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Computational Approach and Morphogenesis;

Role of nature in concept generation process in design and architecture

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Abstract: This article is discussing role of nature in architecture through morphogenesis using computational approach, it's locating biology, nature, chemistry, geology, crystallography, and material structures in an objective framework in the form-finding and concept generation process. on the one hand, it's presenting a deeper, dynamic inspiration source through the integration between architecture and biology. The micro scale of biology systems, in many cases play a macro significance in providing a proper functional and aesthetical solutions, by taking a closer look on material's formation of structure, tissues, or the differentiation and growth of the organs during developments.

Although, the article is clarifying and defining related terms of computation process in architecture, by presenting a general view over the benefits architects have received adopting the computational approach and digital tools in both the early stage of design process or in production phase. The article is representing a bridging between the computation of human brain, biological parameters and digital tools.

In addition, it will be presenting the masters adopted the morphogenesis approach in architecture around the world through the past decades and their attempts in the architectural field for improving early design process, and the developments a design can reach across the integration between pre-determined parameters and the primary expectations of human brain and imagination.

Keywords: Computational approach, form-finding, biology, concept generation, digital tools, morphogenesis,

Introduction:
In able to understand how did architecture met with biology under the shade of computational approach we need to define and trace these terms to highlight the spot of intersection as two completely separated disciplines. The computation as a term itself is a mathematical calculation for a specific operation, not only in design process but in any other field as well, and mathematical here is not limited in numbers but connected operations and components such as parameters, algorithms or any other necessary inputs, it's a way of thinking that can provide a variant solutions for a situated and identified issue to be solved. In our case, the computational approach is presenting the way of dealing with design process from a computation perspective "computational thinking" using nature with morphogenesis tools, methodologies and strategies, starting of the very early stage of concept generation and form-finding process until the production phase. But what exactly is morphogenesis?

Morphogenesis linguistically, is "the organ and development of morphological characteristic", which means the changes, formation, and the biological process that may be a reason behind a specific development of an organism or the way cells grow and organize. It's listed under patterns of life, which was discovered or released by biologists, biochemists, and embryologist.

In addition, Rudge and Haseloff, (2005) defined Morphogenesis in three different categories basing on their transformation and growth of tissues, these types are ***proliferation***, which has an architectural application by Tom Wiscombe, who designed "San Francisco Bus Terminal" using the logic of proliferation morphogenesis. Figure (1) the second type was ***coordinated growth***, then the last was ***cell lineage*** and positional information.

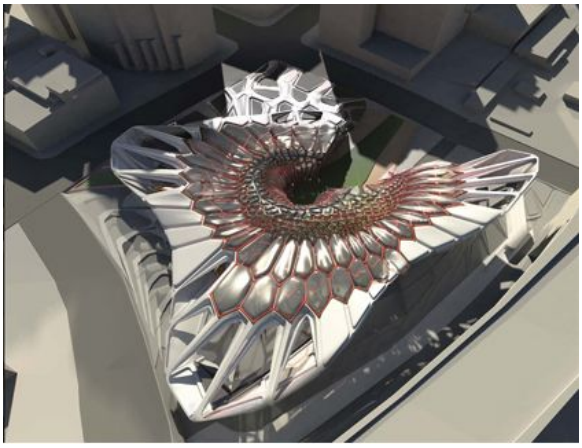

Figure 1. San Francisco's Bus Terminal is an Investigation on Parametric Design and Voronoi Algorithms.

The embryological text of Joseph Needham was one of the discussions that revolves morphogenesis in his publishing of "Biochemistry and morphogenesis" in 1950, In this publishing Joseph Needham defined Morphogenesis as "the process by which an organism acquired its characteristic form". In the 1952, a publishing with the title "Morphogenesis: an essay on development" was released by John Tyler Bonner, a biologist who had the studies of cellular slime molds, were he discussed the development and differentiation for variant organisms; searching for common process in their patterns of growth and development operations.

On the one hand, when taking a look at the educator, mathematician, and code-breaker in the second world war, Alan Turing, we can find an abstract illustration of the integration between morphogenesis and the computational approach in his life accomplishments; he published his first paper 1936 "seminal", which presented a prove of the impossibility of having a universal algorithm as a method of determining truth in mathematics, besides being a code-breaker he made a mathematical explanation for the patterns of animal's skins, when he assumed metaphorically that the skin is a white canvas were two different chemical component of the genetic cells spread on and compete, and the one with the higher hegemony wins and change the shape on the patterns. Turning, put this assumption into a mathematical frame work and wrote an algorithm for the skin pattern. Turning, through his professional career and his biography was completely believing that all surrounding operation issues already has a mathematical solve in nature itself through material's behavior.

Stanislav Roudavski (2009), also in somehow supported the same thinking of Turning, through his biological knowledge in architecture when he said: "architectural designing aims to resolve challenges that have often already been resolved by nature". As well as who supported that the morphogenetic design has the ability to coordinate between several functions through the morphogenetic intelligence that provide us with "ecological understanding of architecture".

Traditional design process vs. generative design process, digital computation approach**:**

Referring to the previously mentioned definition of morphogenesis, we can crystallize a relationship between morphogenesis and the generative design process. Generative process, is presented in a method that has a results gained through considering a set of rules or an algorithm, it's a form finding process that can mimic nature's evolutionary approach to design, and mostly such type of processes relay on computer usage and software as the production system that increase the quality of results and developing processes during design.

In fact, designers and architects has a noteworthy archive through the past few years in using nature as an inspiration source by doing analogies for nature systems and recalling cases, especially for aesthetic ideas and formal styles, or solving design issues. On the one hand, it used to be stated in two main engines as mentioned by (Herbert, Lionel March), these two engines are presented in one for generating the idea and the other for evaluating the extracted solutions.

The conventional "traditional" design process and design thinking methodology, always starts with accumulating the project data, understand it, then go for further investigations depending on the project's pre-identified needs, in able to build design concept and find the proper architectural form and solution. Such a node process has a prominent limitations manifested in the number and type of preserved solutions (El-Khaldi, 2007). Figure (2)

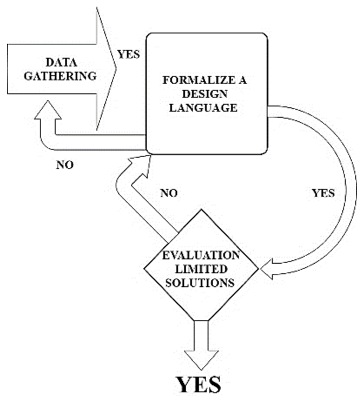

Figure 2. The traditional- computational morphogenetic process, simplified flow chart

Whereas, the computational approach using Morphogenesis sciences, during the analogical reasoning tends to escalate similarities instead of simplifying it, the computational approach is presenting an associative circle that push designers and engineers to use another level of cognitive thinking in able to formulate the issue and generate all possible solutions. But also, the authentic image for nature's systems need to be dragged under the microscope to understand types of relationships and processes complexity's in a simple formula, this formula can be developed to help designers during design process, and because nowadays our world's need to smart cities and sustainability is increasing speedily; digital tool occupied a significant role in developing design process. Figure (3)

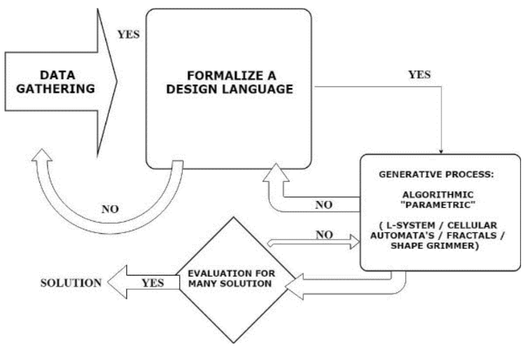

Figure 3. The digital- computational morphogenetic, generative process simplified flow chart

Although, as per other approaches, the digital-computational design process and tools have variant identifications referring to the framework of each one of the field's maters preferences. For instance, (Kotnik, 2010) in one of his publishing's about computable functions in digital architecture identified three levels of design computability namely, which is the representational, the parametric, and the algorithmic.

The representational level of the process is particulated in using digital computing tools for representation purposes only, in this level of functions the thinking form by using computer tools is not regarded as computational thinking, since that processes with computer tools in not necessary in every computational thinking, but in every digital computing process, computational thinking Is a main component.

On the one hand, the second level of digital computational design process by (Kotnik, 2010), parametric level, is associated with the praxis phase of the process as a conductor between various parts of design process, when the third level is Algorithmic level, which focus on the development and flow of the process and care about the logical sequence of the operations and data transfer.

Whereas, another classification method was released by (Oxman 2006), that categorized digital computational design process into five models, starting of the shallowest process into the most complex and integrated process as "CAD Model, Formation model, Generation Model, performance model and the last model was integrated-computational model". The generative model for Oxman is directly connected to the process of morphogenesis approach that involves interplay with intricate computational mechanisms of
form generation derived from principles of morphogenesis.

When (Kolarevic, 2000) had a totally different perspective of categories generated out of the conceptual content of the design processes into six products as:

- Topological architecture: in topological approach the light is spotted on the non-uniform rational B-spline process of controlling points and knots to achieve a coherent space, surface and curves.

- Isomorphic architecture: it's characterized of dynamic behaviors and usually present synthesis of variant irregular shapes and geometries.

- Animate architecture: and for animate approach it's more of a representational software medium than being a generative tool.

- Metamorphic architecture: in the metaphorical approach, it provides designers and architects of a wider ability of controlling geometries using variant techniques, including lattice deformation, key shape animation, and path animation.

- Evolutionary architecture: a design approach that express the procedure of testing and accelerating the architectural concepts and the generative tools that was previously imported to the system in able to be developed using computer models.

Eventually, the variation between the conventional and digital design process can be summarized in the process flow as one start point of the manual sketches or any initial conceptualized design drawings, as an input to solve a design issue, where both orientation runs their inspirations and recall solutions from a data base as the "thesaurus" that feed the design process in both orientations either in the conventional or the digital process, but the articular point that is presenting the substantial difference between the two orientations is located between extracting and recalling the data to initiate the concept sketches and refining design, in the conventional process, the initiated conceptualized sketches has a direct connection to the refining stage of design process, when the digital computational process branch to translating influential environmental forces and processes in able to generate and formulate the algorithm understanding for the entire design process, testing the inputs and to the informative draft, the draft that crosses other alternatives and processes, designer influence, and an evolutionary process.

The conventional and digital orientations meet up again in the design refining process with noteworthy gap between both according to the stages after, that which goes around the production and construction draft, and design details, where usually digital process's results record a further progress that the conventional process and more clear to the level of production stage.

Cases: Implementations of biology in architecture:

[1] The "Potato Beetle bug" pavilion:
In the ICD's "institute for computational design and construction" project of 2013/14 pavilion a novel design showed the actual meaning of digital morphogenesis in computational approach, it was presented by a cooperative team of students from multi-disciplines of biologists, paleontologists, architects and engineers. Figure (4)

The project took a year and a half of planning, manufacturing and constructing, and adopted the "bottom-up" design criteria, they created a pre-fabricated cells structure composite of natural fibers that was groomed over metal base, it was a reinforced polymer structure, and the fabrication process was mainly relied on two robotic arms for the grooming process work together at the same time.

Figure 4. The "Potato Beetle bug" pavilion, source: ICD/ITKE Research Pavilion 2013-14

The main aim behind the project or we can say, the tested issue in architecture and engineering was a geometry freedom with a light weight structure using double shell components. The biomimetic-morphogenesis inspiration of this pavilion was extracted from a deep analysis and simulations of the "Potato Beetle bug", they scanned the back shell of the organism and simulated micro computed tomography for the shell tissues "morphogenetic analysis", the analysis was extremely exquisite" analogical reasoning" for the structure layers of the organism's shells tissues formation , the deepest micro level of simulation generated the macro component of the pavilion's main structure. whereas, the growth of the organism's tissues inspired the fiber fabrication process as the covering material of the cells, using multi layers of glass fibers and carbon fibers applied by the robotic arms. Figure (5).

The pavilion ended up with a total weight of 593.9 KM, and a total area of 50.27 sqm, and consummated 58.54 KM of glass fiber, and 42.48 KM of carbon fiber.

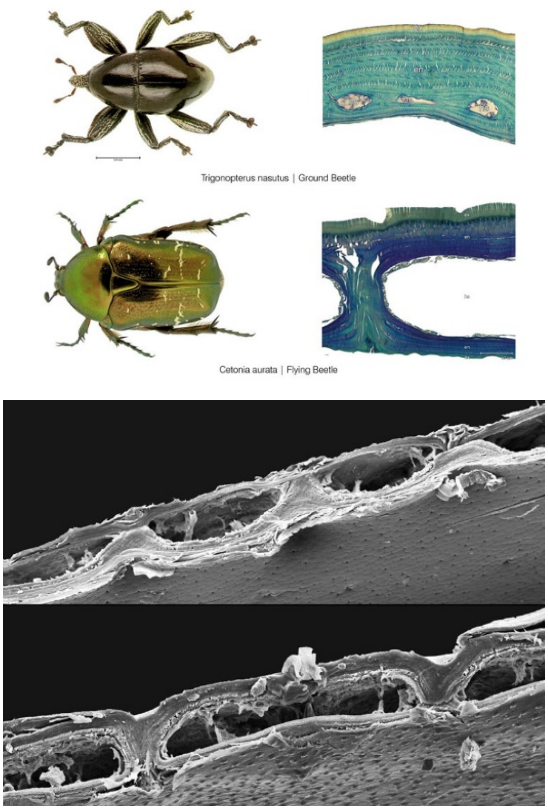

Figure 5. The "Potato Beetle bug" tissues analysis, source: ICD/ITKE Research Pavilion 2013-14

[2] Dublin landmark tower:
Dublin tower is a proposal for a competition that was designed by a cooperative team "Michael Hensel, Michael Weinstock, and Achim Menges" in 2003, they started the design process using the "seed" which is the primary inputs of the system and it was presented in a "tubular element" as the main component of the process, these tubular elements swept around a helix rout. This project obtained (T. Rudge's) classification types of morphogenesis, and developed under the proliferation subsequent.

On the one hand the planning process included the environment mathematical limits and dimensions of the competition site, and not to forget the forces that was applied to the geometry global level and produced variant forms.

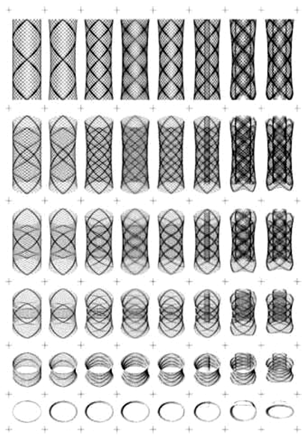

Figure 6. The Dublin landmark tower's evolutionary process

the received forms out of the testing simulating process was filtered depending on the selected orientation for development s through the evaluation process to what fits into the following process, the base and top flared and the waist that has the slightly narrowed dimension was selected, where the form taken into a geometry relaxing process using the rules of parallel construction planes and it was applied for both the inner and the outer shell of helices.

In this project the plant morphogenesis was the generative engine using digital mathematics extracted from nature and imported into the tessellated surface geometry testing algorithm of the "custard apple "that generated the differentiation of the parameters of the panels helped the panels adaptation.

[3] the lightness of being:
Frei Otto as one of the most significant pioneers in observing material behavior's in the nature and morphogenetic processes, thought of soap bubbles as a source of deep insights that provided a fully computational performance. Otto used to say that he might have built only a little on earth but he built hundreds of castles in the air since his soap bubbles inspiration recorder a noteworthy performance in providing a light weight structure, he also mentioned "houses which are two or three kilometers high and balls spanning several kilometers and covering a whole city, actually we have to ask what does it really makes? What do the society need?"

Otto used to obtain the principle of bubbles behaviors extracted from his observations and re-apply it through analogue modelling. It's presenting a sufficient explanation for having all needed processes, behaviors, scientific equations, and how to go direct to the point through your investigations to be able to focus on extracting the most professional results, and that was inspired by the one material of the soap bubbles using air It's absorbing the less amount of materials any process might need, but the ability to present a significant structure solution is not recording any decreasing signs, it motivates the concentrating on the direct relations through design process , and as Otto think less that act as much and fill the society needs is what we need for the future. Figure (7)

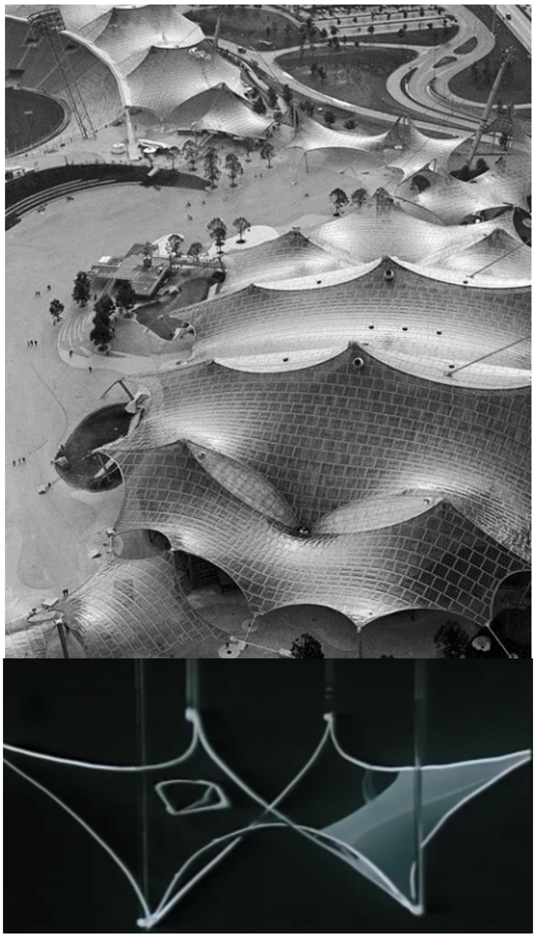

Figure 7. The Olympiapark, Munich lightness of being, Fri Otto's structures inspired by soap bubbles – source: revue Connaissances des arts

Conclusion:

The morphogenesis approach and the presented benefits of building nature knowledge and bridging it with the architectural field formulized an explicit module of dragging architects, engineers and designers to a completely different level of dealing with issues and design process itself, when relaying on computational thinking and a computational cognitive level, morphogenesis is presenting the infinity of inspiration sources by nature.

This paper aims to introduce the wide variations and orientations of integration between biology and architecture and how field's masters obtained different approaches and criteria but still nature phenomena's can fit differently in every situations referring to the architect or engineer who developed it and evaluating process

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