Lora Dikova

943 Steamboat Drive #204
Cincinnati, OH 45244
USA
loradikova@gmail.com

Keywords: information, string theory, M-theory, spacetime, morphologies

Presented at Nexus 2010: Relationships Between Architecture and Mathematics, Porto, 13-15 June 2010

Research

After the Paradigm of Contemporary Physics in Architecture: Spatial Possibilities and Variations

Abstract. Architecture in the information age becomes a mixture of spatial and temporal processes that are directly linked to changes in science, technology and culture. In the digital era, when information becomes a matter of philosophy, methods of informational transitions provide multiple possibilities for conceptualizing space, and thus opening new horizons to architecture. This research explores algorithms of analogy between string theory, M-theory and architecture. The mathematical spacetime concepts of movement, dimension and topology in physics are studied as tools for achieving informational transitions in the design elements and their structures. As a result this methodology opens numerous possibilities for interpretation and creation of new design morphologies.

Fig. 1 Untying Form into Shadow

The function of Art is to imitate Nature in her manner of operation. Our understanding of "her manner of operation" changes according to advances in the sciences

John Cage [1969: 31]

Architecture in space and time

Architecture is not only a spatial statement, but is also a philosophical one. Design transforms data into spatial structures by organizing physical, technical, cultural, functional, aesthetic and economic information, by means of abstract connections. Therefore, architects participate in the design process by analyzing restrictions in space, time and culture. Later, they convert them into a non-accidental spatial artifact. This process of repetitive organization, namely defining the multitude of elements and their connections, requires particular methodology. This paper explores a possible approach for achieving such design methodology by using spatial concepts from the area of modern physics. Employing an indirect analogy with string theory and M-theory, the paper encompasses a variety of questions, bringing architecture, philosophy, and science together, to investigate how the interconnectedness of these questions could affect contemporary design, providing different modes for organization of the design elements in space, time, and context.

To focus on why I bring architecture, philosophy, and science together I would like to introduce a question asked by the physical chemist Ilya Prigogine, when referring to the organization of the embryo: "How can an inert mass, even a Newtonian mass

Nexus Netw J 14 (2012) 25–34
DOI 10.1007/s00004-011-0095-z ; *published online* 13 January 2012

animated by the forces of gravitational interaction, be the starting point for organized active local structures?"[1]

Representing a philosophical paradox in the sciences, namely the mystery of the act of processing organization, the question might just as well be ascribed to architecture, because even though the final result from design is a spatial artifact, that artifact is not a direct product of spatial elements, merely put together. In spite of its peculiar attitude towards physical, technical, cultural, functional, aesthetic, and economic restrictions, initially, each design process deals with structuring pure states of information about objects and their possible relations. Therefore, the primary cause of any designed artifact is a transformation of information; this transformation is in fact "the starting point for organized active local structures".

Moreover, it is precisely such informational transitions that link the facts which are configured in systems by means of science. It is also these transitions which philosophy makes interpretations of. Prigogine stated that, "It is science, not its results, that is the subject of philosophy" [Prigogine and Stengers 1984: 88]. The diversity of the tendencies in philosophy frames our culture. Therefore, by processing the information about how science and culture relate, new patterns of organizational structures could be derived, giving multiple and challenging answers to Prigogine's question.

Living in the twenty-first century we experience the impact of the informational revolution, marked by rapid alterations in science and technology, and consequently in culture. These alterations affect the way we make and comprehend architecture. Inevitably, they impose change in the design process, because our appreciation of space alters as well. Space has become the result of a diverse mixture of the developing scientific, technological, and cultural activities; space has turned into a spatial and temporal layering of information, constantly accumulating and altering the very way space itself is comprehended. Therefore, in order to make and comprehend spaces in the twenty-first century, we need to frame a language of relevant organization of the design elements, precisely because the alterations in the science and culture change the philosophical meaning of architecture. As mentioned, designers, in particular architects, react to these alterations by transforming spatial and temporal information. Architects such as Marcos Novak, Kas Oosterhuis and Stephen Perrella have already undertaken their quests for such a shift in the attitude towards the relation between science and culture.

In relation to the beginning of a new approach towards space and time this paper investigates the possibilities for designers to take advantage of the various methods for transforming cultural and scientific informational patterns into spatial artifacts. To do so, I specifically explore how algorithms of analogies, which are initially derived from the spacetime framework in modern physics, could then be transferred into design methodologies. I consider the main concepts of movement, dimension, and topology, as they are particularly framed in string theory and M-theory, and convert them into design tools for mediating transformations of information in a spatial way. To do that I investigate two ways these concepts could contribute to the design process: first, providing a conceptual ground for organizing a "cause and effect" structure of design elements; and second, exploring the possibilities for form creation.

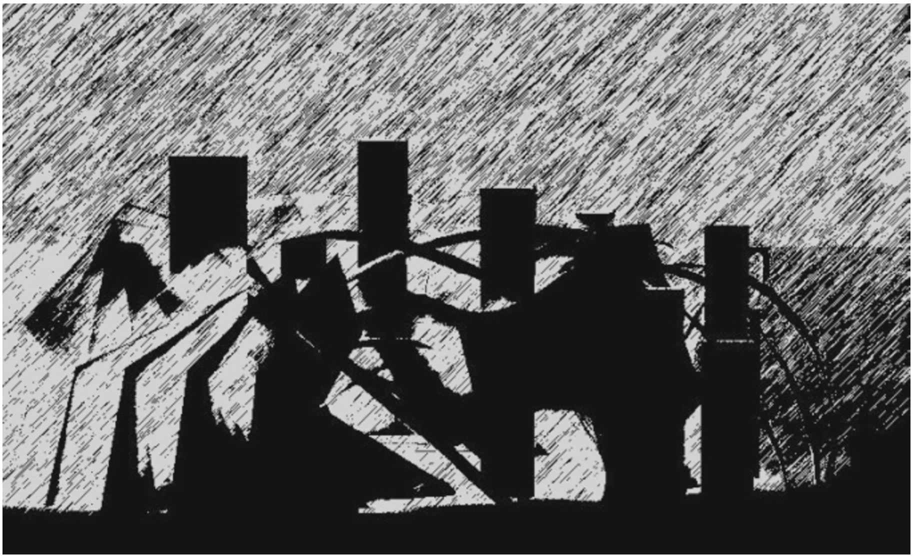

Fig. 2. The Topological City

Even though the indirect analogy with contemporary physics represents one of the many ways to form particular organizational structures in design, its concepts correspond to architecture both by providing a particular method of organization of spatial elements in a system, and by providing tools for manipulating the organization of complex dynamic systems. The theories used in this analysis, string theory and M-theory, are recent examples of ongoing scientific attempts to combine the theory of quantum mechanics and the theory of general relativity into a unified theory of everything.[2] The main concept is that particles, considered point-like in classical physics, are in fact minute strings, vibrating in a sub-quantum world of mathematical multidimensional spaces, thus producing the properties of bigger particles. In M-theory, a successor to string theory, these strings surpass the dimensions of the sub-atomic scale and form huge membranes, "branes" for short, which collide and produce a multitude of new universes. Highly controversial, because they cannot be tested by experiment, and radically strange, because they digress from our general understanding of the physical world, these concepts cannot be applied to the design process directly. However, the inner logic for organization of spatial and temporal elements defined by these theories could successfully be applied in design as a way to transform spatial and temporal information, precisely because they offer challenging connections among the concepts of movement, dimension, and topology. These concepts, derived from modern physics but interconnected with mathematics, art and philosophy, could be applied in architecture as design tools for organizing spatial and temporal information.

Architecture, following the paradigm of modern physics, could therefore result not only in a new morphology, but also in the creation of new contexts. Design might turn into algorithms of informational patterns, which change the x, y, z time variables of objects. Such a change would influence the subjects in the environment of these objects. Therefore, this change of the variables of the objects would help achieve a diversity of spatial and temporal events.

Architecture and movement

The architect Kostas Terzidis stated that, “motion involves time as a measurement of change” [2003: 33]. In string theory and M-theory, “the wild vibrations of the different strings” [Green 2006: 226], which are different from ordinary vibrations because they account for the quantum fluctuations at that scale, could still be considered as a form of alteration in time, on the condition that we accept time, even without being able to measure it in the quantum world. Moreover, the distinguishable difference among the elementary particles, tested by classical physics, results from the difference in the specific vibrations of the strings in multi-dimensional spaces, according to string theory and M-theory. Therefore, such a spacetime framework represents not only a repetitive movement and energy exchange, but also allows the concept of movement to serve as a tool to form informational transitions.

To transform this concept of movement in architecture, we should consider both the dynamic possibilities of the design elements as well as the option of tracing motion in a static form. The first would imply the use of movement as a tool for transforming information about space and time in architecture; the second implies its use as a tool for imposing a form onto a designed artifact.

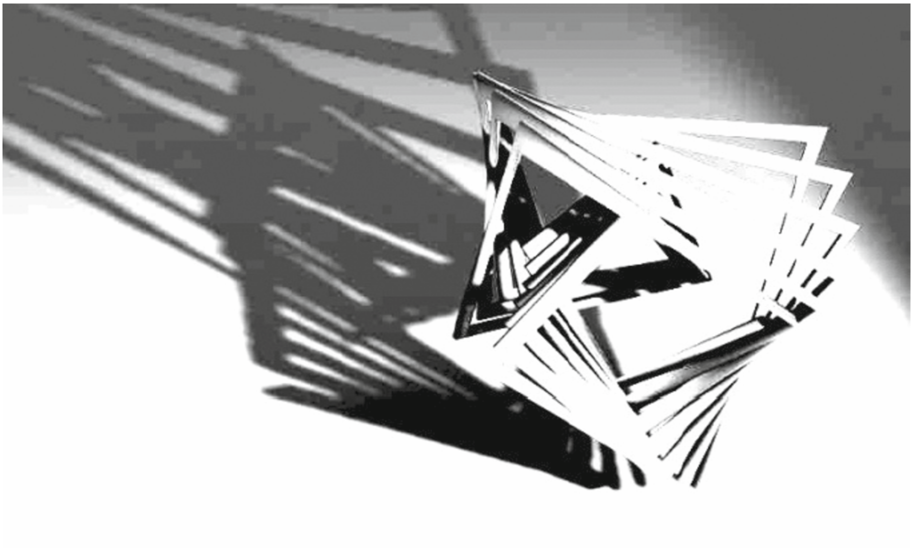

Fig. 3. Temporal Sequence of Form over Time

As an organizational tool, movement in *n*-dimensions could be applied both to objects and subjects in the design process either to force or to imply a particular structure of connectivity. Such a structure would inevitably create a specific frame of information. The awareness of this specific type of communication between objects and subjects provides opportunities for the designers. For example, in his design “Articulated Cloud”, the artist Ned Kahn takes advantage of this by designing a four-dimensional movement (three spatial and one temporal dimensions) in space and time. The dynamic façade of the building, made of flexible, wind sensitive and reflective exterior panels, alters naturally with the change of wind and the dynamics of the reflected sky, thus communicating any change in the spatial and temporal information of the immediate building environment.

Such attempts at animating architectural objects, done by introducing movement to unconventional elements for those purposes, make it possible to assign a new identification to the architectural object. In relation to this the architect Kas Oosterhuis stated that the architectural object turns into a "building body" [2002a: 38], encompassing all design elements, objects and subjects, by forming a homogenous environment of body structures which respond to common informational flows.

However, if we consider the architectural artifact as an overall static structure, excluding movable elements, like doors, windows, equipment, but rather referring to the massing of the architectural object, the tool of movement also provides possibilities for informational transitions, as a result of "cause and effect" design organization. Kas Oosterhuis, for example, treats the classic house as a "vectoral body whose direction is frontally oriented to arrival and departure" [2002b: 114]. Thus, if we consider the dual nature of architecture, being static, and yet imposing dynamic vectoral orientations in space, we could investigate, following the analogy with string theory, movement in *n*-dimensional spacetime as a mode of dynamic organization of static objects. The multi-dimensional aspect of the theory does not denote that we impose these dimensions literally, since additional dimensions merely mean additional states of information. Moreover, that aspect allows for more connections between the static and dynamic states of the objects. In four-dimensional space and time, for example, the architect Zaha Hadid developed such an approach in her early designs, applying, however, predominantly visual organizational patterns to limited elements and using collage design, rather than producing austerely articulated static places in movement.

Movement in multiple dimensions could also allow us to create a particular form in architecture. Even though the architect Kostas Terzidis stated that, "form itself does not involve time" [2003: 33], it could capture the change of time in spatial configurations, depicting the consequence of movement through time and space. Form, as a consequence of the movement in multiple dimensions through spacetime, does not necessarily demand an "animated building", as Greg Lynn would argue, but rather implies the inevitability of tracing movement onto the integrity of the form itself. For example, the Casa Guardiola designed by the architect Peter Eisenman is a result of the rotation, translation, cutting, mirroring, unification and duplication of a cube in space. The final architectural form and structure of the house communicate the notion of these processes of violation of the integrity of space, achieved by the movement of geometrical structures in time. Therefore, the form of the house is "animated" in the sense that it preserves traces of the series of movements in spacetime as geometrical projections, articulated in the final form. Therefore, a form could be considered a spatial memory of certain movement in space-time. Moreover, Michael Leyton argues that shape is memory storage and vice versa. When discussing the two-dimensional structure of paintings, he states that memory storage is also a reflection of the information about the past [Leyton 2006: 1-5]. Thus, we could consider the potential of a form as a consequence of *n*-dimensional movement, to provide informational transitions in space and time, being aware that

> [t]he designer is a stylist of the entire flux through the building body. However, the modern designer is more than that. (S)he also gives shape to the flux of the physical building body itself. The designer shapes the building body that will eventually change its shape and content in real time [Oosterhuis 2002b: 30].

Architecture and dimension

Dimension is the measure of the information on the location of elements in spacetime. Therefore, an element in the design system of four dimensions, relevant to our classical physical reality, is identified in space and time by one temporal and three spatial measures. However, according to string theory and M-theory, there are respectively ten and eleven dimensions in our physical world; therefore, more complex informational structures exist among the elements in these theories. Even though we design in three dimensions and time, we should consider and take advantage of the consequences of the possibility of higher-dimensional spaces, resulting in the creation of more states of information about objects, therefore, more options for them to relate technically or contextually in intriguing manners.

The significance of string theory and M-theory as tools for design methodology in architecture, is that the mathematical meaning of dimension is not isolated on its own, but it is woven into the structure of space and time. Thus the tool of dimension sets very particular conditions on how space and time operate together. "Now although it is hard to picture in more than three dimensions, this conclusion – more dimensions mean more vibrational patterns – is general", states the physicist Brian Greene [2004: 370]. Therefore, the concepts of dimension and movement are interconnected. How would such an analogy refract into the design process? As mentioned before, the concept of movement in architecture, even in static structures, proliferates with design possibilities for meaning and form. Therefore, by altering the concept of dimension, we disturb the tool of movement in the design process, changing the connectivity of the designed elements as well as altering their form. That inevitable dual transformation allows controlling the design in a more flexible way and also provides additional modes of framing information into spatial structures. The artist Tony Robbin, for example, used the concepts of movement and dimension in his sculpture for the Center of Art, Science and Technology at Denmark's Technical University. Working on the geometry of quasicrystals, "three-dimensional projections of higher-dimensional objects", Tony Robbin appreciates the "richness of four-dimensional geometry" by investigating its possibility for "multiple objects in the same place and time, objects appearing and disappearing by rotation, objects passing through one another without interference". Describing his sculpture, Robbin emphasizes the importance of combining concepts of movement and dimension to "allow the viewer to pass under, over, around, and through the work, and to happen upon the many and unexpected occurrences of fivefold, threefold, and twofold symmetry" [Robbin 1997: 434-435], caused by the change of light and the viewer's position.

Since the concepts of movement and dimensions are interconnected, as discussed above, and since the influence of movement as a design tool could shape a particular form in architecture, we can assume that the use of dimension can also indirectly achieve architectural form. Moreover, knowing that a common way to experience a form is by processing visual information, technical manipulation of multi-dimensional projections could serve as a tool to generate form. Tony Robbin expressed his awareness of that fact by referring to Henri Poincaré, who "repeatedly suggested that successive models of the projections of four dimensional figures when seen in sequence could lead to a vision of the fourth dimension" [Robbin 1997: 430]. Therefore, the possibility of framing whole structures, for example, in building sections or on urban level, would provide an immediate tool for generating form in the design process. Moreover, a form generated in this way would differ from other morphologies in architecture by providing a new appreciation of spaces, namely the visual experience of *n*-dimensionality.

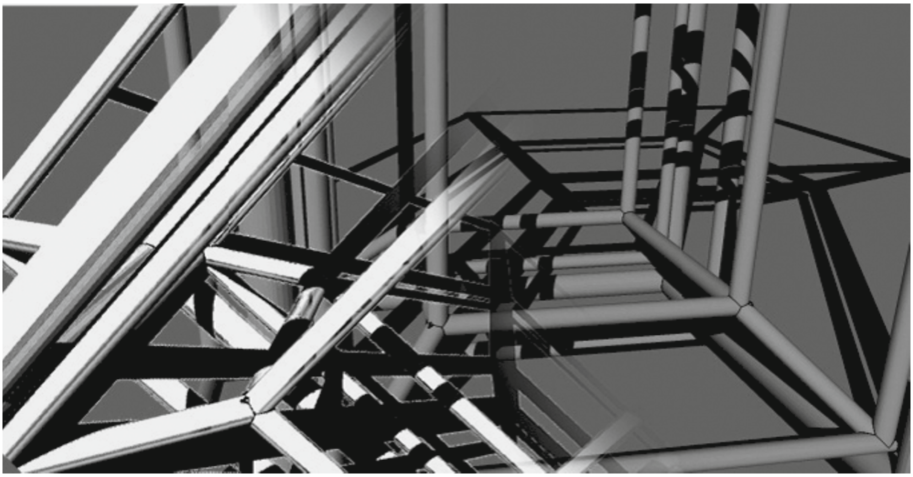

Fig. 4. N-Dimensional Variations on Tracing Form

However, because we are used to the restraints of our four-dimensional world, any representation of *n*-dimensionality could pose a challenge. Treated as a structure of connectivity among elements, *n*-dimensionality could take another direction in influencing the design process, namely by increasing the possibilities for informational transitions. As Brian Greene would argue, "… since a string's vibrational pattern determines its mass and charge," in string theory and M-theory, "this means that the extra dimensions play a pivotal role in determining particle properties" [Greene 2004: 371]. In architecture, the concept of dimension, considered as the link among all design elements in a system, might be investigated in context, not necessarily by technical geometrical projections. The architect Stephen Perrella, for example, tests such contextualism in his studies of hyperspaces, which are richer in informational transitions. Moreover, for him, hypersurfaces "are thought to render a more complex notion of spacetime information" than the mathematically defined ones, because in the hypersurfaces "the abstractness of these mathematical dimensions is shifting, defecting or devolving into our lived cultural context" [Emmer 2004: 57]. Unlike Stephen Perrella, Marcos Novak considers the concept of dimension in M-theory as a way to identify the design elements. Therefore, he suggests that dimension serves not as a tool to combine elements together in a system, but to differentiate their typology:

> …both are manifolds, the difference between hyperspace and hypersurface of a hyperspace of (n)-dimensions is a submanifold of (n-1) dimensions. Thus the hypersurface of a hyperspace of four spatial dimensions is a space of three spatial dimensions, produced by an act of projection or section or screening [Novak 1998: 85].

Architecture and topology

Deriving a form from topological spaces is the predominantly direct way to structure what Kenneth Powell calls "sculptural drama" [Powell 1993: 7]. Intriguing results of the application of the concept of topological forms in the arts are found in the two-dimensional art of M. C. Escher, where spacetime is visually curved, as well as in the sculptures of Eva Hild, improvising with the pressure, curvature, and intensity of a form. Moreover, topology has been already widely utilized in architectural theory by architects such as Greg Lynn, Peter Eisenman and Kostas Terzidis. The "weak form" of Peter Eisenman and the "fold" of Greg Lynn have tested topological structures and the way they relate to morphology in architecture. Greg Lynn implements topology as a tool to investigate flexibility and continuum in a form as well as its signification, affected by "programmatic, structural, economic, aesthetic, political and contextual influences" [Terzidis 2003: 23]. In similar way, UN studio, for example, transfer the Möbius strip directly from topology into architecture in their design for the Möbius House with the concept of infinite interaction of the users' activities.

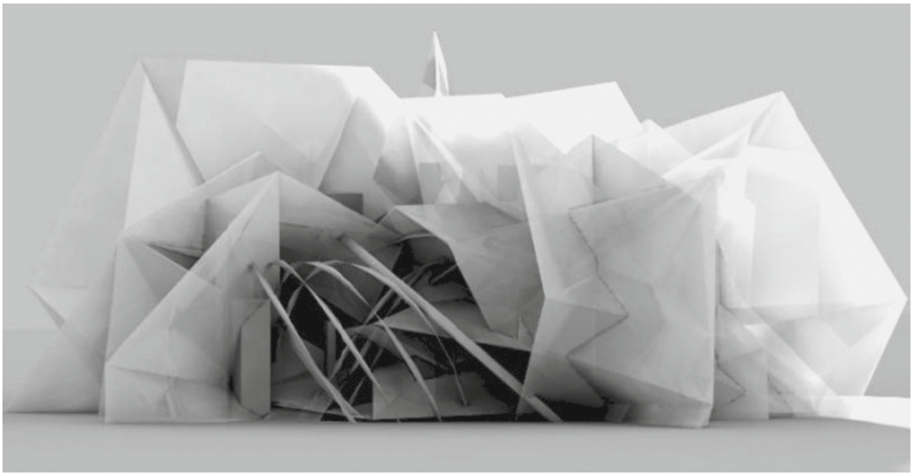

Fig. 5. Topological Invariants on Analytical Cubism

However, the mathematical approach taken by string theory and M-theory towards the concepts of topology and *n*-dimensionality suggests an intriguing relation between topology, dimension, and movement. This relation provides various algorithms for organizing elements in structures. Specifically, it bonds in a unique way the spatial character of the elements with the temporal feature of their structure. The strings vibrate in the sub-quantum world, in six-dimensional mathematical spaces called the Calabi-Yau manifolds, thus forming the properties of the various particles. Brian Greene explained further that the "vibrational patterns of the strings are influenced by the twists and turns in the geometry of the extra six dimensions" [2004: 371]. Therefore, the tools of topology, movement and dimension become interconnected and self-regulatory, given that topology controls deformations of form, such as stretching, twisting, folding, and scaling, while preserving the form integrity. Moreover, the architect Kostas Terzidis argues that form, subject to topological deformations, would reveal particular properties, as it would "allow time to be imprinted on form", as well as be an "object in disguise" because the object could be "composed of the topology of the one object and the geometry of the other" [2003: 16, 24]. This implies that by applying topological transformations to the design elements, we change the concepts of movement and dimension. Therefore, topology could be used to control the design mechanisms and organization in their unity. Kas Oosterhuis, for example, suggested that, "[t]he tension between the dimensions can be made visible and tangible by stretching them almost physically, like a baby in a bunting bag" [Oosterhuis 2002b: 237]. Similarly, movement, as a design tool, could also be transformed, stretched, folded or scaled, which would result in a change of form and connectivity of the design elements. Therefore, topology provides rich possibilities for manipulation of the design elements in form and context.

Dealing with the possible relationships among the elements in architecture, topology could serve as a tool not only for morphological and contextual, but also for programmatic organization of the relations between objects and subjects. Therefore, topology could constitute a powerful instrument for how architects transform the data of all design restrictions into spatial and temporal structures, emphasizing specific characteristics about such an organization. Dealing with deformations, preserving the object's integrity, but defining boundaries – "in and out" conditions – topological transformations could be applied in the design process, for example, as a spatial solution to border contexts. In a single building unit, or on urban level scale, exploring the elements as sets of typologies might serve as a tool to set categories of identities. This could therefore help to deal with a multitude of objects and subjects at once, by introducing them as part of a single topological structure, giving the advantage of controlling complexity because:

> [r]ather than assuming a continuous behavior that governs all finite elements, the behavior of each finite element contributes toward a generalized behavior. Finite elements can be regarded not as arbitrary units but rather as localized samples. In this context, general principles are derived from particular instances [Terzidis 2003: 50].

Architecture after the concepts of modern physics

"We have our own discoveries to make, based on the mathematics and physics of our own time", stated the artist Tony Robbin [1997: 437]. Therefore, if we go back to the question of the organization of the embryo, posed by Ilya Prigogine, we might find that in each time and space we accept different answers to that question. Our way of thinking as artists, scientists or philosophers who organize given information to achieve a developed structure of interconnected elements, is subject to change according to "our own discoveries". This paper presents a way to frame architectural theory through a reflection on a scientific analysis. By applying an indirect analogy with concepts from string theory and M-theory, the paper investigates possibilities for interpretation of information in the design process. The analysis of the tools of movement, dimension, and topology provide opportunities for both, interpretation and generation of design artifacts. It also reveals the importance of the spacetime framework in string theory and M-theory, taken as a design tool for dealing with complex dynamic systems, such as architecture, because unlike acknowledged concepts in classical physics, like phase space,[3] for example, string theory and M-theory link the concept of dynamics with the concept of spatial deformation topologically as well as temporally. Someday string theory and M-theory might prove to be wrong about how they define our physical space and time. However, that would not repudiate any of the places we might have designed as "animated through multi-dimensional spacetime form", exuberant in the diversity of their topological structures On the contrary, it would only be one of the various ways to answer Prigogine's question – one more time, in one of our many understandings of spacetime.

Acknowledgment

All images are by the author.

Notes

1. [Prigogine and Stengers 1984: 82]. Prigogine discusses the relationship between physics and philosophy; in this case referring to the viewpoint of the French philosopher Denis Diderot.
2. The theory of general relativity, including gravity, is mathematically irreconcilable with the theory of quantum mechanics, including electromagnetism, the strong and weak forces. However, scientists assume that under conditions, similar to the ones they suppose formed in the Big Bang or in black holes, these forces should be unified. String theory and its follower M theory represent a way to do it. However, they are only theoretical and due to technological restrictions, unverifiable.
3. Phase space is used for analyzing dynamic systems by introducing six coordinates to an object, defining its location by three spatial coordinates and their respective momentum, relating to the movement of the object.

References

CAGE, John. 1969. *A Year from Monday: New Lectures and Writing*. Middletown, CN: Wesleyan University Press.

EMMER, Michele. 2004. *Mathland: From Flatland to Hypersurfaces*. Basel: Birkhäuser.

GREENE, Brian. 2004. *The Fabric of the Cosmos.* New York: Alfred A. Knopf.

LEYTON, Michael. 2006. *The Structure of Paintings.* Vienna: Springer-Verlag/Wien.

NOVAK, Marcos. 1998. Transarchitecture and Hypersurfaces: Operations of Transmodernity. *Architectural Design* **68**, 5-6: 84-93.

OOSTERHUIS, Kas. 2002a. *Hyperbodies: Towards an E-motive Architecture.* Basel: Birkhäuser.

———. 2002b. *Architecture Goes Wild.* Rotterdam: 010 Publishers.

POWELL, Kenneth. 1993. Unfolding Folding. In: Architectural Design Profile 102: *Folding in Architecture. Architectural Design* **63**, 3-4: 6-7.

PRIGOGINE, Ilya and Isabelle STENGERS. 1984. *Order Out of Chaos: Man's New Dialogue with Nature*. Boulder: New Science Library.

ROBBIN, Tony. 1997. Quasicrystal Architecture: The Space of Experience. Pp. 434-435 in *Beyond the Cube. The Architecture of Space Frames and Polyhedra*, J. Francois Gabriel, ed. New York: John Wiley & Sons.

TERZIDIS, Kostas. 2003. Expressive *Form. A Conceptual Approach to Computational Design*. London and New York: Spon Press.

Young, John Wesley. 1930. *Projective Geometry*. Chicago: Open Court Pub.

About the author

Lora Dikova is a Bulgarian architect. She received her two professional accredited Master of Architecture degrees from the University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria in 2006 and from Miami University, USA in 2010. She has published several studies on interdisciplinary design methodologies, focusing on the relation between architecture and urban design. She has received numerous honours and awards for her design work in the area of Commercial Building Design, and her projects were exhibited on the XI World Architectural Triennale in Sofia, 2006, Bulgaria and on the European Awards for Bulgarian Architecture, Sofia, 2007. Currently, she is a representative to the International Union of Architects on behalf of the Union of Architects in Bulgaria.