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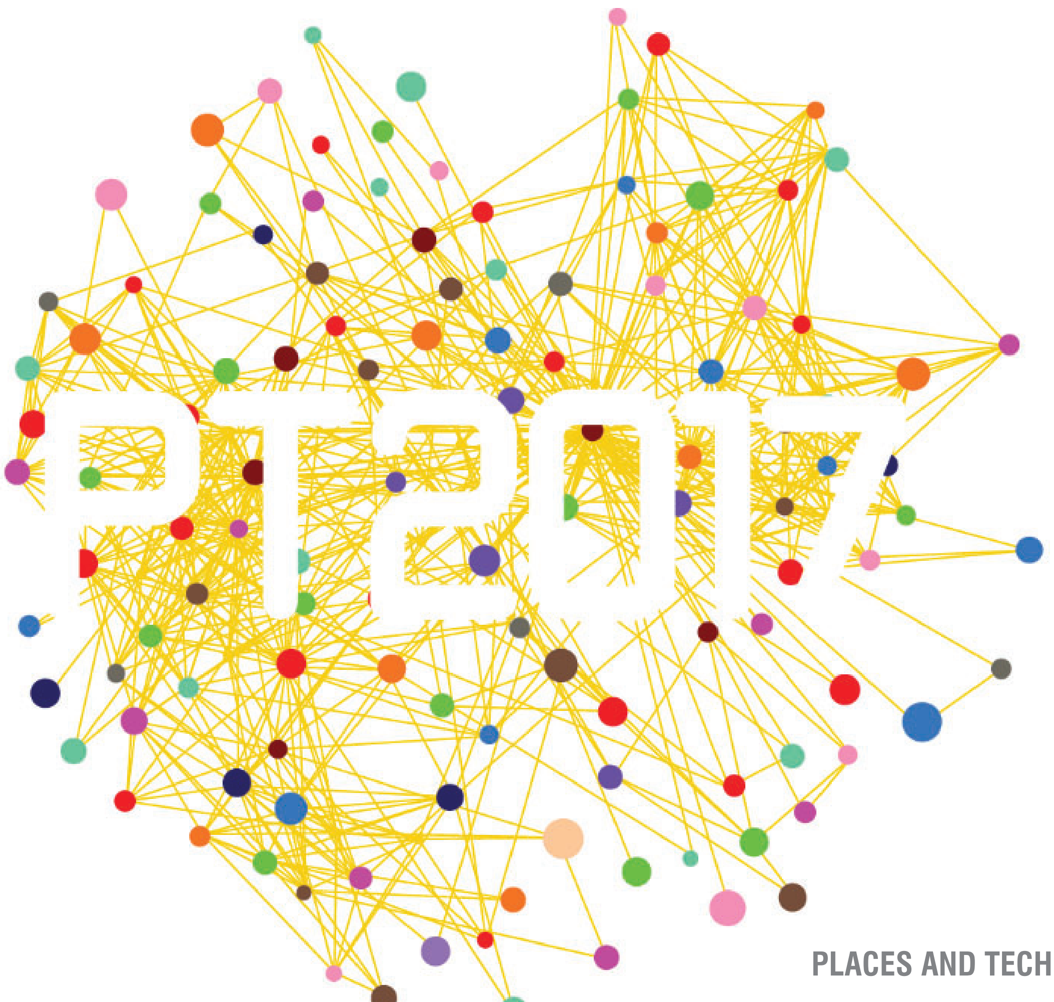

PLACES AND TECHNOLOGIES 2017

KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY

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Sarajevo, Bosnia and Herzegovina, June, 08th - 09th, 2017

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KEEPING UP WITH TECHNOLOGIES IN THE CONTEXT OF URBAN AND RURAL SYNERGY

BOOK OF CONFERENCE PROCEEDINGS

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Dženana Bijedić, Aleksandra Krstić-Furundžić, Mevludin Zečević

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Organizers:

University of Belgrade, Faculty of Architecture, Serbia
University of Sarajevo, Faculty of Architecture, Bosnia and Herzegovina

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TOPIC XIII:
BIOMIMICRY AND SMART INNOVATIONS TO HUMAN CHALLENGES

REVERSE BIOMIMETIC ANALOGIES IN DESIGN OF ARCHITECTURAL STRUCTURES

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ABSTRACT

This paper explores the concept of reverse analogies in biomimetic design of architectural structures. Design paradigms based on biological models are engaged in appropriation of the biological forms, processes and terminology. They are grounded in multidisciplinary studies of modes of transposition and implementation of identified principles and natural laws in the discourse of spatial design with the goal of realization of optimal solutions that have certain desired attributes of the biological systems. On the other hand, reverse analogies are related to the application of concepts initially developed in architecture for research in different fields. It should be made distinction between nature as a source of explanation and source of inspiration. While in the context of natural sciences validity of the analogy is essentially important, in the case when the natural phenomena are used as a starting position for design research week form of analogy is tolerable. Even misinterpretations and heretical concepts could be simulative for design. The main advantage of the reverse analogies is in application of the freedom and liberal nature of the architecture that enables development of the concepts out of pure design reasons. Sometimes in the modelling of the phenomena not explained by the nature this approach could be simulative and catalytic. The goal of this paper is to exploit potentials of reverse analogies for deriving patterns or feedback data that can be used for conception and development of strategies and tools, or as an inspiration for formulation of intern morphological processes in design of architectural structures.

Keywords: Biomimicry, Reverse analogies, Architectural design, Architectural structures

INTRODUCTION

Synonyms biomimetic, biomimicry, bionics, bio-appropriation, bioinspired design, etc., in spite to minor differences in meanings are used interchangeably in the literature (Vincent, 2009), (Gruber, 2011) to denote multidisciplinary studies of modes of identification, transposition and implementation of the natural patterns in the field of science, engineering, art and design. Exchange can be conducted at the distinct levels form literal reproduction, imitating or repetition to derivation of the principles on more abstract level and finding explicit system solutions (Gruber, 2011). In any case, the aim is realization of optimized solutions which have certain desirable attributes of biological systems.

In recent years, design paradigms based on biological models are revised considering the current technological capacities and developments (Hensel *et al.*, 2004, 2006, 2008), (Cruz *et al.*, 2008), (Vincent, 2009), (Spiller *et al.*, 2011). Besides appropriation of natural forms and processes, current tendencies are also characterized by the application of terms borrowed from the biological sciences. Use of the notions such as *morphogenesis*, *homeostasis*, *emergence*, *evolution*, *regeneration*, *adaptation*, *self-organization*, *self-assembly*, *self-replication*, etc., has considerable etymological implications on architectural language consequently changing our understanding of architecture. Equating architectural objects or structures with living organisms involves seeking ways to create conditions in which designs emerge, develop, adapt, react and mutate according to external and internal, subjective or natural parameters. In this way, generated designs are characterized by a symbiotic behavior and metabolic balance inherent to the natural environment. Correspondingly diverse concepts and generative models were proposed (Negroponte, 1970), (Holland, 1975), (Fraser, 1995), (Soddu, 1991-2011), etc. Their results diverge in creation of aesthetically complex, repetitive, variant forms inspired by the works of Novak, Lynn, Parrell, etc. (Novak, 1993), (Lynn, 1999), (Oxman *et al.*, 2014), which often exclude tectonic principles, or in form-finding of shape resistant structural forms, aroused by the researches of Gaudi, Isler, Otto, etc. (Isler, 1980), (Otto, 1996), (Allen, 2010), in which the mechanical behavior is inextricably related to the global spatial configuration. When the structure is not only technical requirement but also interacts with architectural form, technology needed for its development (form-finding or optimization methods and tools) is integral part of the creative design process. And when the objective is to design beyond biomorphic shape a *natural construction* (Otto *et al.*, 1982), that is extremely efficient, sustainable and demonstrates underlaying physical, biological and technical processes, *nature-oriented technology* represents a tool to reach this end.

Although there are numerous studies on the biomimetic design and in specific of architectural structures inspired by nature (Gruber, 2011), the concept of reverse analogies, focused in this work, is not extensively discussed in architectural theory (Fraser, 1995). Furthermore, there is not any study that reviews and investigates systematically the character of reverse analogies concept and their implementations in design of architectural structures. The objective of the present paper is to study concept and framework of such systems. Several indicative examples are examined and discussed. Moreover, we present the potentials of exploitation of feedback data derived from reverse analogies in conception and development of design strategies and tools, or as an inspiration for formulation of intern morphological processes in design of architectural structures.

CONSTRUCT

Reverse biomimetic analogies construct is related to the application of ideas and technologies developed and used in the fields of architecture and engineering for exploration of natural phenomena, and possible application of feedback data of such explorations in the creative design processes. Contrary to the common approach in which nature is a guide or a model for the architecture, in reverse analogies the transfer is inverted and directed from the architecture to the nature, enabling natural sciences (primary biology and their sub-disciplines) to exploit diverse architectural concepts, methods and tools (Figure 1).

Biomimetic analogy:	nature	$\Longrightarrow$	architecture
		transfer	
Reverse biomimetic analogy:	nature	$\Longleftarrow$	architecture

Figure 48: Reversing transfer arrow

The advantage of application reverse analogies approach for the natural sciences could be in using freedom and open nature of architectural discipline that facilitates development of the concepts for pure design reasons (based even on un-orthodox and un-exact standpoints). In the case of modelling phenomena which explanation was not provided by the science this could be stimulating and catalytic. And for the architectural design introduction of feedback information and experience of such studies could generate new impulses directed towards refinement of concepts, improvement of tools, increase rationalization of designs, etc.

Applications

Although the concept of reverse analogies is not frequent examples of its application demonstrate its effectiveness.

Application of the architectural drawing for studies of natural systems morphology and anatomy is one instance. Drawing is basic tool for exploring, describing and communicating

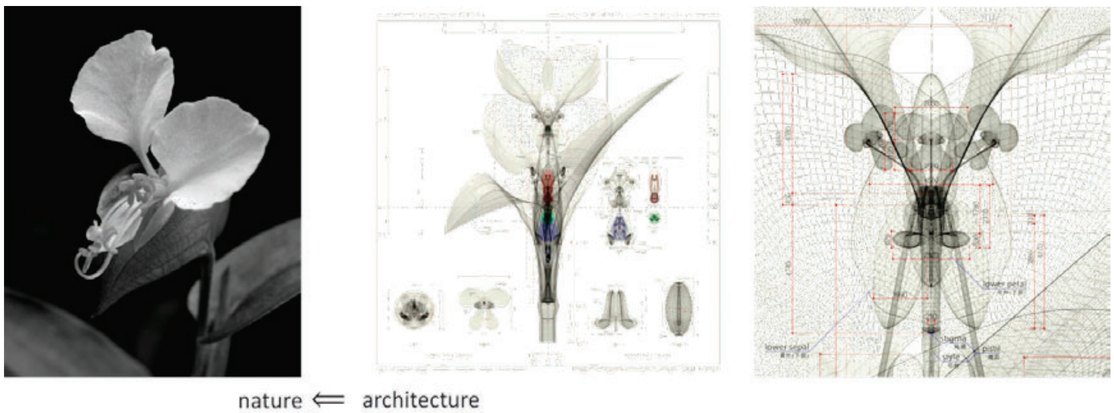

Figure 2: Technical drawing as a tool of representation and study of morphology of plant | *Commelina communis L.* - photography (www.fotolia.com), front view and detail by Macoto Murayama (www.zqjournal.org)

design ideas in architecture. Applied as a tool for record certain qualities of natural systems (such as form, structure, texture, etc.) in the biological sciences, drawings enable exploration of their properties and underlying principles with specific technical precision and accuracy. The results of such explorations could manifest dual art-science nature inherent to the tool and the discipline for which it was originally developed (Figure 2). And visual conclusions of such studies have design potentials that can be utilized and interpreted in architecture.

Another case is application of the engineering simulations in analyses of natural structures behaviour in a way that it provides new models of structure and material organization for architectural structures. For example, Finite element analysis (FEA) can be used, relying on a general nature of this method, in the studies of the integrated morphology of natural systems to clarify their complex structural dynamics, the range of their elastic behaviour, and draw conclusion on the deep strategies evolved by biology to efficiently adapt to changing environmental stresses (Figure 3).

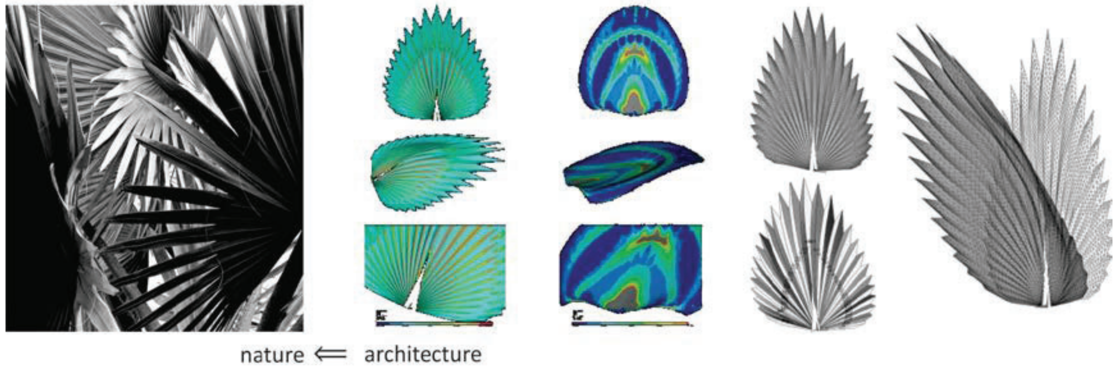

Figure 3: FEA as method for study structural performance of plants │ Palm leaf - photography (www.pinterest. com), FEA obtained stress patterns developed over the folded-plate palm leaf and similar unfolded geometry due to wind pressure, global morphology of the leaf and the structural articulation of folds (Weinstoc, 2006)

Implementation of the architectural models in the botanic as a method and tool for study forms, structures and development of plants represents another example. Generative logic of L-system (Prusinkiewicz *et al.*, 2004), a sort of shape grammar, was originally computationally implemented for simulation of the plant growth. Generative rules of L-system can be very concisely expressed, and a simple set of defined rules can produce very complex objects in a recursive process which consists of only a few steps. With the advent of algorithmic architecture discourse, L-systems along with other biomorphic algorithms (Wallace *et al.*, 2015) found many applications in the creation of formally complex architectural designs.

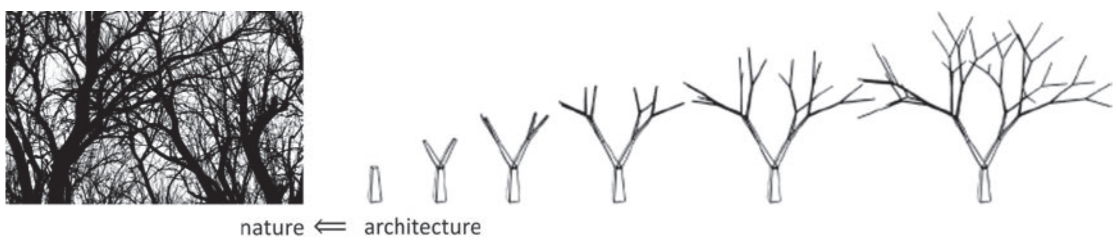

Figure 4: L-system as method for generation tree structures │ Tree branches - photography (www.pinterest.com), Fractal Tree 3D in Processing (Wallace *et al.*, 2015)

Architectural concepts have capacity to be expended in other fields. The example of extending the concept of tensegrity, originally proposed by Fuller, architect, system theorist, designer, and inventor, to other fields is analogy made by Ingber, cell biologist and bioengineer (1985). Work on tensegrity led him to investigate the role of mechanical forces in biological development, and moreover to propose it as fundamental design principle and mechanism that governs how living systems are structured, from individual molecules and cells to whole tissues, organs and organisms. Ingber determined that living cell use tensegrity architecture (Figure 5) to stabilize their shape and that cytoskeletal tension (or prestress, which is central to the stability of tensegrity structures (Nestorović, 1994)) is fundamental regulator of many cellular responses to mechanical cues.

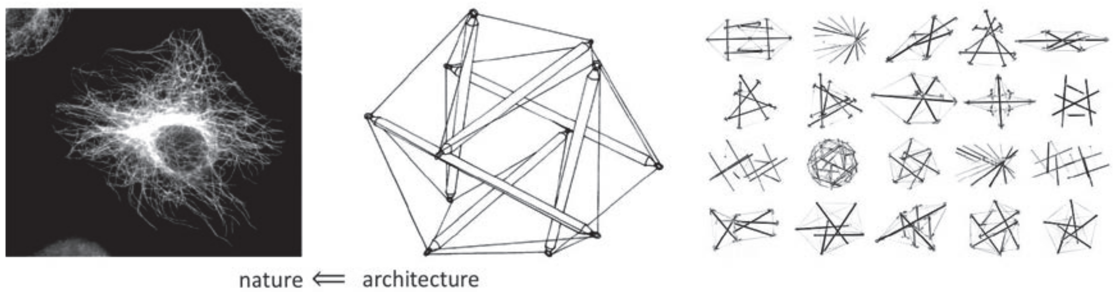

Figure 5: Tensegrity as concept of explanation of cell behaviour | Cytoskeleton (www.wikipedia.org); Tensegrity - Icosahedron by R. B. Fuller, 1949; Tensegrity structures (www.pinterest.com)

FRAMEWORK

We discuss framework of reverse biomimetic analogy in design of architectural structures (Figure 6) from the aspects of nature of interchange, features and levels of transfer.

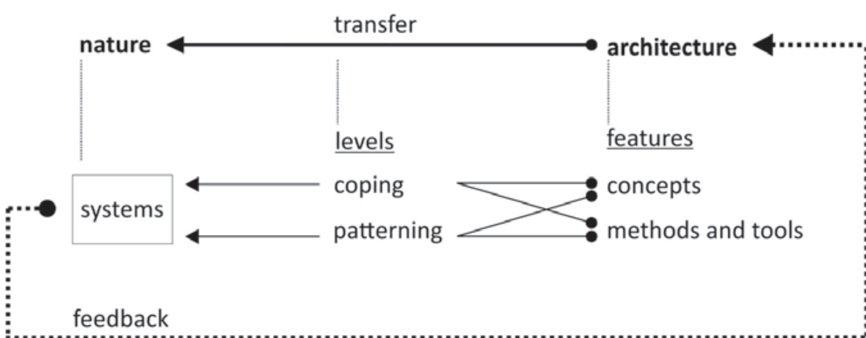

Figure 6: Reverse biomimetic analogies framework diagram

Generally, the interchange between biology/nature and technology/architecture is bidirectional. Transfer introduces approaches characteristic to one field into another - flexibility and soft approach in scientific researches, and objectiveness and rationalization in design processes. However, the realization of the concrete actions of abstraction, interpretation, and implementation is crucial in any transfer. Also, common application of digital technologies facilitates transfer creating integrated environment in which architecture and scientific disciplines crossover, exchange, analyse, and produce information of all kinds.

Features

Technologies and concepts are the features that can be transferred from the architecture to the biology and vice versa.

Technology transfer include application of diverse methods and tools, initially developed for the architecture and engineering, in the studies of natural phenomena. There are many examples of application of drawings and models, a basic mode of architectural communication, for representation and explanation biological structures. Lately there are examples of application of Finite Element Method (FEM), originally developed for engineering diagnostics, for the simulations of structural performances of natural objects. However, it is important to note that these delocalization of methods and tools calls for an approach that involves their tuning to the specific problem exploration while assuring them optimal performance.

Concept transfer implies application of notions originally developed in architecture and engineering for explanation of biological phenomena. It is necessary to make a distinction between nature as a source of inspiration and the explanation. While in the context of life sciences, the validity of analogy is of essential importance, in the case where natural phenomena are used as starting points for the research in the design process low form of analogy is tolerated. It is important to distinguish the nature of diverse types of theories. In this regard, March (1976) wrote: *Logic is interested in abstract forms. Science explores existing forms. Design initiates new forms*. The scientific hypothesis is not the same as design hypotheses. Logic proposal is not to be confused with the design proposal. While certain architectural concepts can be used for production of an exploratory theory in biological sciences, in architecture we are mainly interested in design potentials of the concepts reintroduced through feedback loop, i.e. their ability to generate architectural structures.

Levels

The features from the architecture can be transferred to the biology and vice versa by reproducing and patterning, which represent two distinct levels of translation.

Reproducing is direct coping and utilization of architectural concepts, methods and tools in biological studies. It is obvious, but not enough general approach mainly concerned with the studies of form, structure, texture, etc. of biological objects. Feedback data of such studies can be interpreted in architecture by copying formal patterns of natural structure of leaves, shells, trees, bones, etc. The disadvantage of this approach is that biological structures and their mechanisms can be taken out of context without sufficient understanding of the reasons for their effectiveness. For example, architectural drawing techniques and tools can be used for study of plant morphology and such forms can be taken as starting point in architectural design. However, topic of manifestation of certain characteristics of the organisms (in this case, its form) is far more complex and both dependent on the interpretation of genetics and the influences of the specific environment.

Patterning is more general approach of translation that involves recognition and identification of principles in how to eliminate and solve the problems (that may vary in scale and complexity), in the fields of technology/architecture and biology/nature. A considerable number of successful engineering solutions use simple and obvious natural principles as it is for example the case of tensile structures, which shape eliminates stress concentration. On the other hand, computational modeling could be used for pattern recognition of the plant growth or for the simulation of performance of biological structures. Outcomes of such explorations – derived principles can be interpreted, paraphrased or in another way implemented in design process. Application of ТРИЗ (Russ. *Теория решения изобретательских задач*) ontology specifically developed for the inventive problem solving (Altshuller, 1956, 1984) can be higher level of translation. At this level, patterns are even more abstract, and the problems are defined and solved within the narrow framework set.

While organic forms are common inspiration in architecture, patterns performed on the second level can be used for designs, development of strategies and tools, or for the formulation of internal logic of morphological processes. In both cases, creative potential of reverse biomimetic approach can be implemented in the creation of architectural structures (Figure 7).

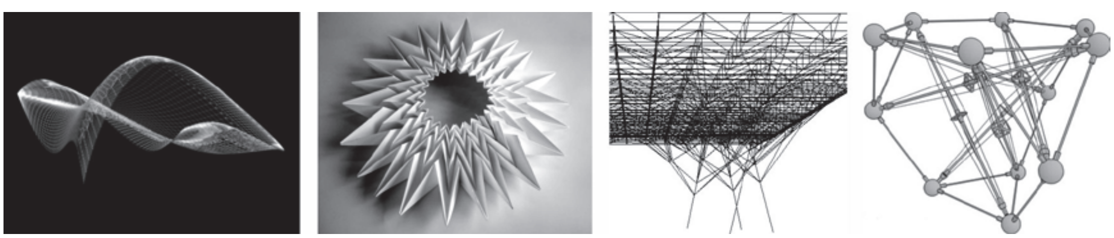

Figure 7: Architectural structures designed by the students of the University of Belgrade, Faculty of Architecture | freeform spatial structure, folded plate structure, branching structure and tensegrity structure

CONCLUSION

Derivation of the solutions for design problems from the nature implies its position as a model that imposes standards to the architecture. Previously is exemplified in perfection and diversity of natural forms and organisms that are metabolically balanced with their environment. Architecture, on the other hand, faced with the task to answer on a whore range of impacts and constraints - spatial, functional, technological and environmental, has developed diverse concepts, methods and tools. While the influence of natural analogies on architectural design is common theme, the reverse analogies appear to be more exceptional. This paper demonstrates that certain architectural features (concepts, methods and tools) can be used for biological studies, and points on the potentials of re-introduction their feedback data in the design processes. This approach ignores the walls between different areas of expertise, enabling a wide variety of knowledge and skills (even those that seem irrelevant to the problem) to participate in the explorations, and supports stance of equal art treatment of natural and artificial systems.

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