

# From the Univocal to the Dissipative

## ***Computation and performance methodology in real-time architecture***

*Constantinos Miltiadis  
Freelance architect and researcher  
<http://at-nowhere.tumblr.com/>  
[c.miltiadis@gmail.com](mailto:c.miltiadis@gmail.com)*

**Abstract.** *The paper develops around a problematic regarding the methodology of contemporary computational real-time design. It begins by exploring the status of computer-driven architecture today, locating its inherent limitations that support the paper's main argument that the problem of this kind of architecture, is the failure of realizing the necessity of a paradigm shift.*

*Utilizing a personal project that falls in the category of real-time computation and design, and guiding the reader to the distinct stages for its development, an attempt is made to introduce an alternative methodology based on the materialist philosophy of Gilles Deleuze, that, displays a great potential to be applied and used as a conceptual framework for such designs.*

**Keywords.** *real-time; kinetic; interactive; methodology; computation.*

## **INTRODUCTION**

In the past few years, with the development of computational tools and their diffusion in the field of architecture, we have experienced an unprecedented development of experimental projects employing these new emergent technologies. Although the world of computer-driven architecture seems quite promising, its indubitable that it is still in its infancy stage. Architecture is still far from realizing what it has to offer, and how to adapt to this context. What this paper attempts to show, in order to overcome the barrier, is the need for the architectural field to devise a conceptual framework, which would enable it to think in these terms. In other words, what we lack today is a methodology to reconsider architecture; not only to keep up with what these tools have to offer or even employ them to a greater potential, but so as to provide the conceptual freedom

for the advancement of architecture itself.

In what follows, I will attempt to elaborate on the problematic of relevant design intentions; the obstacles arising from the need of designing and managing complex structures that could only be realized through computer programming, and above all the necessary methodological assumptions that have to be accepted. To make my points clear, I will in parallel, be using my thesis project "*Interactive Kinetic Structures*" developed in NTUA in 2012 [1], as a paradigm of application of such concepts.

### ***Theoretical shift***

Initially we need to examine the present state of this particular architectural field. I will argue that the use of such systems today, can be characterized, in most cases, as rather primitive, not because of the lack of

paradigms to follow but rather due to the lack of a methodological one. Real-time computation has surpassed the limits of the tool as medium, unlike the previous paradigm of CAD software. While CAD replaced the hand drawing, adding in parallel multiple new tools, computer-driven design offers the architect, not merely ready made tool-sets, but unimaginable new abilities over the actual design. What therefore will be stressed, approaching architecture by way of science, is the inability of the present conceptual model to further advance so as to incorporate modern demands, and the need to be replaced by a new or “revolutionary” conceptual block (Kuhn, 1962).

Such is the philosophy of Gilles Deleuze, as I will subsequently attempt to support, whose work created an ontology based on branches of non-linear sciences: thermodynamics, topology and chaos theory to name a few. His oeuvre was developed as a coherent tool-set for applications in fields beyond theory. The fundamental points of his materialism that we can draw from, are the absolute focus on processes and the intensities that produce them. Applying them in architecture, we can guide us, not only to study and understand complex and dynamic systems, but mainly to learn how to deal with them. In what follows I will make use of his concepts on dissipative dynamic systems and the idea of “the virtual” (Deleuze, 1991; 1994). Of course, I will not support that my application of these concepts is philosophically correct or exemplary, otherwise it has been argued before that concepts and their applications are distinctive objects [2].

## **REAL-TIME COMPUTATIONAL DESIGN TODAY**

The majority of projects implementing computer-driven design that we nowadays come across, are limited, both physically and conceptually to experimental; artistic installations and scaled models, to a degree that can almost sense a reluctance or inability to implement such methods in buildings. It wouldn't be an exaggeration to support that this design method comes with near to none experience and familiarity for architects, and their clients, to be

confident to apply in built projects. Nevertheless, the past few years there has been a creative explosion of published projects mainly through research oriented architectural universities, that display intentions of application in built projects [3] [4]. These could, at least, validate an argument supporting confidence in such technologies. Real-time computation is mainly applied in performance and interaction which we will try to unify under a common umbrella of process based architecture.

Examining the notion of “performative architecture” we come to the conclusion that it in fact describes buildings designed to be, in one or another way, more efficient; or better, perform in a more efficient manner. The application however of this concept is usually *quantitative*. One example could be panels opening and closing a facade on command [5], or apertures adjusting their opening in regard to sun illumination to ensure energy efficiency [6]. These examples can be described as a primitive utilization of so called “smart” mechanical systems in construction, for the reason that they operate as “switches”: a certain event occurs, which triggers a reaction -event A triggers reaction X. The architect here designs an explicit choreography in regard to what is probable to happen and what should be a counteraction to that. The simplest case being a single conditional dictating what the reaction to an event should be; the system consists of a set of expected events and a set of available reactions, in a linear matching -univocation- with each other. A more advanced version, is the one where the reactions pool is replaced by a linear range of reactions that produces a graded effect: the more illumination, the heavier the shading gets. Both implementations are of the same nature, of strictly univocal relationships between cause and effect, controlled by a system with the intention of maintaining the value of the measured dimension -in this case of illumination- of the architectural object between certain limits. In fact, they are both cases of automation of simple mechanisms with an analogy of a window in the first case, and venetian blinds in the second. This kind of performance is related to the

purely technical aspect of architecture that we could call the *mechanistic univocal paradigm*. Opposed to that, we would propose to view performance as not only from the point of sustainability or automation, but as a signifier for targeted processes. Approaching design in this way, leads to an architecture that instead of being efficient in measurable dimensions, is efficient towards performing concepts.

Interactive architecture on the other hand is in a more infantile state, and has not yet managed to leave the sphere of installation design. In most cases the idea of interaction is limited to an analogy of subject proximity related to object visual: a computer generates graphics on a projection screen related to the proximity of people to the screen. Interaction, I would argue, should not be considered purely as a response to a causative event derived from the action and reaction axiom of physics that results in equilibrium. Instead, we have to surpass the concept of linear causality, creating an interactive system of greater degree of freedom to simulate a higher state of interaction.

Viewing therefore, as mentioned before, interaction as a process, instead of a normalizing exchange, we can read it as being in a communicative state where a response reformulates and charges the communicative context every time, and in a way applies the question for the next response, which provokes the answer. Thus, what can be considered as the challenge for computer-driven architecture today, in order for it to advance, is not to respond to a predicted external event, but rather, its response to affect back the external event or causality. In other words, creating an affective system of bidirectional flows where every response is throwing the system away from equilibrium, by a way of performing bifurcations (Kwinter, 1992) instead of ready-made actions. Users or inputted parameters of this architectural object coming together through the interface provided by the first, constitute an assemblage, that displays the emergent behavior of affective interaction (De Landa, 2006). The interactive process in this way, creates a loop that we can call a non-linguistic communicative cycle.

## **GENERIC MACHINES: AN INTERACTIVE KINETIC STRUCTURE**

To present my case in a more comprehensible context, I will use my thesis project to explain the practical application of these concepts.

Starting with the intention of designing for the unexpected rather than for the idealistically defined, we envisioned a structure that could be flexible enough to perform a range of functions. To achieve variable functions we should enable for the structure to take different forms. In other words to be able to move on command and furthermore have a relatively large degree of freedom, as for the produced object to be transformable in both its function and form: a building that can change the space it encloses and also alter the parameter that produces that space. In technical terms, we wanted to extend the flexibility that parametric design has offered us, from the design process, to the period of the life of an object, so as to be able to affect the produced space and the principles that form it, at all times, according to any current need and local parameter.

The actual design of a structure that would be able to undertake different functions can be said to be analogous to the design of a generic machine; an object that is not designed to be purpose-specific, to have an anthropocentric function yet, but instead to have some properties that would allow it to operate under a set of thresholds or physical constraints. These objects thus, are not characterized by the final given function, which in fact would be incidental to the parameters in consideration, but from their virtual space (Deleuze, 1994); their degree of flexibility or generic properties offered by their design (Figure 1).

The workflow of such project is divided into two distinct acts. The first is the invention of the actual structural mechanism that would support the transformation we are looking for: finding its constituent elements and joints, and the principles under which they function. The second and the most daring, is the organization of the structural elements, the formalization of their mechanism and the design of the processes they take part in.

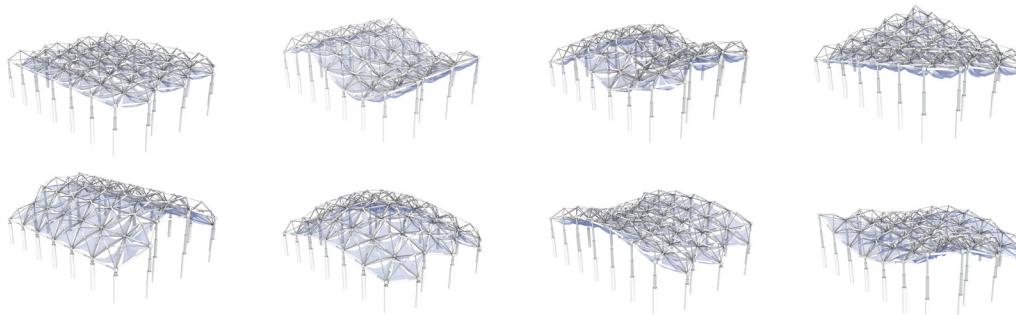


Figure 1  
Mathematical transformations.

Finally, the software controlling the structure that can be considered as its functional representation, is to be linked on the one hand with a parametric CAD software that reconstructs the geometry of the structure for the purpose of generating renderings of any desired moment. On the other hand, it will output data to a microcontroller -Arduino- that in its turn commands the structural elements in the real space -e.g. linear actuators or hydraulic pistons- to produce transformations in the kinetic scaled model or the actual structure.

### Structural behavior

A mechanism was devised as a module (Figure 2) that could assemble a larger flexible space-frame. The modules work as transformable pyramids, having an expandable base and rigid sides, interconnected by another series of expandable beams by their apexes. An analytical approach regards two flexible grids, a lower triangular and an upper hexagonal, with their nodes connected vertically by rigid beams. Having in addition all beam connections modular, allow all linear elements to pivot freely around them. Simply put, the principle allowing transformations, is the ability of each grid, upper or lower, to individually expand in length, while the rigid beams connecting them, convert linear movement to spherical rotation.

Thus, any alteration in beam length of any individual beam, is transcribed to rotation around a pivot point. Furthermore, the overall formation, while maintaining a high degree of malleability, en-

sure static adequacy, because of the multiple spatial triangulations, constituting an isostatic frame at any moment of transformation, regardless of the actual length of any particular element (Figure 3). To conclude, formalizing the structural behavior of the module, requires a transcription of its physical and mechanical relationships of the module mock-up to parametric mathematical ones that are out of the scope of this paper, however the ontology developed will be described below.

### THE ISSUE OF SOFTWARE

Starting to develop a project like this, the architect having in mind conventional tools, will soon encounter a dead end. There isn't any readily provided software or much experience for designing such objects. Common design software, was of course not made to manage neither data nor any notion of non formal based or in other words functional anima-

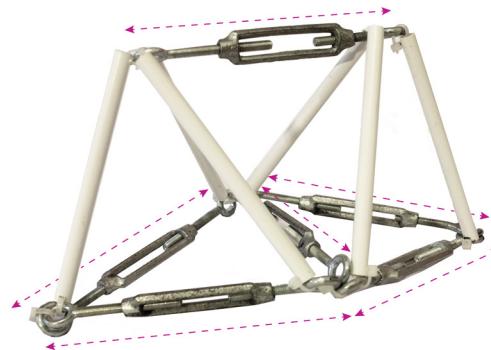


Figure 2  
Structural module.

Figure 3  
3D printed model: Monkey  
saddle surface.



tion. Parametric design software on the other hand, allows only for a mono-directional flow of information. Working thus with the logic of parent and child, its strict hierarchical structure prevents for geometry found lower in the pyramid to affect the top of the pyramid (Davis et al., 2011).

The problem with existing design software is that it was made under a different methodological approach, where design is practically defined as the production of representations, such as plans and sections: the architect designs an object with the end product of this work having to be either 2-dimensional plans or a 3-dimensional model in the case of 3D printing or other similar information based fabrication techniques. In our case however, this production model proves heavy limitations.

Needing to expand this finite design method, we have to devise an alternative framework, and here is the point where the freedom that programming allows, comes into play. It would be naive to support that what computation adds is the extra dimension of time. On the contrary, the surplus gained is not the ability to handle 4 dimensions -geometry in the course of time- but the complete freedom work in a different design modus operandi. In this case however, the architect would need a framework not for designing representations, but actually functions in relation to time; and here is where computation

comes into play. That can be abstractly described as design through organization of two dimensions: information and time, or the change of information over time. The notion of information here includes objects or object types, interwoven by relationships and controlled by functions. Geometry thus, as will be explained further below, is only one aspect of the informational model, or one of its many dimensions.

### ***Procedure based ontological organization***

For the structure to be organized as information, we have to divide it to different entities. Thinking on conventional terms, we would be tempted to create an abstract hierarchical scheme based on structural importance: columns, lower beams, upper beams etc. In a computational context however, this is proved to be impractical, due to the large amount of objects that would even be loosely related to each other in functional terms, thus making the task of logical organization almost unbearable.

To achieve this task, we will have to distance ourselves from the conventional conception of a building ontology instead, and proceed to some reductions that would leave us to the bare minimum of a building block, which we will have to study and simplify to entities and relations. Theorizing the structure from this viewpoint, we come to a completely different schema. Now the complexity of the

structure is reduced to a simple surface, where the lower beam joints (grid nodes) function as its control points, and the rest structural members are merely passive objects that perform degrees of connection between them and the ground, providing also the thresholds of these relations. In other words, the functional organizational schema is found to be the exact opposite of the structural one; the beams are the links of the joints. This way only joints take part as geometry whereas beams are only numerical parameters -a minimum and a maximum.

Proceeding to the actual object construction, we define three main types that are again, not exactly relevant to the an ontology as perceived structure, but instead as ontology relevant to the succession of the distinctive elements' informational construction. These 3 object types, in their order that they take part in the construction of the whole are: lower grid nodes, tetrahedra and finally tetrahedra apex relationships. To explain their interwoven synthesis we have to dive into the process in which they take part for assembling the structure.

The first objects as mentioned before, are the lower grid nodes. These could be considered as the fundamental population from which the rest will be generated from. To distance ourselves from their structural conception, we could imagine them as points in space that are not limited to geometry but instead have a series of properties or relationships between them. Each node object thus, carries organizational information such as its local identity or topological position in the population of nodes -e.g. (5,7)- the identities of the other nodes that is connected to and information regarding whether "carries" a column or not -the column is a property of the node. It is initially given a geometrical coordinate and then allowed to alter it, in regard to a global parameter that dictates the valid range of a beam length, in other words the node's thresholds regarding proximity to its neighbors.

Moving on to the second object type, the tetrahedra are not constructed in geometrical terms, but by an algorithm that obtains the topological position of three nodes making a 3d triangle on top of

them. Here we find again internal topological data regarding the related nodes, its relevant position in the population of tetrahedra as well as internal functions that compute the apex.

The final objects are the tetrahedra apex relationships, that are constructed out of two tetrahedra, having a simpler role, to control for the length of the upper beams dictated again by a global parameter range. These objects have also internal data such as their topological coordinates and the topological coordinates of the tetrahedra they bridge.

What was left out for the sake of simplification, is that besides each object in the genealogy knowing its ancestor, it is also programmed to know its offspring. This way, different objects can affect not only their successors but their predecessors also, in a hierarchy that is only historical rather than of authoritarian character. Therefore, any change the nodes produce will be followed by the successive objects, and any change produced by other objects lower in this hierarchy will be followed as well, regardless of their place in the hierarchy. Each entity can, within thresholds, function separately among its population and pass on instructions for objects of different types, to which is related, to follow. This ontology therefore, makes for an organic weaving of the structure. Created based on a process genealogy distinction rather than division by structural importance and having in mind a process oriented approach for the different elements' links to each other, we end up with an informational model of the structure where all the dimensions of each individual element's freedom can be fully controlled regardless of the degree of the overall complexity (De Landa, 2002).

Disregarding hardwired perceptions of hierarchies and fixed relationships (Alexander, 1965), through this process of fabricating a hybrid mixture of horizontal and vertical organization (De Landa, 1998) as well as transcribing geometrical relationships to topological ones, we are able to approach the structure in a different way. That is the structure itself as a process with its own topological space, with each of its incidental formations as a point in

this space. This approach was based on the notion of “the virtual”, developed by Deleuze (1991) in accordance to branches of mathematics relevant to dynamic systems. What the term virtual describes is the view of a system, as within an immanent field, its multi-dimensional state space, that includes all its possible distinctive states. However, these states are not regarded as a mere possible, but rather as real, not yet actualized. In our case, this translates to treating a system or in our case acquiring control over not only its present moment, but its totality of moments, by envisaging its topological space and handling it by its own dimensions rather than by a superimposed external coordinate system.

### ***Parametric behavior design, two examples of programmed function***

The final task to complete is the design of the different behaviors that we want the structure to perform. In a programming environment these can be called parametric procedures. Taking to account some input data, we output topological transformations that would produce a desired form, according to a set of rules. Having already created the ontological foundation and the inter-dependencies of the different entities that offer the parametrization of the generic structural behavior and ability to affect it either globally or locally, we could go on to produce a myriad of transformational behaviors, that are moreover irrelevant to the actual size of the structure and the amount of constituent elements. To display the multi-functional ability of the structure, two main scenarios were explored: environmental performance and interaction with people.

Regarding performance, we intended to experiment with shading. Unlike static buildings that utilize an optimal throughout the year solution, here we wanted to create a function that would be able to find the optimal solution for any given moment. We therefore built an algorithm that would compute the solar vector for the particular geographic coordinate of the place of installation, and thus we were able to program it to bend and rotate in relation to the angle of the solar illumination, in order to pro-

duce the maximum area of shadow on the ground. Furthermore, controlling for the expansion of the semi-transparent membranes hanging from the structure, we could even produce the desired solar permeability, taking into account the season and the solar illumination, and thus control the sunlight reaching the people under it.

To explore interactive functions, our hypothesis intended to create an urban condenser, in a metropolitan public space, where through people-structure interaction we would encourage interaction between people themselves. The involvement of the structure would be that of a catalyst in social relations, by a way of spatial experience. To do so we wrote an algorithm that makes the structure slightly deform locally, over areas it detects people. These deformations would amplify, proportionally to the density of people gatherings under it, in this way provoking movement and proximity (Figure 4). After testing it with an agent system -boid swarm- we programmed over a Kinect infrared sensor, which scanned and detected people under the structure. Eventually, this behavior made for a real-time collective morphogenesis in a real space with real subjects, acting upon their movements and arrangement. Through the functional scenario described above and experimentation done in a real context, we can support that this concept is feasible and that additionally, does not only offer new possibilities, but also enhances the social aspect and the experience of metropolitan public space through an architectural object as a mediator. Our approach towards interactive architecture, is therefore for an architecture that performs concepts.

## **CONCLUSION**

Through real-time computational design, new horizons have only been uncovered, promising unimaginable new possibilities that will definitely shape the future of architecture to come. Architecture in this context, is not any more a single sided static object, but instead a complex set of relations; the interface between the environment, its subjects and a structure, rendering the latter able to communicate, ad-

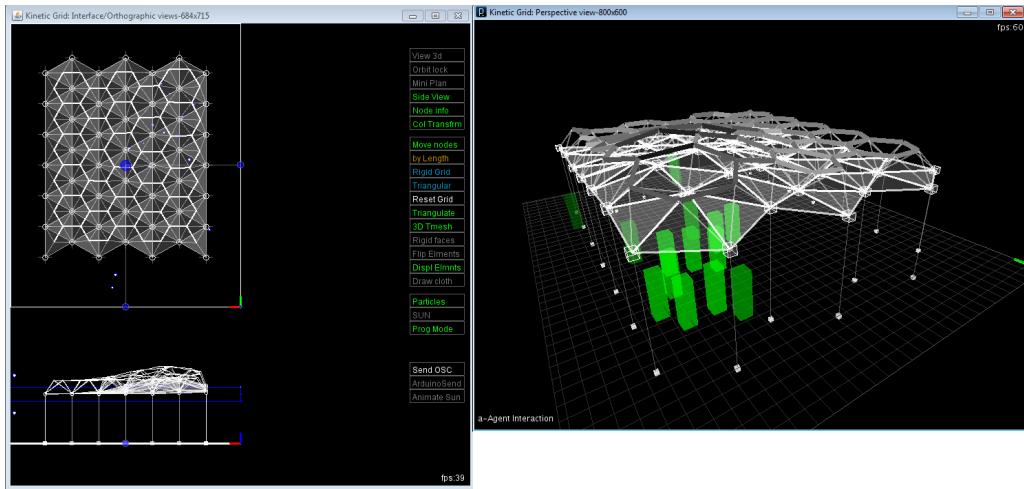


Figure 4  
The software in interactive mode.

just and adapt, in any situation and circumstances. In this system, the role of architecture alters, not only historically, but also as a social and urban encounter, where its potential as an actor in this system is unprecedented.

The growing necessity therefore, for a paradigm shift, capable of leading these efforts is now more evident than ever. As I believe I have shown, Deleuzian philosophy, is a viable theory to take over and replace previous conceptual schemata (Kuhn, 1977). As a coherent theory, it can furthermore serve the unification of the different fields of real-time computational design under the notion of a process based architecture. Applying to design its exhaustive theorization of dynamic systems and organisms, makes for a transgressive approach towards the current limitations, eventually contributing to the advancement of architecture. Eventually, from this scope, the architecture of processes will soon emerge as an intelligent platform for performing concepts and materializing behavior as an active agent of the urban environment (Figure 5).

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Figure 5  
Representation in urban  
context.



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