, Cybernetic Socialism: Making the Chilean Economy Public." In *Making Things Public : Atmospheres of Democracy*, edited by Bruno Latour and Peter Weibel, 708-19. Cambridge, MA: MIT Press; ZKM/Center for Art and Media in Karlsruhe, 2005.

Pias, Claus. "Hollerith 'Feathered Crystal': Art, Science, and Computing in the Era of Cybernetics." *Grey Room* 29 (2007): 110–134.

Riley, Terence, ed. *The Changing of the Avant-Garde* : Visionary Architectural Drawings from the Howard Gilman Collection. New York: Museum of Modern Art, 2002.

Sadler, Simon. *Archigram : Architecture without Architecture*. Cambridge, Mass.: MIT Press, 2005.

Scott, Felicity Dale Elliston. *Architecture or Techno-Utopia : Politics after Modernism*. Cambridge, Mass.: MIT Press, 2007.

Schwarz, Heinrich. "Techno-Territories: The Spatial, Technological and Social Reorganization of Office Work." PhD diss., Massachusetts Institute of Technology, 2002.

Steiner, Hadas. "Bathrooms, Bubbles and Systems: Archigrams and the Landscapes of Transience." PhD diss., Massachusetts Institute of Technology, 2001.

———. "For the Birds." *Grey Room* 13 (2003): 5-31.

———. "The Forces of Matter." *The Journal of Architecture* 10:1 (2005): 91-109.

———. *Beyond Archigram : The Structure of Circulation*. New York: Routledge, 2009.

Wallis, Brian, Lawrence Alloway. *This Is Tomorrow Today : The Independent Group and British Pop Art*. Long Island City, N.Y.: Institute for Art and Urban Resources, 1987.

Whiteley, Nigel. *Reyner Banham: Historian of the Immediate Future*. Cambridge: The MIT Press, 2002.

Other architecture, art and design

Allen, Stan. "Mapping the Unmappable: On Notation." In *Practice : Architecture, Technique, and Representation*, edited by Stan Allen and Diana Agrest, Australia: G+B Arts International, 2000.

Corner, James. "Representation and Landscape." *Word & Image* 8, no. 3 (1992): 243-75.

Dilnot, Clive. "The State of Design History, Part I: Mapping the Field." *Design Issues* 1 no. 3 (1984): 23.

———. "The State of Design History, Part II: Problems and Possibilities." *Design Issues* 1 no. 4 (1984): 30.

Dunne, Anthony. *Hertzian Tales : Electronic Products, Aesthetic Experience, and Critical Design*. Cambridge, MA: MIT Press, 2005.

Gibson, James Jerome. *The Perception of the Visual World*. Boston,: Houghton Mifflin, 1950.

Jones, John Christopher. *Design Methods: Seeds of Human Futures*. New York: Wiley & Sons, 1970.

Kepes, Gyorgy. *Language of Vision*. Chicago: P. Theobald, 1944.

———. *The New Landscape in Art and Science*. Chicago: P. Theobald, 1956.

———. *Structure in Art and in Science*, Vision + Value Series. New York: G. Braziller, 1965.

Kracauer, Siegfried, and Thomas Y. Levin. *The Mass Ornament : Weimer Essays*. Cambridge, Mass.: Harvard University Press, 1995.

O'Doherty, Brian. *Object and Idea*. New York: Simon and Schuster, 1967.

Rittel, Horst and Melvin Webber. "Dilemmas in a General Theory of Planning." *Policy Sciences* 4 (1973): 155-69.

Conferences and exhibitions on architecture, art and computing

Ashby, A. W. Ross. "Talk: Art and Communication Theory." London: ICA, 1960.

Banham, Reyner, Lawrence Gowing, and Richard Hamilton. *Man, Machine and Motion: Catalogue to the ICA Exhibition*. London, 1955.

Burnham, Jack. "Notes on Art and Information Processing." In *Software: Information Technology: Its New Meaning for Art*, edited by Jack Burnham, 10-14. New York, 1970.

Boston Architectural Center. *Architecture and the Computer*, First Boston Architectural Center Conference. Boston: Boston Architectural Center, 1964.

Design Quarterly, No. 66/67, Design and the Computer (1966).

Coons, Steven. "Computer-Aided Design"
Fetter, William. "Computer Graphics."
Jacks, Edwin. "Design Augmented by Computers."
Manheim, Marvin. "Problem-Solving Processes in Planning and Design."
Bernhotz, Allen, and Edward Bierstone. "Computer-Augmented Design."
Scheid, Kenneth. "Computers, Printing and Graphic Design."

Knowlton, Kenneth. "Computer-Generated Movies, Designs and Diagrams."
Noll, A. Michael. "Computers and the Visual Arts."

Greenfield, Sanford R., Duncan Wilson, and John Cummings. *Synopsis and Proceedings of the First International Systems Building Round Table Conference*, November 17-19, 1971, Boston Architectural Center. Boston: Boston Architectural Center, 1973.

Hultén, Pontus, Museum of Modern Art (New York N.Y.), University of St. Thomas., and San Francisco Museum of Art. *The Machine : As Seen at the End of the Mechanical Age*. New York: The Museum of Modern Art, 1968.

ICA. *Growth and Form*. London, 1953

———. *an exhibit*. London, 1957.

Los Angeles County Museum of Art. *A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–71*. Los Angeles: LACMA, 1971.

McShine, Kynaston. *Information*. New York,: Museum of Modern Art, 1970.

Making Things Public : Atmospheres of Democracy. Cambridge, MA; Karlruhe Germany: MIT Press; ZKM/Center for Art and Media in Karlsruhe, 2005.

Milne, Murray, and Yale University School of Art and Architecture. "Computer Graphics in Architecture and Design; Proceedings." New Haven, 1969.

Reichardt, Jasia. *Cybernetic Serendipity; the Computer and the Arts*. New York,: Praeger, 1969.

———. *Play Orbi*t, Showing at Royal National Eisteddfod of Wales, Flint, 4-9 August 1969, Institute of Contemporary Arts, London, 28 November 1969-15 February 1970. London ; New York, N.Y.: Studio International, 1969.

Sanoff, Henry, Sidney Cohn, and Environmental Design Research Association. *EDRA 1/1970: Proceedings of the 1st Annual Environmental Design Research Association Conference*. Chapel Hill, NC, 1970.

Whitechapel Art Gallery. *This Is Tomorrow*. London: Whitechapel Art Gallery, 1956

Christopher Alexander

Books

Alexander, Christopher. *HIDECS 2: A Computer Program for the Hierarchical Decomposition of a Set Which Has an Associated Linear Graph*. Cambridge, MA: School of Engineering, Massachusetts Institute of Technology, 1962.

———. *HIDECS 3: Four Computer Programs for the Hierarchical Decomposition of Systems Which Have an Associated Linear Graph*. Cambridge, MA: MIT, 1963.

———. *Notes on the Synthesis of Form*. Cambridge, MA: Harvard University Press, 1964.

———. *The City as a Mechanism for Sustaining Human Contact*. Berkeley,: Center for Planning and Development Research University of California, 1966.

———. *Pattern Manual*. Edited by Center for Environmental Structure. Berkeley, 1967.

———. *Theory, Organization, Activities*. Edited by Center for Environmental Structure. Berkeley, 1968.

———. *Houses Generated by Patterns*. Berkeley: Center for Environmental Structure, 1969.

———. *The Timeless Way of Building*. New York: Oxford University Press, 1979.

———. *The Production of Houses*. New York: Oxford University Press, 1985.

Alexander, Christopher, Sara Ishikawa, and Murray Silverstein. *A Pattern Language Which Generates Multi-Service Centers*. Berkeley: Center for Environmental Structure, 1968.

———. *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press, 1977.

Alexander, Christopher, and Marvin L. Manheim. *The Design of Highway Interchanges: An Example of a General Method for Analysing Engineering Design Problems*. Cambridge, Mass.: Dept. of Civil Engineering Massachusetts Institute of Technology, 1962.

Alexander, Christopher, Barry Poyner. *The Atoms of Environmental Structure*. Berkeley: Center for Planning and Development Research University of California Institute of Urban & Regional Development, 1966.

Chermayeff, Serge, and Christopher Alexander. *Community and Privacy; Toward a New Architecture of Humanism*. 1st Garden City, NY: Doubleday, 1963.

Grabow, Stephen. *Christopher Alexander: The Search for a New Paradigm in Architecture*. Boston: Oriel Press, 1983.

Articles

Alexander, Christopher. "A City Is Not a Tree." *Architectural Forum* v. 122, no. 1&2 (1965): 58-62.

———. "Systems Generating Systems." *AD* 38 (1968): 605-10.

———. "The Question of Computers in Design." *Landscape* 14, no. 3 (1965): 6-8. (Also published as "A Much Asked Question about Computers and Design." *Architecture and the Computer*, First Boston Architectural Center Conference. Boston: Boston Architectural Center, 1964.

———. "The Revolution Finished Twenty Years Ago " *Architects' Year Book* 9, no. 181-185 (1960).

Nicholas Negroponte

Books

Negroponte, Nicholas. *The Architecture Machine*. Cambridge, MA: MIT Press, 1970.

———. *Reflections on Computer Aids to Design and Architecture*. New York: Petrocelli/Charter, 1975.

———. *Soft Architecture Machines*. Cambridge, MA: MIT Press, 1975.

———. *Being Digital*. New York: Alfred A. Knopf, 1995.

Articles

Fields, Craig and Nicholas Negroponte. "Using New Clues to Find Data." *Proceedings of the Third International Conference on Very Large Very Large Data Bases* vol. 3, Tokyo, 1977.

Negroponte, Nicholas. "Environmental Humanism through Robots." In *EDRA 1/1970: proceedings of the 1st annual Environmental Design Research Association conference*, edited by Henry Sanoff, Sidney Cohn and Environmental Design Research Association., Chapel Hill, 1970.

———. "Recent Advances in Sketch Recognition." *AFIPS '73,* 1973.

———. "An idiosyncratic systems approach to interactive graphics." UODIGS '76: Proceedings of the ACM/SIGGRAPH Workshop on User-Oriented Design of Interactive Graphics Systems, 1976.

Negroponte, Nicholas and Paul Pangaro. "Experiments with Computer Animation." *SIGGRAPH '76: Proceedings of the 3rd annual conference on Computer graphics and interactive techniques*, 1976.

Weinzapfel, Guy and Nicholas Negroponte. "Architecture-by-yourself: an experiment with computer graphics for house design." *International Conference on Computer Graphics and Interactive Techniques: Proceedings of the 3rd annual conference on Computer graphics and interactive techniques*, 1976.

Cedric Price and John Frazer

Books by Cedric Price

Bron, Eleanor, and Samantha Hardingham, eds. *Cedric Price Retriever*. London: inIVAnnotations, 2006.

Price, Cedric. *The Square Book*. London: Architectural Association, 1984.

Price, Cedric, Samantha Hardingham, and Robin Middleton. *Cedric Price, Opera*. Chichester, West Sussex, England: Wiley-Academy, 2003.

Price, Cedric, Hans-Ulrich Obrist, Arata Isozaki, Patrick Keiller, and Rem Koolhaas. *Re-CP*. Basel; Boston: Birkhäuser, 2003.

Articles by Cedric Price

Landau, Royston and Cedric Price. "Evolutionary Housing: Notes on the Context and the Problem." *Architectural Design* 41 (1971): 567-9.

Price, Cedric. "Activity and Change." *Archigram* 2 (1962).

———. "Potteries Thinkbelt." In *Essays in Local Government*. Vol.3, London: Merlin Press, 1965: 133-40.

———. "Discussion." *Datum* (1966).

———. "Ptb: Life-Conditioning." *Architectural Design* 36 (1966): 482-94.

———. "Fun Palace for Camden Town." *Architectural Design* 37 (1967): 522.

———. "Learning." *Architectural Design* 38 (1968): 208.

———. "Expediency." *Architectural Design* 39 (1969): 493.

———. "Non-Plan." *Architectural Design* 39 (1969): 269-73.

———. "Cedric Price Supplement 1." *Architectural Design* 40 (1970).

———. "Cedric Price Supplement 2." *Architectural Design* 41 (1971).

———. "An Architecture of Approximation." *Architectural Design* 42 (1972): 647.

———. "On Safety Pins and Other Magnificent Designs." *Pegasus* (1972).

———. "Protest: Future of Planning." *Architectural Design* 45 (1974): 202.

———. "Recherche sur des équipements de loisirs: from Fun Palace to Generator." *Techniques et architecture* 333 (1980): 108-11.

———. "Anticipating the Future." *RIBA Journal* (1981).

———. "Cedric Price Talks at the AA." *AA Files* 19 (1990): 27-34.

———. "Magnet: The Architecture of Anticipation." *Architecture and Ideas* 2 (1998): 6–13.

John Frazer

Frazer, John. Letter to Cedric Price. Killyleagh, County Down, Northern Ireland, 1979.

———. *An Evolutionary Architecture*.. London: Architectural Association, 1995.

———. "The Continuing Relevance of Generator." In *Cedric Price, Opera*, edited by Cedric Price, Samantha Hardingham, Robin Middleton and Cedric Price. Chichester, West Sussex: Wiley-Academy, 2003.

Secondary sources

Furtado, Gonçalo. "Envisioning an Evolving Architecture: The Encounters of Gordon Pask, Cedric Price and John Frazer." PhD diss., University College London, 2008.

Herdt, Tanja. "The Concept of Micropolitics in the Work of Cedric Price 1961-1984." PhD diss. ETH, In progress.

Hughes, Jonathan, and Simon Sadler. Non-Plan : Essays on Freedom Participation and Change in Modern Architecture and Urbanism. Oxford ; Boston: Architectural Press, 2000.

Landau, Royston. "A Philosophy of Enabling." In *The Square Book*, edited by Cedric Price. London: Architectural Association, 1984.

Littlewood, Joan. *Joan's Book: Joan Littlewood's Peculiar History as She Tells It*. London: Methuen, 1994.

Lobsinger, Mary Louise. "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." In *Anxious Modernisms: Experimentation in Postwar Architectural Culture*, edited by Sarah William Goldhagen and Réjean Legault. Cambridge, MA: MIT Press, 2000.

Mathews, Stanley. "An Architecture for the New Britain: The Social Vision of Cedric Price's Fun Palace and Potteries Thinkbelt." PhD diss., Columbia University, 2003.*From Agit-Prop to Free Space : The Architecture of Cedric Price*. London: Black Dog Pub. Ltd., 2007.

———. "The Fun Palace as Virtual Architecture: Cedric Price and the Practices of Indeterminacy." *Journal of Architectural Education* 59, no. 3 (2006): 39-48.

Mullin, Steve. "Cedric Price or Still Keeps Going When Everything Else Has Stopped." *Architectural Design* 46 (1976): 281-7.

Steenson, Molly Wright. "The Architect, The Sketch and the Response: Construing and Constructing Cedric Price's Generator." Master's thesis, Yale School of Architecture, 2007.

Technological backdrop

General

Burns, R. W., and Institution of Electrical Engineers. *Communications : An International History of the Formative Years*. London: Institution of Electrical Engineers, 2004.

Bush, Vannevar. "As We May Think." *The Atlantic*, July 1945, 101-8.

Bush, Vannevar, and Norbert Wiener. *Operational Circuit Analysis*. New York: J. Wiley & Sons, 1929.

Ceruzzi, Paul. *A History of Modern Computing*. Cambridge, MA: MIT Press, 2003.

Fano, Robert. "Proposal for a Research and Development Program on Computer Systems to the Advanced Research Projects Agency." Cambridge, MA: MIT, 1963.

Feigenbaum, Edward A., and Julian Feldman. *Computers and Thought*. New York,: McGraw-Hill, 1963.

Licklider, J. C. R. "Man-Computer Symbiosis." *IRE Transactions on Human Factors in Electronics* HFE-1, no. 1 (1960): 4-11.

———. "A Picture Is Worth a Thousand Words: And It Costs." In *Proceedings of the May 14-16, 1969, Spring Joint Computer Conference*, 617-21. Boston, Massachusetts: ACM, 1969.

Licklider, J. C. R., and Welden E. Clark. "On-Line Man-Computer Communication." In *Proceedings of the May 1-3, 1962, Spring Joint Computer Conference,* 113-28. San Francisco, California: ACM, 1962.

Mahoney, Michael S. "The histories of computing(s)." *Interdiscip. Sci. Rev*. 30.2 (2005): 119–135.

O'Mara, Margaret Pugh. *Cities Of Knowledge: Cold War Science and the Search for the Next Silicon Valley*. Princeton University Press, 2005.

Pólya, George. *How to Solve It; a New Aspect of Mathematical Method*. Princeton, NJ: Princeton University Press, 1945.

Ware, Willis H. *RAND and the Information Evolution: A History in Essays and Vignettes*. Santa Monica, CA: RAND Corporation, 2008.

Artificial intelligence

Aspray, William. *John Von Neumann and the Origins of Modern Computing*, History of Computing. Cambridge, MA: MIT Press, 1990.

Chandler, David L. "Rethinking Artificial Intelligence: Broad-Based MIT Project Aims to Reinvent AI for a New Era. By Going Back and Fixing Mistakes, Researchers Hope to Produce 'Co-Processors' for the Human Mind." *MIT News* (2009), http://web.mit.edu/newsoffice/2009/ai-overview-1207.html.

Chrisley, Ronald, and Sander Begeer. *Artificial Intelligence: Critical Concepts*. 4 vols. London ; New York: Routledge, 2000.

Englebart, Douglas. "Augmenting Human Intellect: A Conceptual Framework." Stanford: Stanford Research Institute, 1962.

Hodges, Andrew. *Alan Turing*. Burnett Books, 1983.

Kurzweil, Ray. *The Age of Intelligent Machines*. MIT Press, 1990.

Lettvin, J.Y. et al. "What the Frog's Eye Tells the Frog's Brain." *Proceedings of the IRE* 47.11(1959): 1940-1951.

McCarthy, John, Marvin Minsky, Nathaniel Rochester, and Claude Shannon. "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence." 1955. <http://www-formal.stanford.edu/jmc/history/dartmouth/dartmouth.html>

McCorduck, Pamela. *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*. 2nd ed. Natick, MA: AK Peters, 2004.

Minsky, Marvin Lee. "Steps toward Artificial Intelligence." *Proceedings of the I.R.E.* 49, no. 1 (1961): 8-30.

———. *Semantic Information Processing*. Cambridge, Mass.,: MIT Press, 1968.

Newell, A, JC Shaw, and H.A. Simon. "The Processes of Creative Thinking." University of Boulder, CO: RAND Corporation, 1959.

Newell, Allen, and F M Tonge. "An Introduction to Information Processing Language V." Boston: RAND Corporation, 1959.

Russell, Stuart J., and Peter Norvig. *Artificial Intelligence : A Modern Approach*. 3rd ed, Prentice Hall Series in Artificial Intelligence. Upper Saddle River, N.J.: Prentice Hall/Pearson Education, 2009.

Turing, Alan. "Computing Machinery and Intelligence." *Mind* 59 (1950): 433-60.

Turing, Alan Mathison, and B. Jack Copeland. *The Essential Turing*. Oxford: Oxford University Press, 2004.

Von Neumann, J. "First Draft of a Report on the EDVAC." *The Origins of Digital Computers: Selected Papers* (1982): 383-392.

Von Neumann, John, and Miklós Rédei. *John von Neumann*. AMS Bookstore, 2005.

Cybernetics and systems theory

Ashby, W. Ross. *An Introduction to Cybernetics*. London: Chapman and Hall, 1956.

———. "Design for an Intelligence-Amplifier." In Automata Studies, edited by Claude Shannon and John McCarthy. Princeton, NJ: Princeton University Press, 1956.

———. *Design for a Brain; the Origin of Adaptive Behavior*. 2d ed. New York,: Wiley, 1960.

Bateson, Gregory. *Steps to an Ecology of Mind*. University of Chicago Press, 1972.

Beer, Stafford. *Cybernetics and Management*, Management Science Series. New York,: Wiley, 1959.

———. *Decision and Control; the Meaning of Operational Research and Management Cybernetics*. London, New York,: Wiley, 1966.

———. *Platform for Change; a Message from Stafford Beer*. London, New York,: Wiley, 1975.

Beer, Stafford, and R. W. Revans. *Operational Research and Personnel Management*, Institute of Personnel Management. Occasional Papers,. London,: Institute of Personnel Management, 1959.

Conway, Flo, and Jim Siegelman. Dark Hero of the Information Age : In Search of Norbert Wiener, the Father of Cybernetics. New York: Basic Books, 2005.

Forrester, Jay. *Industrial Dynamics*. Cambridge, MA: MIT. Press, 1961.

———. *Urban Dynamics*. Cambridge, MA: MIT Press, 1969.

———*Collected Papers of Jay W. Forrester*. Cambridge, MA: Wright-Allen Press, 1975.

Heims, Steve J. *The Cybernetics Group, 1946-1953*. MIT Press, 1991.

Johnson, Avery. "Organization, Perception and Control in Living Systems." *Industrial Management Review* 10, no. 2 (1969).

Johnston, John. *The Allure of Machinic Life: Cybernetics, Artificial Life, and the New AI*. Cambridge: MIT Press, 2008.

Legasto, Augusto, Jay Wright Forrester, and James M. Lyneis. *System Dynamics*, TIMS Studies in the Management Sciences. Amsterdam, North-Holland Pub. Co.,1980.

Mindell, David. *Between Human and Machine Feedback, Control, and Computing Before Cybernetics*. Baltimore : Johns Hopkins University Press,, 2002.

Pangaro, Paul. "2nd-Order Cybernetics and Modeling of Social Constructs." *Washington Evolutionary Systems Society* (1993).

Pask, Gordon. *An Approach to Cybernetics*. London,: Hutchinson, 1961.

———. "The Architectural Relevance of Cybernetics." *Architectural Design* 7, no. 6 (1969): 494-6.

———. "A Comment, a Case History and a Plan." In *Cybernetics, Art, and Ideas*, edited by Jasia Reichardt, 76-99. Greenwich, Conn.,: New York Graphic Society, 1971.

Rose, John. *A Survey of Cybernetics: A Tribute to Dr. Norbert Wiener*. London: Iliffe Books, 1969.

Rosenblueth, Arturo, Norbert Wiener, and Julian Bigelow. "Behavior, Purpose and Teleology." *Philosophy of Science* 10.1 (1943): 18–24.

Von Bertalanffy, Ludwig. *General System Theory: Foundations, Development, Applications*. New York: G. Braziller, 1968.

Wiener, Norbert. *Cybernetics; or, Control and Communication in the Animal and the Machine*. Cambridge, MA: Technology Press, 1948.

———. *The Human Use of Human Beings; Cybernetics and Society*. Boston: Houghton Mifflin, 1954.

Computer graphics and computer-aided design

Fetter, William A. *Computer Graphics in Communication*, Engineering Graphics Monograph Series. New York: McGraw-Hill, 1965.

Frazer, J.H., J.M. Frazer, and P.A. Frazer. "Intelligent Physical Three-Dimensional Modelling Systems (Draft), Paper Computer Graphics 80." London 1980.

———. "New Developments in Intelligent Modelling, Paper Computer Graphics 81." London 1981.

Scott, Anne, Paul Coates, and John Frazer. "Problem Worrying Program." 1981.

Sutherland, Ivan. "Sketchpad, a Man-Machine Graphical Communication System." PhD diss., Massachusetts Institute of Technology, 1963.

The Center for Bits and Atoms. "The Mind Machine Project." MIT, http://mmp.cba.mit.edu/. Accessed January 2, 2010.

MIT context and culture

Brand, Stewart. *The Media Lab: Inventing the Future at MIT*. New York, N.Y.: Viking, 1987.

Edwards, Paul N. *The Closed World: Computers and the Politics of Discourse in Cold War America*, Inside Technology. Cambridge, MA: MIT Press, 1996.

Leslie, Stuart W. *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford*. New York: Columbia University Press, 1993.

M.I.T. "M.I.T. Report to the President." Cambridge, MA: MIT, 1964, 1965, 1966, 1967.

Redmond, Kent C., and Thomas Malcolm Smith. *Project Whirlwind: The History of a Pioneer Computer*. Bedford, Mass.: Digital Press, 1980.

Shillaber, Caroline. *Massachusetts Institute of Technology School of Architecture and Planning, 1861-1961: A Hundred Year Chronicle*. [Cambridge, MA: Massachusetts Institute of Technology, 1963.

Wildes, Karl L., and Nilo A. Lindgren. A Century of Electrical Engineering and Computer Science at MIT, 1882-1982. Cambridge, MA: MIT Press, 1985.

History of science & technology, STS (science & technology studies)

Beniger, James. *The control revolution : technological and economic origins of the information society*. Cambridge Mass.: Harvard University Press, 1986.

Bijker, Wiebe, Thomas P. Hughes, and Trevor Pinch. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge: MIT Press, 1989.

Bijker, Wiebe E. *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA: MIT Press, 1997.

Bos, Réné ten, and Ruud Kaulingfreks. “Interfaces.” *Theory, Culture & Society* 19.3 (2002): 139–151.

De Certeau, Michel, and Steven Rendall. *The practice of everyday life*. University of California Press, 1988.

De Landa, Manuel. *War in the age of intelligent machines*. Zone Books, 1991.

Galison, Peter. “The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision.” *Critical Inquiry* 21.1 (1994): 228–266.

Galloway, Alexander R., and Eugene Thacker. “Protocol, Control, and Networks.” *Grey Room* (2004): 6–29.

Halpern, Orit. “Dreams for Our Perceptual Present: Temporality, Storage, and Interactivity in Cybernetics.” *Configurations* 13 (2005): 283–319.

———. “Screen-Memories: Temporality, Perception and the Archive in Cybernetic Thought.” PhD diss., Harvard University, 2006.

Hughes, Thomas Parke. *Networks of Power : Electrification in Western Society, 1880-1930*. Baltimore: Johns Hopkins University Press, 1983.

Hughes, Thomas Parke, Agatha C. Hughes, Michael Thad Allen, and Gabrielle Hecht. *Technologies of Power : Essays in Honor of Thomas Parke Hughes and Agatha Chipley Hughes*. Cambridge, Mass.: MIT Press, 2001.

Latour, Bruno. *Aramis, or, the Love of Technology*. Cambridge, Mass.: Harvard University Press, 1996.

———. *Reassembling the Social : An Introduction to Actor-Network-Theory*, Clarendon Lectures in Management Studies. Oxford ; New York: Oxford University Press, 2005.

———. *We Have Never Been Modern*. Cambridge, Mass.: Harvard University Press, 1993.

Latour, Bruno, and Steve Woolgar. *Laboratory Life : The Social Construction of Scientific Facts*, Sage Library of Social Research V. 80. Beverly Hills: Sage Publications, 1979.

Mackenzie, Donald A. *Inventing Accuracy : A Historical Sociology of Nuclear Missile Guidance*, Inside Technology. Cambridge, Mass.: MIT Press, 1990.

Marx, Leo. The Machine in the Garden: Technology and the Pastoral Ideal in America. London: Oxford University Press, 1964.

Mattelart, Armand. *The Invention of Communication*. Minneapolis, Minn.: University of Minnesota Press, 1996.

———. *Mapping World Communication : War, Progress, Culture*. Minneapolis: University of Minnesota Press, 1994.

———. *Networking the World, 1794-2000*. Minneapolis, MN: University of Minnesota Press, 2000.

Schivelbusch, Wolfgang. *The Railway Journey : The Industrialization of Time and Space in the 19th Century*. Berkeley CA: University of California Press, 1986.

Star, Susan Leigh. “The Ethnography of Infrastructure.” *American Behavioral Scientist* 43, no. 3 (1999): 377-91.

Star, Susan Leigh, and Karen Ruhleder. "Steps Towards an Ecology of Infrastructure: Complex Problems in Design and Access for Large-Scale Collaborative Systems." In *Proceedings of the 1994 ACM conference on Computer supported cooperative work*. Chapel Hill, North Carolina, United States: ACM, 1994.

Turkle, Sherry. *The Second Self: Computers and the Human Spirit*. New York: Simon & Schuster, 1985.

Media and technology theory

Allen, Ken. "Understanding information." *Conceptual art: theory, myth, and practice*. Ed. Michael Corris. Cambridge: Cambridge University Press, 2004.

Caillois, Roger. *Man, Play and Games*. New York: Free Press of Glencoe, 1961.

Doehlemann, Martin. *Langeweile? : Deutung Eines Verbreiteten Phänomens.*. Frankfurt: Suhrkamp, 1991.

Healy, Seán Desmond. *Boredom, Self, and Culture*. London: Fairleigh Dickinson University Press, 1984.

Heidegger, Martin. *The Fundamental Concepts of Metaphysics : World, Finitude, Solitude*. Bloomington: Indiana University Press, 1995.

———. *The Question Concerning Technology, and Other Essays*. New York: Harper & Row, 1977.

Huizinga, Johan. *Homo Ludens: A Study of the Play Element in Culture*. London,: Maurice Temple Smith Ltd., 1970.

Kittler, Friedrich A. *Discourse Networks 1800/1900*. Stanford, Calif.: Stanford University Press, 1990.

———. *Gramophone, Film, Typewriter*, Writing Science. Stanford, Calif.: Stanford University Press, 1999.

———. "Computer graphics: a semi-technical introduction." *Grey Room* 2 (2001): 30-45.

———."Code." *Software studies: a lexicon*. Ed. Matthew Fuller. Cambridge, Mass: MIT Press, 2008. 40-47.

———. *Optical Media : Berlin Lectures 1999 / Friedrich Kittler ; Translated by Anthony Enns ; [Introduction by John Durham Peters]*. Cambridge, UK ; Malden, MA: Polity Press, 2010.

Kierkegaard, Søren. *Either/Or : A Fragment of Life*, Penguin Classics. London, New York: Penguin Books, 1992.

Luhmann, Niklas. *The Reality of the Mass Media*. Stanford: Stanford University Press, 2000. [1996]

McLuhan, Marshall. Understanding Media: The Extensions of Man. Cambridge: MIT Press, 1995 [1964].

Simondon, Gilbert. *On the Mode of Existence of Technical Objects*. Trans. Ninian Mellamphy. London, ON: University of Western Ontario, 1958.

Svendsen, Lars Fr H. *A Philosophy of Boredom*. London: Reaktion Books, 2005.

Toffler, Alvin. *Future Shock*. New York: Random House, 1970.