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

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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.

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ex-craftsman’s designer is faced with a new, multi-variable world in which the old delineations of his activity are no longer applicable.” With what Landau called the “accelerating growth of information and knowledge” came “an increase in doubt.” One response to the conditions Landau described was architecture’s turn to computation: to computers, conceptually and practically, and toward disciplines like cybernetics and artificial intelligence. 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.

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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, Gordon Pask, Marvin Minsky, Douglas Engelbart and J.C.R. Licklider. 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.”

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
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

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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).


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. 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).  

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) 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. 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. Notes presented a logical, quantitative model of architectural computing influenced by such texts as Ashby’s 1952 Design for a Brain, Minsky’s 1961 “Steps Toward Artificial Intelligence,” and D’Arcy Wentworth Thompson’s 1917 On Growth and Form.

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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.
26 Ibid.
27 This is a direct interpretation of Thompson’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, Hides 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.” 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. 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. 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 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. 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”) and the 1975 book Soft Architecture Machines, and a series of computer-aided design tools and programs throughout the 1970s.

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33 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.
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.” 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.” 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. 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), tablet-based sketching stations and “an assemblage of software.” 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.” “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.

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38 Ibid., 11-12.
41 SEEK was featured in the Software show at the Jewish Museum in Boston in 1970 and Smithsonian in 1971.
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.” 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. 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.” 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.

Price designed Generator (1976–79, unbuilt) to create conditions for shifting personal interaction in a reconfigurable and responsive environment. It would be “intelligent—it should have a mind of its own,” wrote programmer-architects John and Julia Frazer, with whom Price collaborated. 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. “If you kick a system, the very least that you would expect it to do is kick you back,” they replied. 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,

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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.
52 Ibid.

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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.

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.
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**Nicholas Negroponte**

**Books**


**Articles**


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Books by Cedric Price


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John Frazer

Secondary sources

Technological backdrop
General


Artificial intelligence


Cybernetics and systems theory


Computer graphics and computer-aided design


MIT context and culture


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


Media and technology theory