Crystal Formations and Symmetry in the Search of Patterns in Architecture

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Nature is always full of patterns inspiring all the disciplines and especially architecture in many ways. Currently, with the advances in technology and growing interest towards nature-driven studies, retrieving information from nature has a new connotation in scales and dimensions including both living and non-living beings. In this study, it is aimed to explore the scales of nature from Nano to Macro and a holistic approach is embraced to cope with the complexity of nature and architecture. To understand these complexities, patterns in different forms and scales serve as valuable tools to decode and recode information from one domain to another through locating the order and how patterns exist in different and changing environments with respect to forces and the urge of the existence of the being. This research focuses on the behavior of crystal formation which can be observed both in biotic and abiotic nature to understand the order generating the patterns in nature and its adaptation into a different and changing environment. This information of crystallization has great potential for architecture in terms of spatial structures, new materials and introducing a novel lattice for freeform structures. In this study, the potentials, limits and possible contributions of crystal formation are stated for architecture in the search of symmetry and patterns.

Keywords: nature-driven, computational design, crystal formation, symmetry, pattern

INTRODUCTION

Men always search patterns which bring order and predictability into Architecture. Observing the weather, recording the earthquakes, decoding DNA are some examples of the quest for patterns. Architecture since from Vitruvius search for order as a way to achieve strength, harmony, aesthetics. Different architectural styles with prominent features manifested in the façades, structural systems, ornaments, tiling, the use of materials and even spatial organizations can be considered as the examples of how patterns in architecture determine the design. Nature is always full of patterns inspiring all the disciplines and especially architecture in many ways. Currently, with the advances in technology and growing interest towards nature-driven studies, retrieving
information from nature has a new connotation in scales and dimensions such as molecules, organelles, cells, tissues, organs, and living beings, behavior, and ecosystem (Zari, 2010). In order to explore various dimensional patterns, nature reveals as an important model, mentor and measure in architecture (Benyus, 1997) both living beings and inanimate part of it as a whole. Since nature and architecture are different complex systems, finding patterns in nature which represent the ordered behavior is highly advantageous to transfer information to architectural domain. Moreover, locating the disordered behavior according to force and formation provides a valuable source to understand the adaptation of resultant patterns into changing conditions. Although this adaptation is mostly seen as an imperfection of the existing pattern, it is also possible to acknowledge it as a new kind of order with new symmetry rules and patterns.

In the scope of this study which is presented as a part of an ongoing Ph.D. research, it is aimed to explore nature in terms of new orders and resultant patterns. Then the discussion of the broadened reference domain towards a holistic one including both living and non-living beings is carried by focusing on abiotic nature as a source of information. In this respect case study is focused on the behavior of crystal formation which can be observed both in biotic and abiotic nature to understand the order generating the patterns in nature and its adaptation into different and changing environment. The information embedded in crystallization has great potential for architecture in terms of spatial structures, new materials and introducing a novel lattice for freeform structures.

**PATTERNS AND NATURE**

Nature has always been source of inspiration and information for science, mathematics, architecture, engineering, and arts. Among the information embedded in nature, symmetry and resultant patterns which reflect the ordered and disordered behaviors are prominent for these domains. Today, with the advents in technology and need for novel solutions for new challenging tasks like economic, environmental and social ones, researchers again gravitated towards nature with new tools and perspectives. Among these approaches, biomimetics is taking attention with its methods, tools and exemplary studies.

![Figure 1](url-1)

**Figure 1**
Flow systems in action: the delta of the Lena River in northern Siberia (left) and a cast of a human lung (right). (A. Bejan/Doubleday)
living nature’s aspects to survive and thrive on Earth is the only valuable strategy, although water, stars, air, and rocks are counted as important substances of “nature” (Biomimicry Institute, 2013).

As the Constructal Law introduced by Adrian Bejan claims that nature works with same physical laws both for animate and inanimate nature (Bejan & Zane, 2012), it is seen that both animate and inanimate nature reacts to forces of their environment in a similar manner which architecture is also seeking for. The exemplary study of Philip Ball shows that abiotic subjects have great potential to understand, analyze, predict and generate the built environment, and biotic and abiotic nature is not that much different from each other, and they form the ecosystem together (Ball, 1999). As it is shown in Figure 1, the generation and growth of geographical formations and our lungs behave similarly depending on the flow of water and air and this can be explained by Geometric Similarity which is one of the similarity types that can be established between two different scales. These similarities are described as “tree model” which is the non-dimensional pattern based on fractal branching according to the acting forces.

Learning from abiotic nature is not a new concept in architecture e.g. the hanging structural model of Antoni Gaudi and book of Bruno Taut describing a utopian city are still valuable examples showing the potentials of understanding the role of forces on the forms in architecture. In Taut’s unrealized drawings and explanations, a new city and architectural approach is proposed based on the geographical formations formed by the natural forces.

The drawings created between 1917 and 1920 shows the influence of inanimate nature in his works, also explains the crystal inspiration on Crystal Pavilion (1914) (Gomel & Weninger, 2004). Both the utopian drawings and the pavilion can be seen as the explorations of the influence of environmental forces both on nature and the architecture. Recently, Speck et.al. proposed “Geology” as “geo-derived development” and nature-derived development along with “Biology” as a source of information that have potential to contribute to design and engineering (Speck, et al., 2017).

Hence, in the scope of this study, it is aimed to broaden the extend of biomimetic studies by re-introducing inanimate nature and well-known natural forces with their lessons to be learned and adapted to architecture. Approaching nature through only living organisms is found to be underestimating the potentials of balance between animate and inanimate nature. It is also stated that inanimate nature along with natural forces has great potential for architecture, since the contemporary examples are seemed to be limited with formal approaches like biomorphic ones. Thus, comprehending the natural system as a whole with all or related relations and changes in time provides more information to architecture then acknowledging only one instance of a part.

It is a fact that each of the natural beings is a complex system showing “a complicated mix of ordered and disordered behavior” (Johnson, 2009). In understanding these complexities, patterns in different forms and scales serve as valuable tools to decode and recode information from one domain to

![Figure 2](url-2) (a) Cave of Crystals, found in Mexico (url-2), (b) Collage of protein crystals and viruses grown in space (Credits: NASA) (url-3), (c) Examples of Crystal structure of human DNA (Manvilla, et al., 2012)
In nature it is not a surprise to find geometrically well-defined patterns like hexagonal honeycombs, spiral seashells, branching fractals of trees and leafage, molecular distribution and lattice structures of crystals helping to define growth and generation. These patterns can be found in both two and three dimensions in different scales. In order to understand the order in complexity and relate it with architectural patterns, it is important to decode the existing symmetries and how the resultant patterns exist in different and changing environments with respect to forces and the existence of the being.

Hence, considering the importance of the tangible case studies in nature-driven research in architecture, in this study, the order of crystal structures is examined to retrieve information for architecture to learn from its adaptive capacity and order based on the symmetry groups and elements. Crystallization processes are chosen to understand the relation between different behaviors in different scales from nano to macro.

**CASE STUDY: CRYSTAL SYMMETRY AS A PATTERN**

Crystal formations are observed as an important example on how animate and inanimate nature should be taken into account in a holistic way. Crystallization process can be observed both in animate and inanimate nature as can be seen in crystal caves (Figure 2a), in proteins and viruses (Figure 2b) and in human DNA and RNA (Figure 2c). The crystallization process regulates the being’s growth, by either adapting itself to the changes of its environment or fitting to new ones which are also very prominent for adaptation.
Figure 4
Screenshot of the developed algorithm simulating the growth of crystals based on unitcell, growth rates, twinnings and defects. The algorithm is developed by the authors.
in architecture. In this vein, crystal polymorphism is a very appealing trait with its capability to adapt to various environments as well as preserving the inner order.

Although polymorphic crystals have different habits and costumes, the faces which grow as a response of the environment providing the efficient solution for the growth process will occur and the response of the environment based on crystal defects and growth rates based on the inner code of the crystal (Kang, et al., 2014). This code, which can also be interpreted as the genetic code of the crystal, regulates all the behavioral features of the crystal and can be explained by means of symmetry operations of the unit cell and the lattice structure (Bravais Lattice).

In this respect, to comprehend and provide an information for various levels of architecture, a computational model is developed based on the crystal class, metrics regarding the unit cell (lengths {a,b,c} and angles {alpha, beta and gamma}), growth rates of faces according to local axise. Then, the model is elaborated to generate a cluster with numerical data such as the number of crystals, and number of twin crystals if a twinning process is foreseen among the most common defects in crystals. Also, considering the unpredictable emergence location of initial crystallization, a randomization seed is included to illustrate some of the potential configurations. Spinel Crystal (Al2MgO4) is generated based on the Crystallography Information File (CIF) data retrieved from “crystallography.net”. One of the instances of the algorithm showing the process can be seen in the Figure 3.

As a result of aforementioned analysis and simulation, the potentials of crystal study are revealed with the adaptive features, the varied strength of 3-dimensional patterns, and force-driven formation. The outcome 3d spatial pattern based on a unit cell has great potential in terms of space filling, adaptation and structural behavior. Decoded and recoded pattern of Spinel crystal is shown in Figure 4.

The growth process of the crystals along with defects such as intergrowth and twinning are prominent in architecture with its unique characteristic of repetition of the 3d pattern while adapting into a different environment. The simple ordered pattern underlining the complex structure of crystals...
is important for architecture to comprehend and 3-dimensional tessellations which can evolve and grow in time. Also, various configurations of same atoms revealing varied patterns show quite different structural behavior, such as diamond and graphite. Structural simulations show that these configurations can also lead architecture to search for new 3-dimensional structural patterns.

NEW PATTERNS FOR ARCHITECTURE

Architecture can learn from form generation from nature and crystallization which is a process occur in any ordered matter is a prominent source. The idea of creating the form based on forces is not a recently developed idea, contrary it is being discussed in the last century which can be discussed on the quotation from D’Arcy Thompson: “Form is a diagram of forces.” (Thompson, 1917)

Therefore, the formation process of crystals which occur according to thermodynamic forces of the environment provides a valuable lesson regarding the force-form relationship to architecture. The information transferred from crystals can be mapped into many architectural scales i.e. materials, components, structural systems, buildings and building blocks etc. Transfer or information among different scales is a problematic process, especially all the thermodynamic reactions in nanoscale are completely different than macroscale. Therefore, there is a need for a common ground which defines the similarities between not only different scales, but also different knowledge domains namely crystallography and architecture.

CONCLUSION

This study constitutes the basis of a generic model in search of extreme architecture. The main challenge in this study is to associate disciplines (which are crystallography, chemistry, physics, mathematics, and architecture in this study) on a single case study. Thus, regarding the interdisciplinarity of the subject, a group of researchers from different fields are contributed to provide a model and a method. In the proposed model, crystal formation is explored in various scales which are exhibiting different behaviors yet, contributing the existence of crystal structure by adapting into different environmental forces and conditions. It shows that abiotic nature which is mostly disregarded in the current studies can guide architecture to exist in different conditions through the principles of emergence and growth of crystal structures. These principles are illustrated with the example of a spinel crystal which is a part of abiotic nature. Yet, it is possible to demonstrate similar behavior with a biotic example with respect to its own order and symmetry conditions.

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