2.1. INTRODUCTION

This chapter presents an understanding of properties and attributes of nature and how they may be selectively transferred to digital design, while simultaneously speculating on the potential of digital technology and nature principles.

Additionally, It focuses on the process of thinking as a generative, biological design operation with a genetically driven process of living cells and subatomic forces meeting perceptual, remembered and imagined reality and thereby streaming spontaneous impressions, interpretations or visualizations as ideas within our biology of consciousness, with the help of the new cybernetic, globalization and digital technology.

From the formulation of the necessity of bonding design with nature, it could be concluded that nature produces design and architecture with the presence of digital technology especially in the concept of evolutionary architectural design, this will be studied in chapter 2 and 3 in details.

2.2. NATURE IN ARCHITECTURE

Nature does not have a design problem. People do. Instead of using nature as a mere tool for human purposes; however, we can strive to become tools of nature who serve its agenda. What would it mean to become, once again, native to Earth- the home of all our relations? Contemporary theories have recently proved that architecture has frequently drawn inspiration from nature, simply from its structure. This chapter will show the role of nature in architecture (Mcdonugh, W., Braungart, M., 2009)

2.2.1. Nature of the Analogy

Architecture has frequently drawn inspiration from nature, from its forms and structures, and recently, from the inner logic of its morphological processes. It is, therefore, necessary to be clear as to where architecture is literally considered a part of nature, where there are analogies or metaphors, and where nature is a source of inspiration.

It can be said that architecture is literally a part of nature in the sense that the man-made environment is now a major part of the global eco-system. Man and nature share the same resources for building. In turn, our description of an architectural concept in coded form is analogous to the genetic code script of nature.

2.2.2. Inspired Expressions From Nature to Architecture

Nature plays an important role in many architectural concepts. The following forms of architectural design vary with regard to their adherence to many definitions yet they all share a desire to derive architectural incentive from nature.

- Evolutionary Architecture – *"...an all-encompassing applied philosophy based upon the profound study of nature's processes, organisms, structures and materials at a multitude of levels, from sub atomic particles to the kinesiology of insect and animal anatomy, to the ecological relationships of living habitats, and then applies this knowledge to the design and construction of our built environment."* (Tsui, 1999)

- Organic Architecture – *"...exalting the simple laws of common sense—or of super-sense if you prefer—determining form by way of the nature of materials..."* (Wright, An organic architecture:The Architecture of Democracy, 1939)

- Anthroposophy Architecture – *"…which seeks to respond to the human form and human needs [where] buildings should appear in harmony with the landscape in which they are built, with regard to both form and material."* (Pearson, 2001)
- Bio–Mimicry [From the Greek bios, life, and mimesis, imitation] The emulation or imitation of natural forms, structures and systems [in design and construction] that have proven to be optimized in terms of efficiency as a means to an end. (Benyus, 1997)

2.3. GENERAL PRINCIPLES USED IN NATURE DESIGN

There are a number of methods from which the principles of the environment examination strategy is derived. See figure (2-1)

Figure (2- 1):Diagram presenting the general principles used in nature
Source: Researcher 2014

2.3.1. A direct method

A direct method of investigation, which actively seeks to define the nature of the design problem and the context of its creation and use, with a clear understanding of the design requirements it is then possible to look to the natural world for examples that fulfill them. It is useful to investigate an array of divergent organisms that rely on different approaches to solve similar problems. This will yield a greater variety of ideas with which to develop structural solutions. (Benyus, 2004)

2.3.2. An Indirect Method

An indirect method of investigation seeks to find solutions through defining the general principles of natural design and using those as guidelines for developmental progression. While it is difficult to effectively categorize the entire collection of natural designs into discrete units there arise recurring principles.

Through these methods some principles are highlighted which form a coherent strategy for investigation by which nature can inform the development of technology and architectural design these principles are: (Benyus, 2004)

2.3.2.1. Emergence

"Ecosystems are diverse in components, relationships and information" relationships are complex and operate in various hierarchies, and emergent effects tend to occur. The evolution of all the multiple variations of biological form should not be thought of as separate from their structure and materials. It is the complex hierarchies of materials within natural structures from which their performance emerges. Form, structure and material act upon one another, and the behavior of all three acting on each other cannot be predicted by analysis of any one of them alone

2.3.2.2. Materials as Systems

Nature builds from small to large with a corresponding scaling of function in relation to the materials and components involved for particular functions.

2.3.2.3. Self-Assembly and Self-Organization

The self-organization processes underlying the growth of living organisms can provide important lessons for architects. Natural systems display higher-level integration and functionality evolving from a dynamic feedback relation with a specific host environment. Colored X-ray of hyacinth flowers at different stages of growth, environmentally sensitive growth can deliver a paradigm for architectural design as shown in the below figure (2-2).

Figure (2- 2): The ability of an organism to direct its own process of development.
Source: AD Journal, Volume 76 no.4, 2006.

2.3.2.4. The Power of Shape

Nature uses many structurally efficient non-orthogonal forms with which to create its structures.

2.3.2.5. Energy savvy movement and transport

Locomotion and internal circulation systems have adapted to require a minimal investment of energy for their purpose.

2.3.2.6. Resilience and Healing

Living organisms have the ability to absorb and rebound from impacts and can repair themselves if damage is incurred.

2.3.2.7. Natural selection as an innovative engine

Environmental forces that act on an organism and affect its fitness will direct the development of future organisms.

2.3.2.8. Material Recycling

Create structures using materials that are non-toxic and can be fully recycled at the end of their life.

2.3.2.9. Evolution

Nature's complex forms and systems arise from evolutionary processes. Living forms grow, and growth is a complex process intertwining contributions of the genotype with the variable contributions of environment and phenotypic dependencies. See figure (2-3)

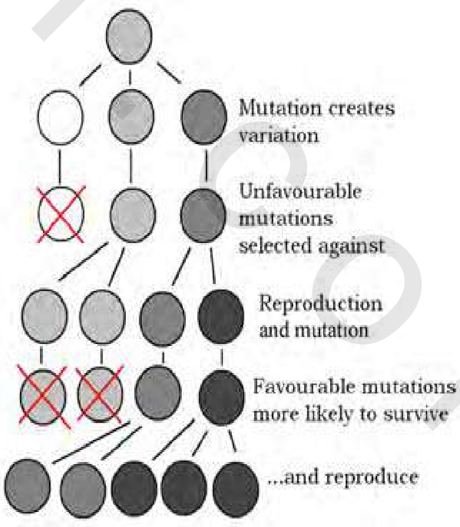


Figure (2- 3):Mutation & Selection diagram of natural evolution
Source: www.wikipedia.org

2.3.2.10. Adaptation, Sensing and Responding

A series of feedback systems within an organism allow it to sense a variety of environmental factors acting on it and to respond to these in a suitable manner.

2.3.2.11. Solar Transformations

Many organisms respond actively to the sun to maximize their energy absorption. See figure (2-4).

Figure (2- 4): Sun flower solar transformation concept
Source: (Benyus, 2004)

2.3.2.12. Chemistry specially in Water H2O

Nature produces all of its compounds in normal environmental conditions without a necessity for extreme temperatures or harsh chemicals. See figure (2-5).

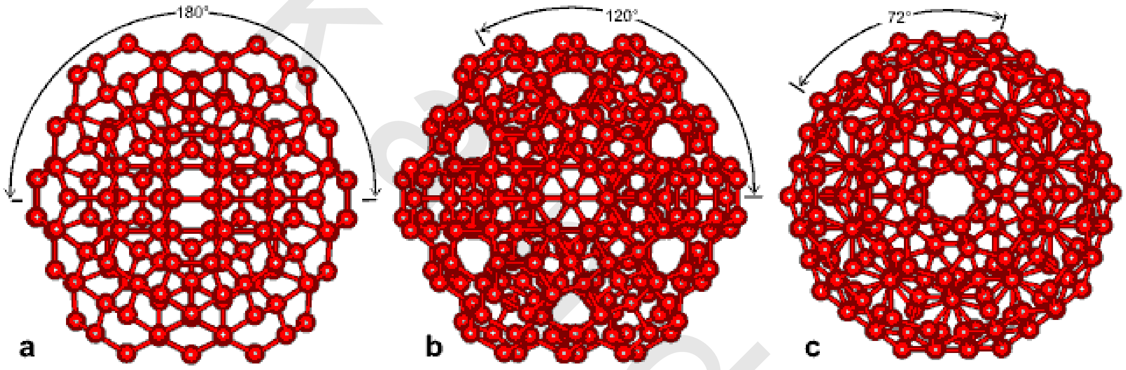


Figure (2- 5): Representative views of one of the 15 two-fold rotation axes of co2 (C2, a), one of the 10 three-fold rotation axes (C3, b) and one of the 6 five-fold rotation axes (C5, c); only the oxygen atoms of the constituent water molecules are shown for interactive structures
Source: (Benyus, 2004)

2.3.2.13. Ecosystems

Systems are created that have a net surplus of production without a corresponding drawdown of environmental resources.

2.4. DIGITAL TECHNOLOGIES IN ARCHITECTURE

Similar to other fields invaded by modern technology, architecture has its share of influential factors that guide and enlighten its approaches.

Fundamental knowledge of new terminologies

A wide range of digital technology has been utilized as part of a new medium that aids the methods of architecture. Multidimensional as well as digital technology such as 3d modeling software, generative systems/algorithms and CAD/CAM fabrication are also contributing to the changes. These changes produce new aspects, factors, new terminologies and approaches in architecture; with reference to these issues the research will be investigated (Benyus, 2004)

2.4.1. Globalization

In its literal sense is the process of transformation of local or regional phenomena into global ones. It can be described as a process by which the people of the world are unified into a single society and function together. This process is a combination of economic, technological, social, cultural and political forces.

Globalization is often used to refer to economic globalization that is integration of national economies into the international economy through trade, foreign direct investment, capital flows, migration, and spread of technology. (Robertson, 2000)

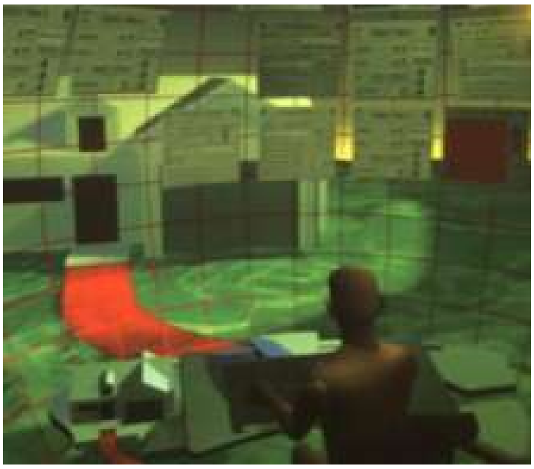


Figure (2- 6): Cyber space
Source: (Robertson, 2000)

2.4.2. Technology

Technology is a broad concept that deals with an animal species usage and knowledge of tools and crafts, and how it affects an animal species ability to control and adapt to its environment. However "technology" can refer to material objects of use to humanity, such as machines, hardware or utensils, but can also encompass broader themes, including systems, methods of organization, and techniques. The term can either be applied generally or to specific areas: examples include "construction technology", "medical technology", or "state-of-the-art technology". (Borhmann, 2006)

2.4.3. Cybernetics (cyberspace-cyber society-cyber world)

Originally the world "cybernetics" is associated with the study of control and communication in living and artificial made systems. The word itself come Greek word which means 'to govern'. In the latest developments there are separated disciplines like artificial intelligence, neural networks, systems theory, and chaos theory, but the boundaries between those and cybernetics has not yet been properly defined. (Pulli, 2003)

Many terms associated with cybernetics as cyberspace, cyber society and cyber world, cyberspace term now has become a conventional means to describe anything associated with computers, information technology, the internet and the diverse internet culture. See figure (Benedikt, 1991)

Cyber society is a society where computerized information transfer and where the normal functioning of this society is severely degraded or totally impossible if the computerized systems no longer function correctly. It is an advanced form of human-computer interaction. (Lorents, 2009)

While for cyber world the word "cyber" is associated with the world of intra-communication and networked devices, a world of advanced technology used for a better human interaction and information. Cyber world can be defined as a virtual world, a parallel world created and sustained by the computer's world. In the cyber world we can stay in touch with our agents, knowledge databases, communities, and use electronic services and transactions. (Pulli, 2003)

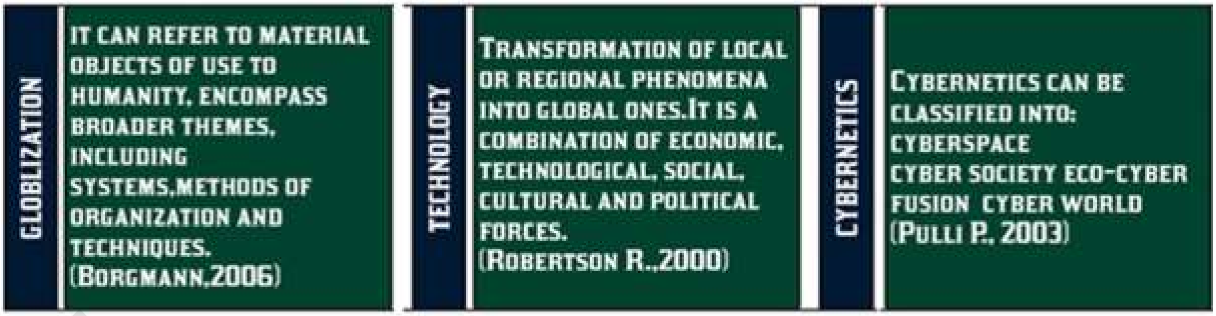


Figure (2- 7): Digital terminologies
Source: Researcher 2014

As a result of the presence of these fundamental terminologies and without the rapid evolution of the computer and its ways of processing and keeping check on large amounts of data, none of these new fields would be possible, all these fields had developed the Digital Architecture's revolution with its all new applications and approaches, digital architecture will be briefly defined then we will be introduces to the different approaches of digital architecture which will be demonstrated in the following paragraphs.

2.5. DIGITAL ARCHITECTURE

One of the definitions of digital architecture, used in my research, originates from Rijsenbrij. He defines digital architecture as:

> *'A coherent, consistent collection of principles, particularized into rules, guidelines, and standards which describe how an enterprise, the information supply, the applications, and the infrastructure are shaped and behave in their usage.'* (Rijsenbrij, 2004)

These principles can be reviewed as: principles are guiding statements for the purpose of essential decisions. They consist of a fundamental idea meant to fulfill a general requirement. Architecture principles find their origin in the mission statement, the vision and the chosen competition strategy of the organization as well as from the environment. Moreover they must fit the intended culture of the surrounding world. (Rijsenbrij, 2004)

2.5.1. Digital Thinking

The computer has gone from being an isolated box to become a part of a gigantic digital network of networks, which shapes our collective future. The way and pace at which we connect, communicate, memorize, imagine and control the flows of valuable information have changed forever. Consequently, the built world's role, importance and nature have changed. Architecture as traditionally understood has become more marginalized than before. Many practices, however, have been repositioning themselves to take advantage of the new opportunities. Design, practice, fabrication and construction are increasingly becoming networked affairs. Consequently the architecture of a new world needs to recognize the transformations and the think differently (Bermudez, klinger, 2003)

2.5.2. Digital Design

Describing design as a sequence of steps cannot convey the complexity of social interactions that it embodies. Design is not merely a process, but a co-evolution of efforts and events in various places and times -both synchronous and asynchronous. Digital design is described as hybrids: hybrids that integrate virtual and physical space. In these integrations, designers use overlapping physical and virtual artifacts and tools to arrive at a co-operative design resolution. Within collaborative design, these artifacts take on an additional role. As embodiments of design ideas and actions, they become media for communication.

Donald Schon asserts that design should be considered a form of making, rather than primarily a form of problem solving, information processing or research. The technologies for this already exist in collaborative tools, networked computing, scanning and immersive media. (Bermudez, klinger, 2003)

The term digital design system, according to our definition implies the digital integration of attributes related to morphology + structure + behavior of certain morphological-geometric classes of material form. (Ali, Brebbia, 2006)

Therefore digital design is defined by design methods that are driven by an occupation with computability, the characterization of digital design relay on the form of design thinking rather the form of presentation. (kotnic, 2007)

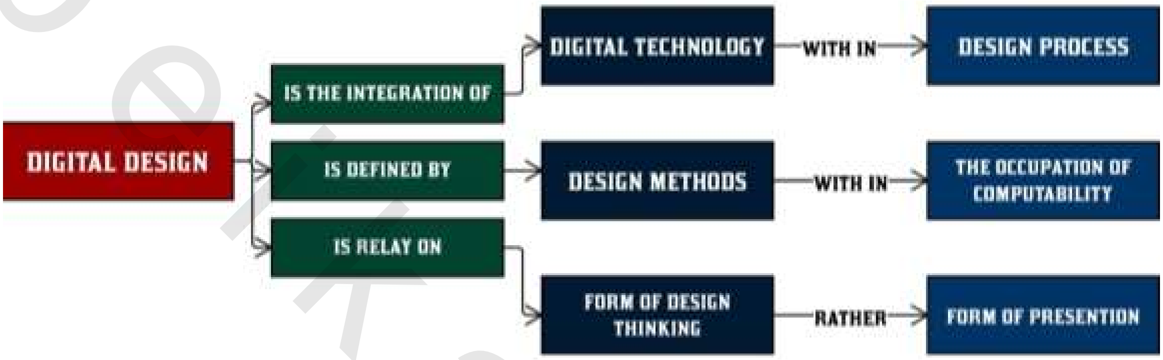


Figure (2- 8): Digital design definition
Source: Researcher 2014

2.5.3. Computer and Technology Representation in Digital Design

As digital technologies and connective systems begin to redefine traditional notions of place, space and time, Architecture itself transformed. Over the past century, extreme conceptual and spatial transformations have come about in relation to the introduction of mechanical reproduction, computer graphics and redundant systems. However, Architecture and representation have remained somewhat constant.

This is evident in the continuity of traditional architectural representation methods that draw primarily from Renaissance models though the original impetus from which such projection methods evolved no longer bear the same significance to culture. (Norma, 2003)

The use of computers in the design process started more than 4 decades ago and has been widely researched and discussed meanwhile. The first use of a computer to generate an architectural representation for appraisal was in 1966 (Kolarevic, 2004). One of the first tools for digital performance analysis was developed in 1973 (Maver, 2000)Further development of computer technology, computing power and the emerging of a new kind of architecture evolved which will be reviewed in the following lines.

2.5.4. Evolved Approaches on Understanding the Role of Computers in Design Process

Development of computer technology, computing power and the emerging of a new kind of architecture evolved in two different, but not always very distinguished approaches on understanding the role of computers in the design process which are:

A first approach reduces the use of computers to a simple design tool with the main intention to speed up the design and development process and in some way substitute the human designer in those tasks which are repetitive and cumbersome.

Drafting and modeling software are examples of the use of computational power replacing traditional means (pencil and paper) but without fundamentally changing the task of drafting or modeling. It is still the designer who has to give detailed instructions. In the same spirit the computer has also been used to assist the designer in predetermined tasks such as calculating complex geometrical operations. (Kalay, 2006)

Another approach is the use of computers as a medium. This implies that the computer assists the designer in the creative process, providing him with a new understanding of the design problem by presenting unexpected solutions, such as illustrated by the use of morphogenetic design (Hensel, Menges, Weinstock, 2006). It is this approach, which is of more interest for designers, and it is this search for the role of computer technology in design, which will lead to other and different solutions in contemporary design and architectural design. This approach is the most applied in this research.

2.5.5. Practical Research in Applied Applications in Digital Design

Computer processing power capacities have improved significantly in the last decade and have become at the same time affordable for any individual designer. A lot of different software applications which can assist the designer in almost every task. Some of these applications which are used in the design process are: Performance based application, generative applications, optimization applications and simulation which will be studied in the following lines and will be used in this research. (Augenbroe, 2004)

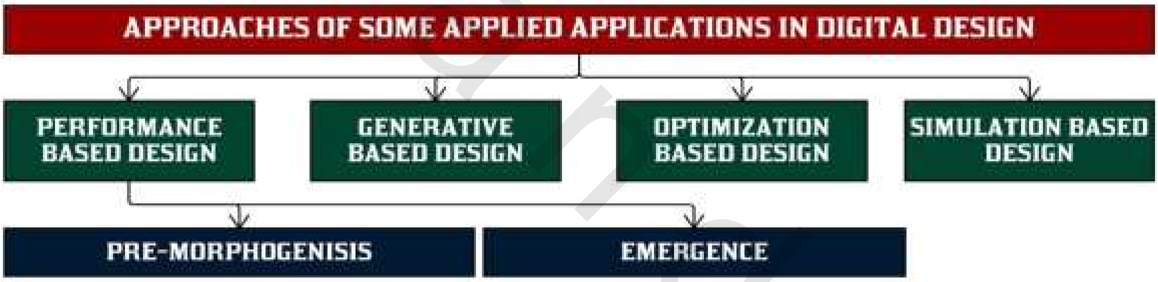


Figure (2- 9): Approaches of some applied applications in digital design
Source: Researcher 2014

2.5.5.1. Performance Based Design

Performance based design is an applied approach in which certain qualitative and measurable objectives are the guiding principles of the design process. In architectural design this may be defined as the exploitation of building performance simulation for the modification of geometrical form towards a predefined objective. Per formative design is thus an alternative approach for designing where form, material, structure and performance are understood as inherently related and an integral part of the design process. (Oxman N. , 2006)

A- Per-formative Morphogenesis

Performance-oriented design is at the basis of a fully developed paradigm that combines different holistic and integrated processes and aspires to be the design solution for an alternative model for sustainable development. It is this holistic integration of evaluative simulation with digital form generation and modification which is at the core of what is generally known as per-formative design. (Oxman R. , 2008)Within the framework of a digital design this process of “form finding” is also called **“per-formative morphogenesis”** (Oxman N. , 2006). This is directly related to the notion of morphogenesis. During the last decade the idea of morphogenesis has been the main driver for the development of many architectural projects.

Since 2003 Achim Menges and Michael Hensel have been researching the intricate relations between morphology and environment with the development of material systems for form finding coupled to environmental performance. They have called their approach “Morpho-Ecologies”, and describe it as a correlation between morphogenesis and ecology, rooted within a biological paradigm, and concerned with issues of higher-level functionality and performance capacity (Hensel, Menges, 2007). Those material systems are used as the main generative drivers in the design process of a complex polymorphic systems based on input and feedback relations.

B- Emergence

Performance based design is also closely related to a specific process of form finding based on the principles of emergence, Emergence has been defined as “the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems” (Goldstein, 1999), but emergence has to be understood as a “descriptive term pointing to the patterns, structures, or properties that are exhibited on the macro-level” (Goldstein, 1999)The concept of emergence has been widely explored in the form finding process in architectural design. It is a process of exploration of the solution space by turning implicit form, explicit. This way it can suggest new forms and possible conceptual directions. See figure (2-10) (Goldstein, 1999)

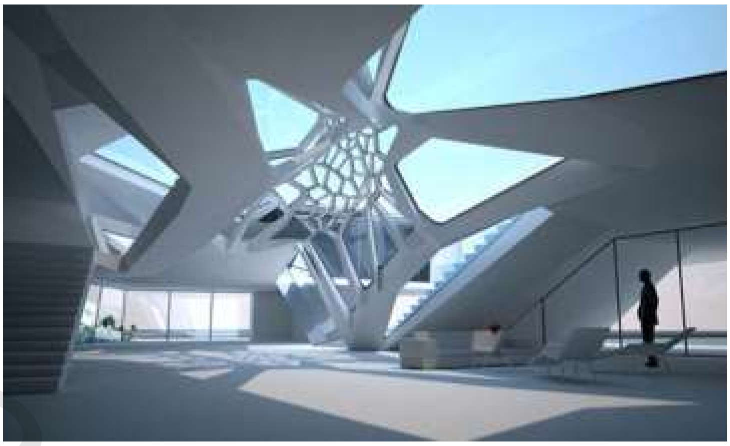


Figure (2- 10): Emergence in Form Finding: Cell House by Tom Wiscombe
Source: Goldstein, 1999

2.5.5.2. Generative Based Design

Generative design is yet another and different approach in form finding applied specifically in architectural design. Frazer was one of the first architects who applied the concept of generation and he pioneered a design process where architectural form is developed based on code that contains detailed instructions about the generation of the form (Frazer, 1995). The results (Fig2-10) of this process are visual representations which are evaluated on encoded selection criteria. Similar methods, based on this pioneering work are still further researched, refined and adapted. One such example is the research by (Janssen, 2006) into team based design development of buildings based on an orthogonal grid. With this generative evolutionary design method Janssen demonstrates the design of complex, intelligible and unpredictable three dimensional buildings.

Figure (2- 11): Inter activator: Networked Evolutionary Design System
Source: Fraser, 1995

Generative systems are an essential part of the future development of per-formative architectural systems where evolutionary principals are applied in the initial stages of the design process with the intent to automate and intensify explorative research.

2.5.5.3. Optimization Based Design

Ever since the very beginning of the use of computers in the design process, optimization has been used in every design field with the sole purpose of finding a "best" solution in relation to a set of previously defined performance requirements and optimization is understood as the process or methodology to make something as perfect, as efficient or effective as possible. This is also how optimization is defined (Merriam, 2003)and how it is understood and accepted among researchers in different fields (Rao, 2009)Radford and Gero state:

> *"Optimization models effectively search the whole field of feasible solutions and identify those best suited to the designer's stated goals. Thus, optimization directly approaches an answer to the designer's fundamental question of what is the best solution".*

Recent development of readily available computer technology and successful research in the mathematical tools and techniques for optimization allowed for new and different approaches to design. While traditionally design was a cyclical process of analysis, synthesis and evaluation where the designer simultaneously learns about the problem and the range of possible solutions, design by optimization uses decision making algorithms in order to generate prescriptive information on the nature of an optimal solution satisfying initially specified objectives and within previously specified boundaries. Design by optimization, as is proposed in this thesis, offers the potential for better design by considering a much broader solution space searching for eventual serendipity.

2.5.5.4. Simulation Based Design

Simulation is the imitative experimental modeling or representation of the functioning of a system or process by means of the functioning in another, mostly computer based system. Simulation enables researchers and designers to preview and evaluate systematically how effectively a proposed solution corresponds to prevailing boundary conditions and requirements. Sometimes simulation is applied, before the detailing phase, but most of the time simulation provides information and confirmation during the detailed development of the project.

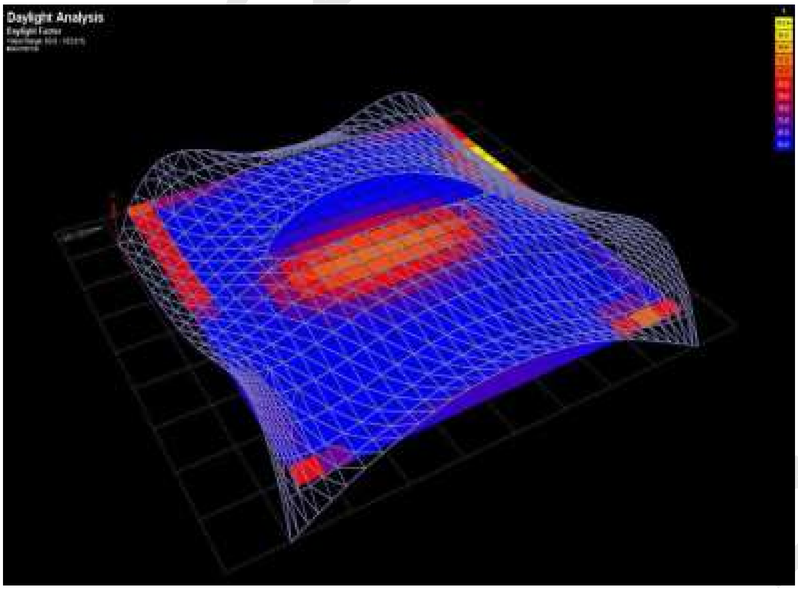


Figure (2- 12): Example of tested Daylight simulation Analysis: can now support the design process by offering a better understanding of the behavior of the designed object in the future physical world, in Autodesk Ecotect 2011.
Source: Merriam Websters, 2003

Computational simulation can also reduce or even overcome limiting constraints of testing in the physical world and can investigate systems which are too complex to be understood by simple analytical reasoning. It can also describe a system's behavior and show its spatial properties. In this way it can be used as representation and as a tool for communication, which is very important since most of the time the amount and the structure of the data is much too rich or not suitable for simple verbal communication. See figure (2-12). (Augenbroe, 2004 ; Schwede, 2006 ; Merriam Websters, 2003)

2.6. APPROACHES OF DIGITAL DESIGN

Digital technologies have many concepts in the architecture which can be considered as a new tool, new theory, new age and a revolution according to its duration and integration of design process; architects are increasingly using computers to generate 2d and 3d drawings in the design process. They use a computer not only to represent the final product but also to explore architectural form during the schematic phase of design. They survey some different approaches in which architects use the computers to find a building form in contemporary architectural design.

So several digital designs are identified based on the underlying computational approaches to be: (Kotnik, 2008 – kolarevic, 2000 – riekstins, 2011)

- Topological space modeling (Topological design)
- Isomorphic surfaces design (Isomorphic design)
- Motion Kinematics and dynamics, integrated urban planning and architecture Animate.(Animate design)
- Metamorphic architecture design
- Parametric design (Parametric architecture)
- Evolutionary computing design (Evolutionary design)
  - A-Parametric Evolutionary Design (Algorithms)
  - B-Generative Evolutionary Design (Genetic and Bio digital design

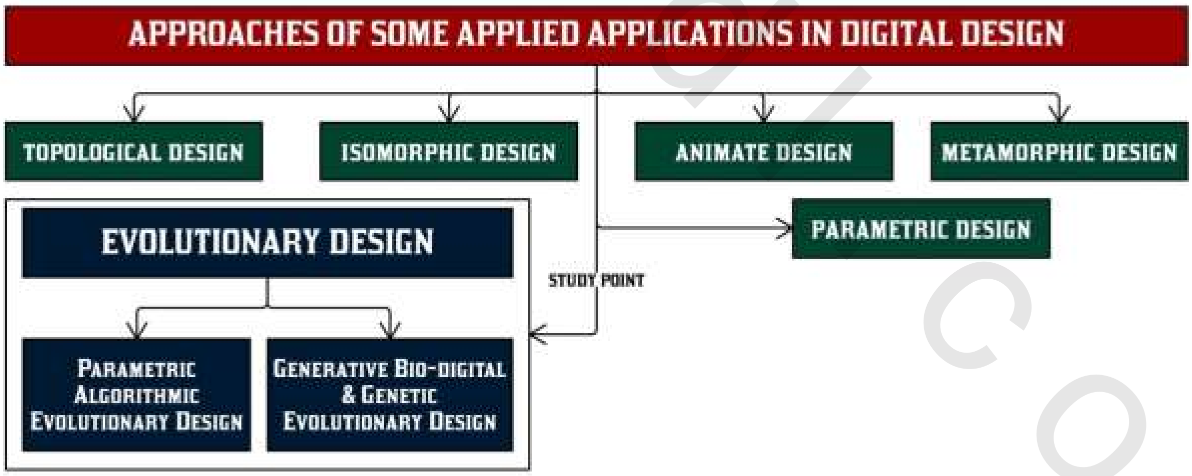


Figure (2- 13): Digital architectural approaches during the computational phases of design process
Source: Researcher 2014

2.6.1. Topological Space Modeling (Topological Design)

In "architecture curve linearity" Greg Lynn offers examples of new approaches to design that move away from deconstractivism's" logic of conflict and contradiction" to develop a "more third logic of connectivity" this manifested through folding that departs from Euclidean geometry of discrete volumes, it employs topological, "rubber-sheet" geometry of continuous curves and surfaces. (Kolarevic, 2001)

In topological space, geometry is represented by parametric functions, which describe a range of possibilities. The continuous, highly curvilinear surfaces are mathematically described as NURBS – Non Uniform Rational B-Sp lines. What makes NURBS curves and surfaces particularly appealing is the ability to easily control their shape by manipulating the control points, weights and knots. NURBS make the heterogeneous and coherent forms of the topological space computationally possible. See figure (2-14)

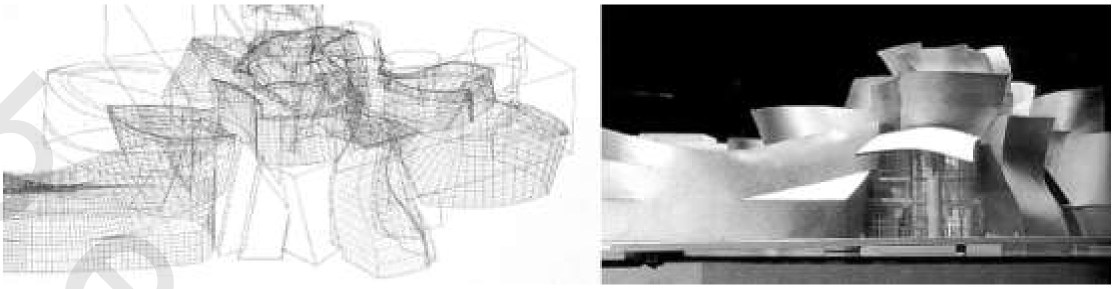


Figure (2- 14): Figure Topological architecture: Gehry's Guggenheim Museum in Bilbao.
Source: Kolarevic, 2001

2.6.2. Isomorphic Surfaces Design (Isomorphic design)

Isomorphic surfaces represent another point of departure from the Euclidean geometry and the Cartesian space. Blobs or meta-balls, as isomorphic surfaces are sometimes called: amorphous objects constructed as composite assemblages of mutually inflecting parametric objects with internal forces of mass and attraction. They exercise fields or regions of influence, which could be additive (positive) or subtractive (negative).

The geometry is constructed by computing a surface at which the composite field has the same intensity. Objects interact with each other instead of just occupying space; they become connected through logic where the whole is always open to variation as new blobs (fields of influence) are added or new relations made, creating new possibilities. (Kolarevic, 2001)

Based on the exercised forces the transformation and interaction of the objects are defined correspondingly. The blobs (fields of influence) may be numerous and the whole is modified according to their intensity and location; the outcome is characterized by a dynamic behavior. See Figure (2-15) (Kolarevic, 2000)

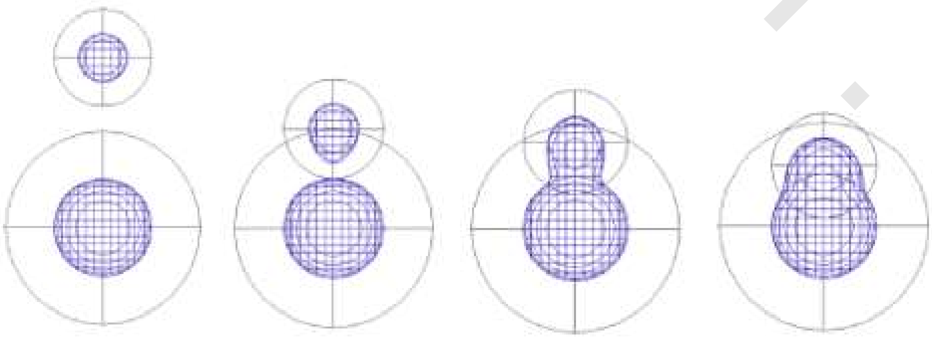


Figure (2- 15): Bernard Franken's ''Bubble'' BMW Pavilion – isomorphic surface Source: Kolarevic, 2000

2.6.3. Motion Kinematics and dynamics, integrated urban planning and architecture (Animate design)

Animation software is utilized as medium of form – generation. Animate design is defined by the co-presence of motion and force at the moment of formal conception. Force, as an initial condition, becomes the cause of both motion and particular inflections of a form. While motion implies movement and action, animation implies evolution of a form and it's shaping force. The repertoire of motion-based modeling techniques are key frame animation, forward and inverse kinematics, dynamics (force fields) and particle emission.
Kinematics are used in their true mechanical meaning to study the motion of an object or a hierarchical system of objects without consideration given to its mass or the force acting on it. Dynamic simulations take into consideration the effects of forces on the motion of an object or a system of objects, especially of forces that don't originate within the system itself. Physical properties of objects, such as mass (density), elasticity, static and kinetic friction (roughness), are defined. Forces of gravity, wind and vortex are applied, collision detection and obstacles (deflectors) are specified, and dynamic simulation computed. See figure (2-16) (Kolarevic, 2010)

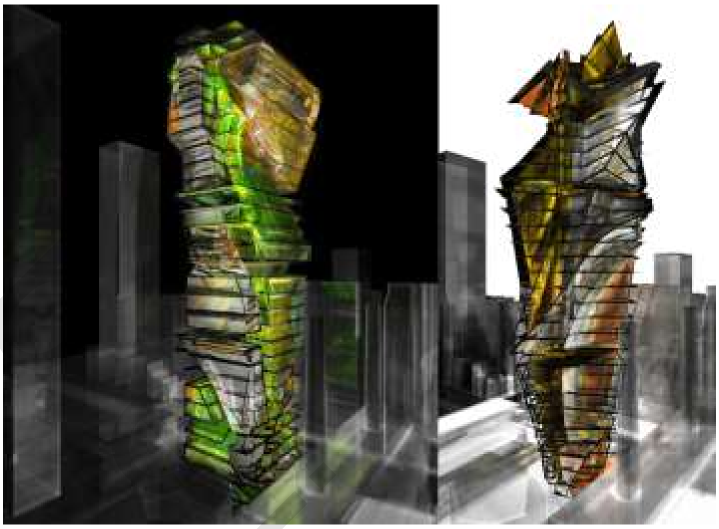
Figure (2- 16): Greg Lynn's design of a protective roof and a lighting scheme for the bus terminal in New York
Source: (Kolarevic, 2010)

2.6.4. Metamorphic Architecture Design

The morphology manipulation, according to the metamorphic approach can be controlled through various modeling techniques such as key shape animation, morphing, path animation etc. In key shape animation, several transformative stages of the object are recorded and thereupon, computed through interpolation, in order to create the animated transition from one stage to another. In morphing, divergent forms are mingled in order to generate new hybrid instances which compound formal properties of the initial forms. In path animation, the objects are being transformed as they conform to the changes in the geometry defined by a specified path (Kolarevic, 2005)

Figure(2- 17): Design alternatives for the mass housing in New York by Kolatan Macdonald.
Source: Kolarevic, 2005

2.6.5. Parametric Design (Parametric Architecture)



The outcome of this approach depends on the parameters that acquire values assigned by the designer. The parameters are employed within equations that control the interdependencies of the objects. Hence, the parametric design defines an associative geometry whose final product is differentiated according to the values assigned. See figure (2-18)

Figure(2- 18): For a parametric design approach examples: a/b- permutations by Michael Hansmeyer c- parametric tensile canopy d-tower form optimization structure e- parametric street footbridge
Source: Kolarevic, 2005

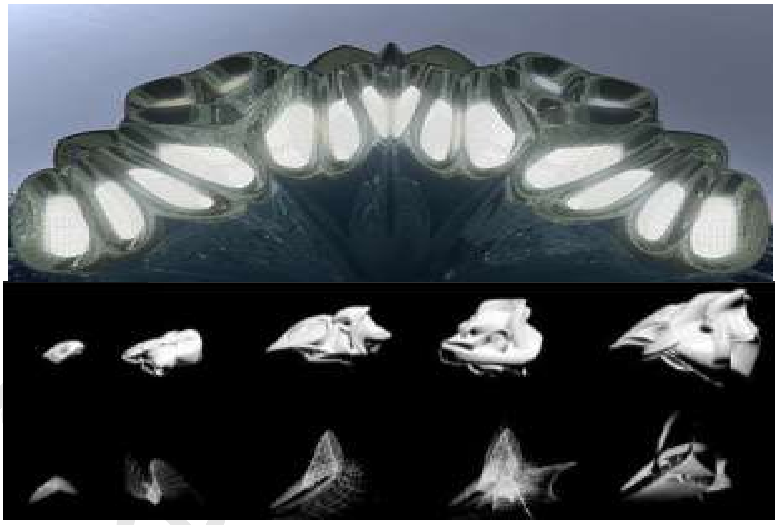
2.6.6. Evolutionary Computing Design (Evolutionary Architecture)

Evolutionary architecture proposes the evolutionary model of nature as "*the generative process for architectural form*" (Frazer, 1995). Concepts are described in a genetic language which produces a code script of instructions for form generation. Architectural concepts are expressed as generative rules so that their evolution and development can be accelerated and tested by the use of computer models which are used to simulate the development of prototypical forms which are then evaluated on the basis of their performance in a simulated environment. Very large numbers of evolutionary steps can be generated in a short space of time and the emergent forms are often unexpected that can generate many design concepts. (Kolarevic, 2010)

The key concept behind evolutionary architecture is that of the genetic algorithms. The key characteristic is a string like structure equivalent to the chromosomes of nature, to which the rules of reproduction and mutation are applied. Optimum solutions are obtained by small incremental changes over several generations. Moreover there are two main types of evolutionary design, and they are discussed in the following lines:

2.6.6.1. Generative Bio-digital and Genetic Evolutionary Design (Genetic and Bio digital Design Concepts)

The generative evolutionary design is created that uses information in the genotype to generate alternative design models. This process consists of a rule-based growth procedure that is capable of generating design alternatives that vary significantly from one another. Such systems are sometimes described as "divergent systems", "exploration systems" or "synthesis systems". The rules that direct the genesis of living organisms, that generate their form, are encoded in the strands of DNA. Variation within the same species is achieved through gene crossover and mutation, through the interactive exchange and change of information that governs the biological morphogenesis. The combination of the generative concept seeding approach with the evolutionary approach result in a new type of design method . See figure (2-19) (Janssen, 2006) (Speed, 2007)



Figure(2- 19): Evolutionary model of generative bio-digital and genetics by Manit Rastogi, Peter Graham and John Frazer, Globally evolving virtual environment 1994.
Source: Janssen, 2006

2.6.6.2. Parametric Algorithmic Evolutionary Design (Algorithms)

A design is predefined and parts that require improvement are parameterized. The evolutionary system is then used to evolve these parameters depending on computer software. Computer software creates space and form of a rule-based logic of the architecture algorithmic programs, typologies, building codes.

Parametric evolution through algorithmic logic is not to push out the traditional "manual" methods, but to combine computer-based complexity and creativity of computer architects algorithmic design to solve structural and design problems. It allows the designer to combine the two roles unique properties the human mind and computing capabilities. (Janssen, 2006) (Speed, 2007)

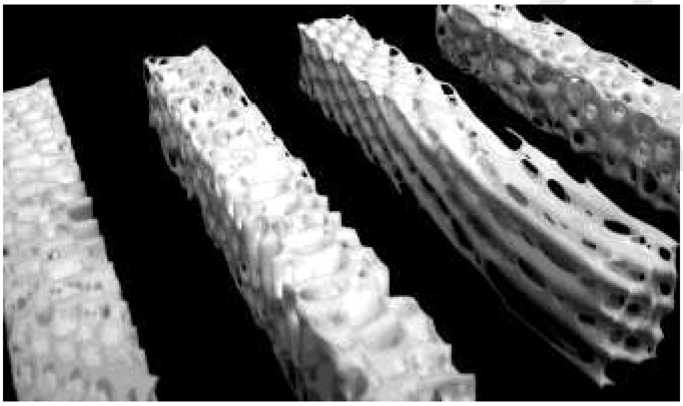


Figure (2- 20): parametric evolutionary design through algorithmic architecture, gene Wave algorithmic design – structure optimization
Source: Speed, 2007

This evolutionary architectural design approach with its two types will be the main research topic of this thesis which aims to achieve in the built environment the symbiotic behavior and metaphor balance found in nature.

2.7. ADVANTAGES IN DIGITAL CONTEMPORARY ARCHITECTURE

In contemporary architectural design, the technological aspect is being enhanced with computational attributes of topological, kinetic, dynamic systems and genetic algorithms. The latter properties underpin the conceptual, formal and tectonic exploration and constitute the platform from which a new architectural morphology emerges through new and adaptive design procedures. “Instead of modeling an external form, designers articulate an internal generative logic, which then produces, in an automatic fashion, a range of possibilities from which the designer could choose an appropriate formal proposition for further development” (Kolarevic, 2005).

2.8. SUMMARY:

Digital architecture now has the computational power to focus not on `products' but "processes". This can accelerate evolution and grow relationships between forms and users. The desired outcome for this part, being the development of more efficient and streamlined overall approach to design and construction through the principles of natural design and digital technology in architecture, which helps in applying and understanding the main architectural approach of this thesis (evolutionary architecture approach). Evolutionary architectural concept depends mainly on nature, natural design concepts, parametric and generative approaches which were highlighted in this chapter.

Evolutionary architecture which will be studied in the next chapters is the main research point where all algorithms, genetics and bio-digital design approaches will be introduced in the next parts, their involvement through morphogenetic evolution and computational design and their digital tools and applications.