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Architectural Designs Through Algorithmic Program "Formian"

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Abstract. Through the implementation of algorithmic design, there has been a revolution in digital architecture both in architectural design and construction. By implementing algorithmic design, architects are able to integrate powerful computional instruments with creative design to play the role of programming on behalf of architect. This paper has studied configuration free forms in conceptual design by using algorithmic programs such as 'Formian'. Formian is regarded as a computational instrument for the purpose of configuration forms, which is commonly used to geometric compositions including points, lines and surfaces. Producig configuration with parametric components can be considered as one of the main characteristics of Formian. Therefore, there can be an improvement in the formulation of configurations where a change takes place in parameter components. This program can pave the way for towers, domes and other structures to obtain a new dimension. The Formian not only is able to increase the architectural and space structure designs, but also it can conceive them. There is a paradigm shift in architecture when such a software is used, resulting in more constructive presence of architects in building constructions.

Keywords: Digital design, Configuration freeform, Formex aljebra, Computitional, Formian

INTRODUCTION

The implementation of advanced technologies like design assessed with computer (CAD) and fabricate assessed with computer (CAM) has been changing the design and manufacture of architecture. These professional tools have created new doors and new opportunities to build and produce complicated forms which was already difficult and expensive for assembling and fabrication. The results are interesting , as new digitally-driven processes of design, fabrication and construction are increasingly challenging the historic relationship between architecture and production.

The purpose of digital architecture is to use the multiplicity of approaches; actually, there is no monolithic movement among the digital avant-garde in architecture. What relates digital architects, designers and thinkers is not a tendency to "blobify" everything, but applying digital technology as providing apparatus which directly consolidates conception and production in unprecedented ways since the medieval eras of master builders.

Architects have chance to place themselves in the center of attention and as a key role in the buildings construction and maybe even retake the absolute powers of the medieval master builders by digitally producing, communicating and controlling the information exchanged among numerous parties in the building process. If they intend to perform that is a complicated issue, in a way that there are numerous social, legal and technical obstacles to the full restructuring of long-ago established relations among the different building professions and trades.

Architectural practices are changed by digital technologies as few could predict. In the conceptual realm, computational, digital architectures of topological, non–Euclidean geometric space, kinetic and dynamic systems and genetic algorithms are replacing technological architectures (1).

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Algorithmic design uses the software programs designation to create space and form from the rule-based logic existing in architectural programs, typologies, building code and language. Instead of direct programming, the design codification can build stability, structure, coherency, traceability and intelligence into computerized three-dimensional form by using scripting languages available in three-dimensional packages (i.e. Maya Embedded Language (MEL), SdMaxScript, and FormZ). Designers by using scripting languages can proceed beyond the mouse, overcoming the factory-set restrictions of current three dimensional software. Algorithmic design combines both computational complexity and innovative utilization of computers without eradicating the differences. For architects, algorithmic design allows designer to shift from architecture programming to programming architecture. Computational terms rather than investing in arrested conflicts might be better utilized by this alternative option. Perhaps, architectural design might be initially aligned with neither formalism nor rationalism but with sagacious form and traceable creativeness (2).

An algorithm is a computational procedure to deal with a problem in a limited number of stages which entails deduction, induction, abstraction, generalization and structured logic. It refers to the systematic exploitation of logical principles and the generic solution plan's expansion. Algorithmic strategies seek the repetitive patterns, universal principles, interchangeable modules and inductive links. The ability to infer new knowledge and to extend certain limits of the human intellect give intellectual power to an algorithm.

Algorithmic Form

An algorithm is regarded as a computational process for the purpose of dealing with a problem in a definite number of stages. Deduction, induction, abstraction, generalization and structured logic can be regarded as some instances of these stages . It is the systematic extraction of logical principles and the advancement of a generic solution plan. Algorithmic strategies implement the search for repetitive models , universal principles, interchangeable modules and inductive relations. The ability to extract new knowledge and to expand certain limits of the human intellect can be considered as an intellectual power of an algorithm.

Although many algorithms have been designed and utilized for the intention of architectural design in space allocation and planning problems, their use and application in aesthetics and formal theories has been constrained. Most of the theories are dealt with establishing pertain, which are principally subject to interpretation and perception. On the other hand, algorithmic logic includes a deterministic approach to form suggesting rationality, consistency, coherency, organization and systemization. The main conern of architects for algorithmic is that they believe in an ethos of artistic sensibility and intuitive playfulness in their work. However, an algorithm is not regarded as a man-made creation and is kept distant thanks to its mechanistic status.

Traditionally, creativity in architecture was more related to intuition and talent, in which stylistic approaches are suggested by an individual, a “star,” or a group of talented partners within the model in practice while , in reality, an algorithm is a procedure, in which the result is not necessarily dedicated to its creator. Algorithms are regarded as abstract and universal mathematical operations that can be utilized to almost any kind of elements. For example, an algorithm in computational geometry is not conerened with the person who invented it but it is more related to its efficiency, speed and generality. In conclusion, the implementation of algorithms to deal with formal problems is considered by some as an effort to disregard human sensitivity and creativity, which give reputation to an anonymous, mechanistic and automated procedure.

While most algorithms are used to automate time-consuminh manual methods, there is a certain clasification of algorithms whose purposes are not to obtain predictable results. Their strategy is to discover generative processes or to simulate complex phenomena. Such inductive algorithms are used to ehance human thinking, which may motivate one to jump into areas of unprecedented and unimaginable abilities. For example, artificial neural networks are considered as systems of algorithms that simulate the human brain's functions, which are used in categorizing, forecasting and modeling applications. For this purpose, neural networks use several principles, including gradient-based training, fuzzy logic, genetic algorithms and Bayesian methods. However, there is a distinctive difference between these algorithmic processesand common algorithms. It is related to their behavior, which is non-predictable and produce patterns of thought resulting in surpirizng their own creators, also. In the same way, there are some algorithmic processes in designing, shaping grammars, mathematical models, topological properties, genetic systems, mappings and morphisms, which are aimed at discovering uncommon and unpredictable features and behaviors.

The dominant mode of utilizing computers in architecture today is that of computerization; entities or processes that are already conceptualized in the designer's mind are entered, manipulatetor stored in a computer system. In contrast, computation or computing, as a computer-based design tool is generally limited by the fact that the designers do not take advantage of the computational power of the computer. Instead some venture into manipulations or criticisms of computer models as if they were products of computation. While research and development of software involves extensive computational techniques, mouse-based manipulations of three-dimensional computer models are not necessarily acts of computation. For instance, it appears from the current discourse, that mouse-based manipulations of control points on non-uniform rational b-spline (NURBS)-based surfaces are considered by some theorists to be acts of computing. While the mathematical concept and software implementation of NURBS as surfaces is a product of applied numerical computation; the rearrangement of their control points through commercial software is simply an affine transformation, i.e. a translation.

There are still some misconceptions about the role of the computer in the process of design. Design, like many other mental processes, at the information-processing level has nothing specifically neural about it. The functional equivalence between brains and computers does not imply any structural equivalence at an anatomical level (e.g., equivalence of neurons with circuits). Theories of information processes are not equivalent to theories of neural or electronic mechanisms for information processing. Eventhough, physically, computers may appear to be a set of mindless connections, at the information level they are the materialization of mathematical and syllogistic procedures.

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. For instance, a pen is a device that allows one to perform or facilitate the manual or mechanical work of writing or drawing. The capabilities, potency and limitations of a tool are known or estimated in advanced. This is not the case with computers performing inductive algorithmic computations. Neither is their capacity or potency understood, nor can their limitations be pre-estimated. Indeed, designers are frequently amazed by processes performed by algorithmic procedures, over which they have no control and of which they often have no prior knowledge.

Since the mid-1970s, beginning with shape grammars and computational geometry and continuing through topological properties and morphism, designers and theorists have been concerned with the use of algorithms as a mechanism for exploring formal compositions. These theories have attempted either to automate and enhance existing manual techniques or to explore new uncharted territories of formal behavior. Various methods have been employed in the search for new forms: formal analysis involves the investigation of the properties that describe an architectural subject. Composition, geometrical attributes, and morphological properties obeying Galilean, Newtonian, and lately, molecular and organic principles are extracted from figural appearances of an object. In contrast, structural analysis deals with the derivation of the motivations and propensities which are implicit within form and which may be used to extract their generative processes. Morphism employs algorithmic processes for the interconnection between seemingly disparate entities and the evolution from one design to another.

Similarly, Euclidean geometry was understood as an extension of human perception. The divinity of its nature can be ultimately linked to its ability to infer abstract concepts that appeal to the mind rather than the eye. Like religion, it was the revelation of an abstract system of relationships that transcended above and beyond the material objects it represented. Similarly, algorithmic form is an extension of human understanding. The mere existence of the term “unimaginable” can be linked to the ability of algorithms to surpass the sphere of human control and prediction. Likemeta-structures, algorithmic forms are manifestations of inductive processes that describe, extend and often surpass the designer’s intellect (2).

Formian

Formex algebra is a mathematical system providng a simple tool for configuration processing. The concepts are general and can be implemente in many fields of study. Also, the ideas may be utilized for obtaining or creating information about differnet features of structural systems such as element connectivity, nodal coordinates, loading details, joint numbers and support arrangements. The created information may follow different purposes, such as graphic visualization or input data for structural analysis.

The introductory ideas were first suggested in the early seventies and Formex algebra were origizted from these ideas (3).

The term “ configuration”in Formex configuration processing implies an 'arrangement of parts'. For example, the elements of a structure lead to the establishment of a configuration, the component parts of an electrical network and the atoms of a protein molecule. This configuaruon mostly used for creating geometric compositions including points, lines and surfaces.

Regarding **'configuration processing**', it can refer to the creation and manipulation of configurations and the term '**formex configuration processing**' implies configuration processing through the use of formex algebra (5).

Although the configuration of space strucure are sensitive and influential, generating them is rather difficult on the condition that some suitable conceptual tools be provided for the designer. The ‘**formex configuration processing**’ creates the conceptual instruments which are essentail for controlling space structure configurations as easy as possible. The concepts of formex configuration processing can pave the way for innovative structral engineers and architects to make imaginative and economical space structure forms (6).

Structures which are used to cover large public spaces are more equipped with innovative forms, which are called “freeform” including combinations and/or modified forms of classical simple shapes like plane, cylinder, sphere, ... etc, and are generated through the interaction between practical aspects for the structures and the artistic sense created by the designers. Formex algebra and its programming language Formian can be useful for establishing the geometry of freeform structures. Although there are some formex concepts, the concepts of "pellevation" and "novation" were considered for the purpose of the present study (7).

Figure 1 indicates a configuration created by exposing a plane grid to three successive parabolic cap pellevations. Also, Figure 2 shows a freeform obtained by eliminating the elements remaining in the initial plane of the grid in Figure 1. In the formex formulation of Figure 1,2:

• The variable Grid represents the original plane grid.
• The variable FormA represents the configuration of Figure 1.
• The variable FormB represents the freeform of Figure 2. The removal of the elements is achieved using a relection function, see Section 2.A.10 of Ref (8).

```
Grid = rinid(20,21,1,1)|[0,0,0; 1,0,0]#
rinid(21,20,1,1)|[0,0,0; 0,1,0]
Form = capel(3,6,8,10,4)|capel(3,9,8,12,5)|
capel(3,12,10,14,6)| Grid
Use &, vm(2),vt(2), vh(10,-10,60, 10,10,0, 10,10,1);
Clear
Draw Form
```

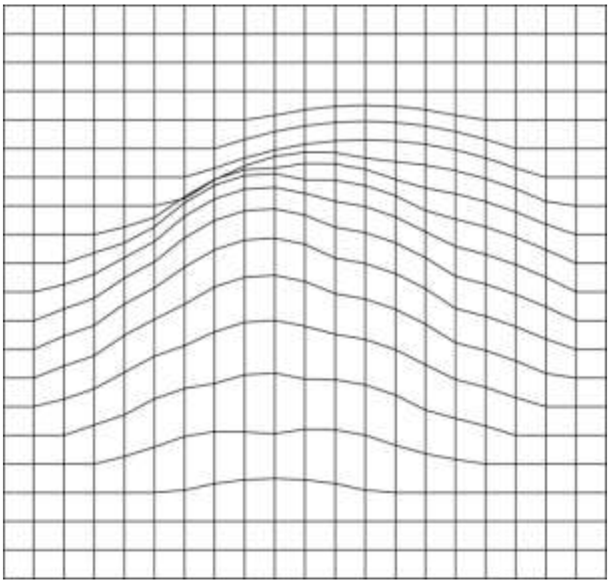

Figure 1. A configuration created by exposing a plane grid to three successive pellevations.

```
Grid = rinid(20,21,1,1)|[0,0,0; 1,0,0]#
rinid(21,20,1,1)|[0,0,0; 0,1,0]
FormA = capel(3,6,8,10,4)|capel(3,9,8,12,5)|
capel(3,12,10,14,6)| Grid
FormB = rel(U(1,3)>0 || U(2,3)>0)|FormA
Use &, vm(2),vt(2), vh(10,-10,60, 10,10,0, 10,10,1)
Clear
Draw FormB
```

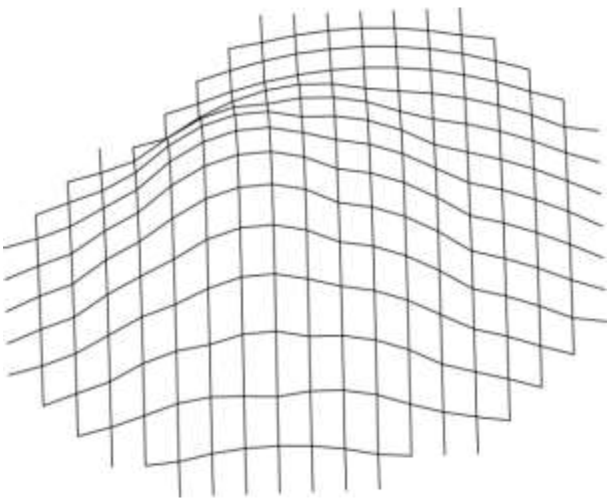

Figure 2. A freeform created by eliminating the elements in the plane to the initial grid of figure 1.

The freeform in Figure 3 is obtained by novating a plane grid configuration. In the formex formulation of Figure 3:

• The variable Grid represents the plane grid that is exposed to novation.
• The variable Fix showing the four corner points of the grid.
• The variable Initial represents the initial positions of four internal points of the grid.
• The variable Target represents the points to which the initial points are to be moved.
• The variable Form represents the novated configuration shown in Figure 3, where mode 3 novation function is used and the points represented by Fix#Initial are determined for moving the points represented by Fix#Target.

```
Grid = rinid(12,13,1,1)|[0,0,0; 1,0,0]#
rinid(13,12,1,1)|[0,0,0; 0,1,0]
Fix = lamid(6,6)|[0,0,0]
Initial = {[7,1,0], [4,9,0], [10,8,0], [2,11,0]}
Target = {[7,1,5], [4,9,0], [10,8,3], [2,11,2]}
Form = nov(3,1, Fix#Initial, Fix#Target)|Grid
Use &, vm(2),vt(2), vh(12,-24,30, 12,12,0, 12,12,1)
Clear
Draw Form
```

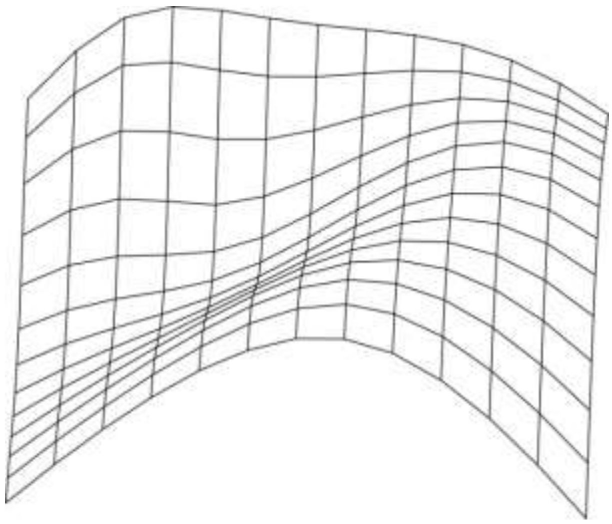

Figure 3. A freeform obtained by exposing a plane grid to novation mode 3.

CONCLUSION

A paradigm shift is described as a step-by-step change in the collective approach. It is regarded as the change in basic hypothese, values, goals, beliefs, expectations, theories and knowledge. It is more related to transformation, transcendence, advancement, evolution and transition. While paradigm shift is almost related to scientific development, its main effect is concerned with the collective realization a new theory needs for understanding traditional concepts in innovative methods, ignoring old assumptions and substituting them with modern ones. According to Kuhn (1996), scientific revolutions takes place during those periods in which two paradigms exist together, one traditional paradigm and at least one novel one. The paradigms have no common standard of measurement as it is the case for the concepts used to understand and explain basic facts and beliefs. They are living differently and the shift from the old to a new paradigm is called a paradigm shift.

Traditionally, regarding architecture production, they more deal with human intuition and ingenuity. For the first time, paradigm shift is being formulated downgrading the previous ones. Algorithmic design utilizes different methods and devices that have no precedent. If architecture is stepping into the unidentified world of algorithmic form, its design methods should also combine and integrate computational processes. If there is a form beyond comprehension, it will lie within the algorithmic domain. Although human intuition and ingenuity can be considered as the pioneer for new revolution , there should also be the integrartion of the computational and combinatorial capabilities of computers.

However, the main purpose of the exploration of computational formal is not to eliminate human imagination while the extension of its potential limitations is regarded as the priority. Computation is not taken as a replacement for human innovation and creation. Therefore, it cannot be antagonistic while it paves the way for exploration, experimentation, and investment in an alternative area. In other words, form might be first combined with neither arbitrary production nor computational determinism but with creative computation and computational creativity. Computation is not merely related to perception or interpretation while it is more concered with the process of exploration, codification, and extension of the human mind. Both the algorithmic input and the computer’s output are not distinguisbale within a computational system of complementary sources. In this regard, design becomes a process, which can be obtained through a logic of mutual contributions, which can be both related to the human mind and the machine’s assistance (9).

Through using Formian, architects can reduce the limitations of other software in order to be able to design and to have more signifinat role in construction, resulting in having programming architect. ‘It can be observed that the concept of novation and pellevation is regarded as an effective tool in shaping geometric configurations. The concept is particularly powerful in creation of freeform configurations. The examples used in the paper relate to the field of structural configurations. However, the idea is general and could, for example, be used in the geometric design of the body of a car, an aircraft or a ship (10).

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