Algorithmic Design: A Paradigm Shift in Architecture?

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This paper inquires into the nature of computation as a conceptual source of design. Algorithms are used, not to enhance architectural designs, but rather to conceive them. Such a possibility departs for the dominant assumption that design is entirely conceived within the designer’s mind. If true, it may constitute a paradigm shift in architecture.

Keywords: Algorithm, design, paradigm shift, unpredictability

The nature of computation

Recent theories of form in architecture have focused on computational methods of formal exploration and expression. From "topological geometry" and hypersurfaces to blobs and folds, there is a clear tendency to seek and explore formal properties as sources of ordering systems. For the last two decades, beginning with Marcos Novak’s (1988) Computational Compositions, William Mitchell’s (1990) Logic of Architecture, Peter Eisenman’s (1992) Visions Unfolding, and John Fraser’s (1995) Evolutionary Architecture and continuing through Greg Lynn’s (1999) Animate Form, designers have been concerned with the use of computational mechanisms for the exploration of formal systems. These practices have attempted to readdress formal issues using new techniques and methods.

Computational tools are central protagonists in this exploration. The traditional problematic of space, form, and order are informed, reformed, and transformed by the new possibilities and strategies open through technological cross-pollination, particularly digital technologies and a new computational relationship to space and time. The theoretical possibilities cut-across disciplines and get affected by concepts and mechanisms that have no precedence (Lonsway, 2002). In response to architecture’s strive to critically embrace and understand the new formal possibilities, two approaches have been dominant; either a reevaluation of past theories and practices in search for parallel or reoccurring themes or a search for new unprecedented themes that derive their existence to concepts and mechanisms foreign, alien, or external to the discipline of architecture.

The first approach builds upon historical precedence and seeks to metaphorically or indirectly associate past concepts in a new context, ultimately aiming at establishing historical continuity, transformation, and evolution. It approaches digital tools as recording and representational devices at the service of human creativity and interpretation. Human’s intel-
lectual dominance over the machine is a necessary assumption. Within the human realm, any logic that deals with the evaluation or production of form must be, by default, originated from within the mind of the human designer. The problem with this approach is that it does not allow thoughts to transcend beyond the sphere of human control. In fact, while it praises and celebrates the uniqueness and complexity of the human mind, it becomes also resistant to theories that point out the potential limitations of the human mind. For instance, in Warped Space Vidler (1999) looks at current architectural formal experimentations in the light of digital techniques but relies heavily on psychoanalytical thought and artistic interpretation. By doing so the author allows himself to investigate the complexity of the human mind but misses to engage into inquiring about the ontological aspects of the „digital mind“ and the increasing dependency on its existence by designers and architects.

In contrast, the second approach aims towards a new theoretical framework necessary to critically evaluate computational mechanisms by seeking for evidence beyond previous understanding and outside the context of predictable events. Digital devices are seen not as tools for exploring what is known but as portals for entering into what is unknown. Computational mechanisms are employed not only for exploring existing formal concepts but also for forming entirely new concepts. In this sense, digital devices become portals for exploration of forms that extend beyond the limits of perception. What makes this approach problematic for architects is that they have maintained an ethos of artistic sensibility and intuitive playfulness in their practice. Because of their mechanistic nature, computational mechanisms are perceived as non-human creations and therefore are considered distant and remote.

Traditionally, the dominant mode for discussing creativity in architecture has always been that of intuition and talent, where stylistic ideas are pervaded by an individual, a „star,“ or a group of talented partners within the practice. In contrast, computation is a process, the result of which is not necessarily credited to its creator. Computations are understood as abstract and universal mathematical operations that can be applied to almost any kind or any quantity of elements. For instance, an algorithm of computational geometry is not about the person who invented it but rather about its efficiency, speed, and generality. Consequently, the use of algorithms to address formal problems is regarded suspiciously by some as an attempt to overlook human sensitivity and creativity and give credit instead to an anonymous, mechanistic, and automated procedure. For example, Lynn reveals that „because of the stigma and fear of releasing control of the design process to software, few architects have attempted to use the computer as a schematic, organizing and generative medium for design.“ (Lynn, 1999)

**Algorithmic design**

An algorithm is a computational procedure for addressing a problem in a finite number of steps. It involves deduction, induction, abstraction, generalization, and structured logic. It is the systematic extraction of logical principles and the development of a generic solution plan. Algorithmic strategies utilize the search for repetitive patterns, universal principles, interchangeable modules, and inductive links. The intellectual power of an algorithm lies in its ability to infer new knowledge and to extend certain limits of the human intellect.

Despite the proliferation of computers in architecture today, the use of algorithms in architectural design is generally limited. Instead, the dominant mode of utilizing computers in architecture today can be identified as that of computerization, i.e. that where entities or processes that are already conceptualized in the designer’s mind are entered, presented, or stored on a computer system. In contrast, algorithms, as process of creating design solutions by the use of mathematical or logical methods, are generally limited. While the research and
development of software itself involves extensive algorithmic techniques, mouse-based manipulations of 3D computer models on a computer screen are not necessarily algorithmic processes. Presently, a new direction is being formulated: algorithmic design. It involves the designation of algorithms to generate space and form from the rule-based logic inherent in architectural programs, typologies, building code, and language itself. Instead of direct programming, the codification of design intention through algorithmic scripts build on top of existing modeling systems can build consistency, structure, coherency, traceability, and intelligece into computerized 3D form. By using algorithmic scripts designers can go beyond the mouse, transcending the factory-set limitations of current 3D software. Algorithmic design is a conceptual framework for the exploration of forms, structures, and processes of architectural design. It combines both the theories and methods of computer science as well as the abstract design space embodied in current modeling and animation systems. While most algorithms are tailored to automate tedious manual methods, there is a certain category of algorithms, referred to here as inductive, that are not aimed at predictable results. Their inductive strategy is to address and explore generative processes or to simulate complex phenomena. In the field of design, rule-based grammars, recursion, stochastic search, cellular automata, genetic algorithms, mappings, and morphing are algorithmic processes aimed at exploring uncommon, unpredictable, and uncharted formal properties and behaviors.

A defining characteristic of inductive algorithms is the degree of unpredictability expressed in the final outcome. Yet, this type of unpredictability is not

Figure 1
House of worship: an ambiguous algorithmic structure that uses fields to create transparency out of solidity and at the same time has the ability to camouflage its interiority through rotational recursion (designed by GSD student Andrew Sanders).
based on the materiality of the medium used but rather on the intellectual mechanisms involved. Material events, such as chemical changes or physical phenomena, may be unpredictable yet are certainly not intellectual. In contrast, the computer as a medium has indeed intellectual characteristics as it entails the capacity for knowledge and understanding. Its ability to resolve unpredictable events is based on its active logical mechanisms and not on passive observable physical or chemical reactions.

While the notion of predictability is typically linked to human control, its negation implies the presence of an alien unforeseeable realm. Such an alien realm can be unveiled through inductive algorithms since such processes embed an equivocal ability to connect human language with electronic mechanisms. For architecture, the notion of unpredictability challenges one of its traditional modes of thought where typically the designer is in full control of the tangible or virtual representation of one’s design ideas.

The word “tool” is often used to describe the synergistic interaction of designers with computers. A tool is defined as an instrument used in the performance of an operation. The connotative notion of a “tool” implies control, power, dominance, skill, and artistry. A pen, for instance, is a device that allows one to perform or facilitate the manual or mechanical work of writing or drawing. The capabilities, potency, as well as, limitations of a tool are known or estimated in advanced. This is not the case with computers performing inductive algorithmic computations. Neither their capacity or potency is understood, nor their limitations can be pre-estimated. Indeed, designers are frequently amazed by processes performed by algorithmic procedures, which they have no control or, often, knowledge of.

**Design Experimentation**

The following paragraphs present a series of buildings conceived through the use of algorithmic processes. The main premise is to start with an algorithm and then use manual methods to enhance. Theoretically, the algorithm should precede the designer’s conception of the architectural form. First, the process of iteration and its aesthetic value in architecture is explored. Iteration is a process of repeated performance of an event. It is invoked by executing the same set of instructions a given number of times or until a specified result is obtained. In architecture iteration is employed as an ordering device that produces repetitive patterns. Such patterns suggest the presence of motion, change, or progress as a visual impression. Figure 1 shows a project entitled “house of worship”: an ambiguous algorithmic structure that uses fields to create transparency out of solidity and at the same time has the ability to camouflage its interiority through rotational repetition.

Next, algorithms involving the process of Boolean algebraic operations are investigated. Boolean algebra involve the partial order on subsets defined by inclusion, i.e., the Boolean algebra on a set A is the set of subsets of A that can be obtained by means of a finite number of the set operations union (OR), intersection (AND), and complementation (NOT). Boolean architecture is an accumulating process that results into intricate assemblies by combining elements progressively into increased complexity. In this context, a concert hall composed of a series of ellipsoid acoustical modules is presented as an example of Boolean algebra. The project illustrates

![Figure 2](a-concert-hall-composed-of-a-series-of-ellipsoid-acoustical-modules-is-presented-as-an-example-of-boolean-algebra-designed-by-valerie-chatelet-and-jean-hwang).
not only the aesthetical potential of such operations but also the structural complexity involved (see figure 2).

Following, an algorithm referred to as constraint-based stochastic search was developed. While stochastic search involves repetitive random selections, user-defined constraints can limit these selections to those that satisfy the given problem. As a result, unpredictable arrangements of elements are generated as a result of a repetitious process of „hit-and-choose“.

For architecture, such an algorithm, involves two antithetical design strategies: rationalistic determinism and stochastic processes. The intermixing of both strategies leads not only to a harmonious balance but also to a synergistic integration of two powerful yet dialectically opposed directions. To illustrate their applicability within an architectural/urban design context, an office building hosting IRS offices situated within a typical private office building is designed. It is a type of symbiosis where two systems from different categories coexist in close proximity to one another, in which one member depends on another. A constraint-based stochastic search algorithm has been used to resolve the symbiotic yet parasitical relationship (see figure 3).

Finally, morphing as an algorithmic architectural process is investigated. Morphing is a term used to describe a process in which an object changes its form gradually in order to obtain another form. It is a gradual transition that results in a marked change in the form’s appearance, character, condition, or function. The result of morphing is an, often, unpredictable hybrid object, which combines characteristics of both parent objects involved in the transformation. The essence of such a transformation lies not that much in the parents’ forms but rather in the intermediate phases these transformations pass

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**Figure 3**
A private office building hosting IRS offices situated within the building (designed by UCLA students Henri Leung and Steve Knudsen)
through, as well as, in the extrapolations, which go beyond the parents' forms. It is the transitional continuity of a form that expresses it own history and identity through a series of evolutionary phases. As an example, a high-rise is presented to illustrate the value of morphing schemes (see figure 4).

**Paradigm shift?**

A paradigm shift is defined as a gradual change in the collective way of thinking. It is the change of basic assumptions, values, goals, beliefs, expectations, theories, and knowledge. It is about transformation, transcendence, advancement, evolution, and transition. While paradigm shift is closely related to scientific advancements, its true effect is in the collective realization that a new theory or model requires understanding traditional concepts in new ways, rejects old assumptions, and replaces them with new. For T.S. Kuhn (1996), scientific revolutions occur during those periods where at least two paradigms co-exist, one traditional and at least one new. The paradigms are incommensurable, as are the concepts used to understand and explain basic facts and beliefs. The two live in different worlds. The movement from the old to a new paradigm is called a paradigm shift.

Traditionally, the dominant paradigm for discussing and producing architecture has been that of human intuition and ingenuity. For the first time perhaps, a paradigm shift is being formulated that outweighs previous ones. Algorithmic design employs methods and devices that have no precedent. If architecture is to embark into the alien world of algorithmic form, its design methods should also incorporate computational processes. If there is a form beyond comprehension it will lie within the algorithmic domain. While human intuition and ingenuity may be the starting point, the computational and combinatorial capabilities of computers must also be integrated.

However, computational formal explorations do not intend to eradicate human imagination but rather extend its potential limitations. Computation is not a substitute for human creativity and therefore cannot be antagonistic. Rather it provides the means for exploration, experimentation, and investment in an alternative realm. For the first time perhaps, form might be aligned with neither arbitrary production nor computational determinism but with creative computation and computational creativity. Computation is not about perception or interpretation but rather about the process of exploration, codification, and extension of the human mind. Both the algorithmic input and the computer's output are inseparable within a computational system of complementary sources. In this sense, design becomes the embodiment of a process obtainable through a logic of mutual contributions: that of the human mind and that of the machine's assistance.

**References**

Eisenmann P.: 1992, Visions Unfolding: Architecture In The Age Of Electronic Media, Intelligente Ambiente, Ars Elettronica. Eisenman referred to the idea of an electronic paradigm shift in architecture in 1992. He wrote: „During the fifty years since the Second World War, a paradigm shift has taken

**Figure 4** Hybrid Tower: A 50-stories high apartment building constructed through a morphing/hybridization algorithm. The algorithm blends a cylinder (step 1) with a deformed NURBS surface (step 8) in 6 in-between steps. The resulting hybrid components form the pieces of the building (designed by Kostas Terzidis).
place that should have profoundly affected architecture: this was the shift from the mechanical paradigm to the electronic one. This change can be simply understood by comparing the impact of the role of the human subject on such primary modes of reproduction as the photograph and the fax; the photograph within the mechanical paradigm, the fax within the electronic one."


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