Nature Simulation in Iterative Systems of Contemporary Structures

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Abstract. Contemporary architectural structure characterized by some features that have a similarity with the structures of the past periods, one of these features is Iteration. The sources of this concept, its strategies, and its generated system differed from contemporary to traditional architecture in previous studies, especially between the building structure and its skin. One of these strategies called Nature simulation or “Biotic Structures”. The research problem stipulated the “The need to clarify the relationship of Iteration system within nature simulation strategy between architectural form and its structure”. To solve the problem, three steps were conducted: first, establishing a theoretical framework about Iteration systems indicators within this strategy, second, investigating the nature of relationship levels of these systems between the outer skin and the structure created through a practical study on selected samples that fall into three different functional types, and third: analyze the results and determine the conclusions.

1. Introduction
The research has been focused on what we called as"Bio structure in contemporary Architecture". Which is formed by many effects such as (the human environment factors and physical environment factors), when these factors are complement each other they effect on this structure so make it a structure in harmony with nature. These structures are making use of the organism from its apparent or mechanical specialization, all this to produce an efficient structure with consistency of parts. These structures created a strategy that based on rules which control of structure.

The research has included three parts to understand this structure: The first, included the concept of architectural structure, its function, types and the studies that explained the architectural structure, where included recitation systems to determine the problem of research. The second has explained the concept of system and repetition then is explained the definition of iterative system and its specialization and also it’s provide the most important strategies that taken from nature. Where the third is included a practical study and this study is provided for different functional patterns and also provide the importance results and strategies.
2. Architectural structure concept:
The architectural structure is different from its nature, function, and its type. And for the purpose of studying the topic carefully the concept of architectural structure will be clarification, definition it "linguistically and idiomatically". The concept of structure has shown a various expressions such as "something or effort or form ", so its express of the form of thing, its picture or its shape such as (building, origin structure[1], from the other hand these phrases has indicated to what the human is providing to get it done such as (build, organizes, construct, originates, structures [27], or these phrase has indicated also to constructed building or composed of parts or complex elements that covered by the relationship and arranging so the importance concepts that associated with it is (the building, the shape, the formation, the composition and the fabric[2].
The word "structure" comes with most of essential references and the architectural studies for expressing and description a many sides of the product of thought, where all these are special in its description and relationship with other sides. The architecture "Emitt" was described the structure as a system that formed from some of element general structural material and the main structure with consistency between them [13], the structure is considered in the opinion of the architecture "Hawerd" is the essential part of building that resist the load and forces that affecting it [10], this system is represent the general form of a building or maybe it's come inside the skin [9]. We conclude from this, that the architectural structure is considered the most essential part in architecture "its core of the architecture. The basic principles on which it is based by achieving the principle of strength, function, art and beauty, as well as its considered the main component of the building to give the expression side, in addition to its essential function such as (conviving the load, weight and achieving stability.

3. Architectural structure function:
The previous knowledge has shown many functions of architecture structure with five functions such as structural function: it means the functional side that the architectural structure expresses it clearly, which represents, by the organization the power, budget, and stability without any effect on the exterior of the building[7]. Magnificence function: Magnificence function: this function is associated with what the architectural structure expressed about its specialization such as (symbol and signal with meaning) that we can understand what show Sandakar8, as well as is to stimulate the suggestive relationship that expressing on the balanced nature of the forces of action and reaction. These relationships are approved by a human to understand the relationship between physical shape and forces, the magnificence of the building is generated from distinguishing the architectural structure shape [25]. Environmental function: the architectural structure has been shown during the time, many of the environmental sides that appeared recently to a chive the side of the environment, which related to sustainability that represented the use of technology, intelligent systems and design of mechanisms. All to create a structure that adapted to the environment through many series of adaptation of architectural structure elements, as well as of these elements are treated separately within the structure [14]. Protection and safety function: is the most important function that the architectural structure is a chive it because this function is characterized by strength, hardness, resistance to the influence and external load to keep the architectural product safe. The benefit of the protection and safety function is to achieve the suspense and fun to appear some of the stress and suspicion in it ability of achieving the safety through dealing with the structure, that it's not balanced, although it’s at the top of the balance by working to change the style of architectural structure and the Mechanics to achieve it [15]. Architectural function: this function is dependent on the number of determinants which considered the basis of the form production process, where the method and mechanisms generating the structure are determined. The determination are (the relationships between the architectural structure and the building function or as what called ), "structure functional compatibility", Alkhafaji Referred to that the function has increased, where due to diversity in structural
requirement or diversity in the structural division, which leads to functional inference. The benefit of this diversity is to know nature and the function of the building, where all these come through the formal expression of the architectural structure [25]. The other determine is the relationship between the architectural structure with architectural space. This determines have shown through surrounded it with the building space and wrapped it up or showed it to functional space, because this determine is contain of spaces with various expressions, so the architectural structure is specialized of expression side [15]. From all the above functional we conclude that the function of the architectural structure is speaking on conveying load, organizing the power, achieve the balance and stability, crest the visual and mental communication through formal expression and achieve adaptation to environment by structural processing of the level of the element and structure as a whole with enclosed and wrapping the building.

4. Architectural structure types:
The previous knowledge has been shown many types of architectural structure that change according to the building material and according to the points of view that increased in classified the architectural structure types. All of points of view are clear it according to:

- The type of building material: the structures are divided into : (architectural structure of concrete, which consists of concrete. The architectural structure of steel and the third type is an architectural structure of Nano where this type is also added within the architectural structure by combined this material Nano on concrete and iron, due to increasing in quality of the properties, because it has several features such as (lightness, resistance and durability) [23].
- According to the relationship between the architectural structure and the shape such as (cortical, bloated, structural, membranous, polygon, frame and steric) [24].
- According to the relationship between the architectural structure and the type of the space that concerned with a particular function, so it has been classified into: (a system of form efficient, structural system with effective section, structural system with effective vector, structural system with active height and system) [12]

For more information about problem of research it will be provide many studies that included the architectural structure in the contemporary architecture.

5. Clarifying the cognitive reality of the previous studies:
Many studies has provided the subject of the architectural structure, some of these studies has been focused about what the digital technology is provide to develop the architecture concepts, as well as to produce architectural structure by using virtual reality technology such as (Majid's study 2015), while the other focus was about development of building materials, construction of techniques and its role in forming the structure like study of Test&Wieser 2002), the study of (Chris Apel 2004) has been focused on the change that happened in the intelligent of the relationship between the architecture and nature through the structure, while the study of (charleson,2005) has been discussed the architecture structure as a physical intently, which reflect the zeitgeist and its techniques, as following:

5.1 Majeeds study 2015 (digital technology and its applications in organic structure): Majeeds study was focused about what the technology development has provided and its effect in the new development that happens in the concept of architecture, through procedure the design, manufacture and operation process by using artificial intelligence and intelligent system, which distinguished with curved and irregular lines (p: 123). this process is proceed by to steps: - First: is proceed by using "digital modeling" and provide many choices and adjustment to create a complex structure. Second step called as "manufacturing and production step", where this step proceeds by change the design data and convert it a physical form (p: 143), the architecture system study was classified according to the function and creation, that depending on the relationship between structural system and the space. The most important
system on which this system relied are (effective surface system and the cortical structure system) (p: 63-70). It also mentioned the role of smart materials that have elastic properties in forming organic structures (p: 42). From all the above, we conclude from this study (Majeeds study), that the study has been shown role of the technology and its capabilities in creating of structure as well as the ability to adjust according to choices and with the help of material technology ,with what distinguishes these materials from flexible configuration addition to the efficient performance.

5.2 Testa&Weiser 2002 (Emergent structure morphology):-
This study has explained the function of the digital revolution and its effect on architecture structure with many changes in design and construction method, all these come with the development of materials science and construction techniques. This study was shown, that there are many theoretical frameworks to link the design process with digital ideas such as (linking the programming with industrial integration, materials engineering, and the structure). the study has provided the concept of the form of morphology, by working to simulate the evolution and also by using "algorithms" to find the relationship between the shape and technique, that due to developing the structure by using the development computing (p: 13) There is two way that the study takes it :
- The first way is taking a space side with sufficient information to describe the structure.
- The second way is taking a structure side identical to the expansion of the structure (p: 14) the study has provided also important mechanisms, that using it to simulate the organic growth. Many important mechanisms are (a Lindermere system which depended on rewriting rules and frequent replacement, all this is to form the structural system and the highest performance (p: 16). From all the above, we conclude from this study that the study was depended on simulation of the natural structures and the process of organic growth .The benefit of these processes is to produce morphological structures, which are specialized of (vitality, dynamic and transparent ) it doesn’t effect on structural performance as well as using digital technologies.

5.3 Chris Apel 2004 (Architecture technology and process):
This study has indicated about what the architecture pass through, such as the step of testing, experiment, and changes .This step is to focus on the technological development and it’s affecting in changes that happened in the architecture, intellectual sample and the effect that happened on the production through imagine and expect the imagination architecture. (P: 1-9) the study has provided many concepts, that took it from the study of the behavior of the living systems, such as (balance, recovery, self-organization and according to the mechanism of abstraction and transformation of the classical structure formal nature. From the other hand... the concept is to provide another side that out of familiar (p: 61, 62), and also by using the repetition of the measured units to give the structure the flexibility to use the exposed structural mechanism (p: 172-174), among the side that this study is provide also is produce what called "Biotechnology architecture" through the interface between the environment and digital technology and also produce a structure that inspired (p: 78). This study has confirmed the function of technical development in producing structure. This structure is changing what mythical and fictional into reality, due to of virtual reality technology and to produce a structure with structural and economic efficiency and by using the simulation strategy, the mechanism of repetition and the structural frankness.

5.4 Charleson 2005 study (Structure as architecture):
This study discussed the topic of the architectural structure as a physical entity that reflects the zeitgeist and technology and also to show the relationship between the architecture and the structure. This study has appeared also the relationship between the structure details and building function, as considered that the most of building having two or three structures system. There is two type of structure that this study has
mentioned it, where the two types of the structure combine the architecture side with building side, which is (histological, cortical and arch system), with an emphasis on not using the traditional solution and finding new architectural forms, by finding a structure system that fits with these forms and by using the principle of structural frankness and digital technique on the structural system. (p:78). This study has explained the relationship between the structure and shape and the relationship between the structure and space, by providing many types of structure that reveal about this relationship, such as (the surface structure and the spatial structure), with clarification of the diversity of source of these structures (p:85-94). From this study we conclude that the study has shown the function of architectural structure in the form of the outer skin of building, where affected by several factors such as "cortical, continuous and histological," these factors have focused on two sides:

- First the physical side of the architectural structure that represented by its features and its relationship with building.
- Second is the object of using the architectural structure and the method of benefit from the structure as a creative element or for structural purpose.

When we collected all the studies, that we mentioned in the research, we had found that studies have discussed the concept of architectural structure in its relation with (shape, outer skin and its function for nature system simulation strategy) without any mention of function of iterative system in the generative process, which happened in the structure and thus appeared the need to define the research problem, which represented of (cognitive need to discuss the repetitive systems within the strategy of simulating nature and its function in the relationship between the form and the architectural structure in contemporary architecture).

6. Theoretical framework
6.1 Iterative system within simulation strategies:
6.1.1 Definition of the concept of nature: Linguistically, the nature is known as power that represents of universe and individual [27], and known as nature and it’s considered as the force that exist in our bodies, while in idiomatically the concept of nature is known as the framework and the content in which the person develops on it, whether organic or in organic and visible or invisible [29], and it’s the physical universe or matter world, which is concept that refers to life in general [28]. From the other side...the nature is defined in procedurally as the visible or invisible world, which contain all forms of life that abide by system, rules and principles for achieving a complete.

6.1.2 Nature simulation strategy:-
In general, the simulation means reform and reconstruct the shape from of the original source. This strategy is based on two groups of the exploration and cash processes that lead to find the fact of heritage, so this lead to create an architectural production that distinguished of the creativity therefore, it focuses on the concept of appearance [18], there is many way that the human deals with nature, with different ways, which starting with future system, after that to the ecosystem direction, then to the self-adaptation ways all these ways is done through looking at nature as borrowing source, the simulation and its affected in the architecture in general and the architecture structure in particular was either visual at the level of outer appearance or conceptualization to transfer the action or behavior the organic or biological simulation at the level of self-organization and the dynamism in the structure that lead to create a complexity at the apparent level, mechanical simplicity, organization parts and achieving a structures with more efficiently.

6.2 The iterative system in the structure of contemporary architecture:-
6.2.1 The concept of iterative system:-
In linguistically the system means as an arrangement and consistency, where the order system is (strength and baptism)[2], The system is refer to principle and procedures, that doing, according to an organized scheme, method, set of mechanism or connected network, that are installed from different and connected parts[2], while the word "system" means the coordination, gathering, Abundance, Integrity and power [43].

Idiomatically, the concept of system in general is associated with two sides:-

- First side has described the result and focusing on the concept that describing the thing and to produce a formula that express of homogeneity, which means arrangement of element within a specific formation, a specific organization or a specific basis.

- Second side the concept of system is focus of process which considered as the geometric formulas that work on achievement the arrangement and organization of a group of element of level of the building, and this according to many set of relationship and for many human needed [35]."Venturi" has classified the system as a simple and complex system, which include many parts that overlap with each other in complex way, such as in the architecture of complexity and contradiction, through linking every elements with each other [30]. Repetition in linguistically means a critical term that comes from the verb (repeat), which means return or repeat the word for several time either for assumed, threat, encouragement and warning or for interpretation of meaning for the purpose of complexity [33]. Repetition in idiomatically means the organized unified and harmonic of elements. The repetition is considered as a tool that organizing the shape and the space, through the age movement, which following the elements of the structure and objects [19]. The repetition has used in architectural structure to create the unit within the composition such as repetition a structure element to produce a pattern or to work with repetition to produce an effective work [20]. While the repetition in contemporary architectural structure is adopt on sequentially of creating a one specific element or more scale and periods of time which the feedback enter it, so the iterative process enters in all way of production of structures whether it be natural or algorithm. The first type of the properties are contributes in giving a preliminary definition of the created form, while the second type contributes to give the diversity by using method and mechanisms, where all these contribution are produced through the relationship between the shape such as the symmetry and the standard hierarchy, which gives the coherence of the architectural structure [32].

We conclude from these definitions that the repetition system in the architectural structure from the component, rules and qualities is a structural process and recycling, reorganization and reproduction of a specific object that represent one of the important evolutionary processes that produce the external appearance or shape of the architectural structure, which considered a system with rules that controls on specific the system is consist from the element and the compounds that consist with each other, with the whole and with its surroundings also its subject to external lows or special lows of the same system, so it’s depending on arranging in its elements and components for a specific purpose with non-random method.

6.2.2 Specialization of repetitive system in contemporary of the architectural structure:-

There is two types of characteristics of repetitive system:-first specialties that linking with the same system and the element that associated with it, which means that this specialties was in the level of the relationship between the element of structure and the system (part to part relation and whole to part relation), the characteristics that belong to the first type is:-

- Self-regulation: this property is concept to create a relationship between (the concept) and (the materiality), with two ways: the first by using the self-regulation, which working as a mechanism to simulate the biological system and to use material techniques. The second: by activating the simulation strategy with a fractional pattern through activating the self-organizing logic to distributed the point of the intection and loads of the structure.
• Standard hierarchy: its mean scale the system according to the, for example the level of the built environment represents the hierarchical by reducing the standard levels and organized the complex distribution of elements with the hierarchic [32]. The hierarchical is achieveble in architectural structure either by level of the element size of the structural element, or by the level of the scale, where the overall structure (the large structure) and the repetitive elements (the small scale) [19].

• The balance and the symmetry: the system is associated with standard hierarchy in the architectural structure, this associate is made through the relationship that linking the minimum standers with high standards and all this is to have a simple degree of the symmetry and was either on the whole of the level of a building or just in the part of building. The balance is associated with the symmetry in order to achieve the stability through lifting the loads (symmetrical balance and asymmetric balance).

• The domination: the domination is about through repetition of an element of the architectural structure and confirm it visually during the exceptional size, strategic locator or distinctive look. The domination is depending on distinguishing the element [19].

• The unity in composition: this unity is created from the part to part relation and whole to part relation and also to achieve a sense of harmony and perfection. The recurring element within one pattern in the architectural structure is producing a reflective pattern of unity, due to that each element or part has the system identity and is known through the system as a whole but not a separate form [20].

• The complexity: the complexity in the architectural structure means, the fabric of two or more systems, that related by certain way with associated elements [37]. The architecture Jencks was confirmed that the complexity is located between the system and the chaos, either by collecting many of the inconsistencies or by manipulating of the structural system. This process is made through the relationship between the systems element to produce a linear reaction, which result a new system that the internal system is tending to stabilize by feed, as well as depended on algorithms, that takes the previous output when entering new entering. The successive generations depended on many of genes with best solution from the previous iteration by using a digital and material techniques to produce a curved structures (no linear) [36].

• The dynamic: the most important properties of a repetition system in the architectural structures that due to survey the system in a continuous and a stable movement. The benefit of this property is giving the active to the system, so it lead to change the stable from the old case to new case, by using a new inputs to the system. The inputs are entered to the system by two ways, the first way by using the repeated rhythmic structural organization [31], or the second way by using the similar and the simulated in arrangement of the component parts of the biological structure [11].

• Flexibility: its means keep the system in a stable form or back to the previous situation in case of exit the system of its normal position and continued the production processes and for each to a state of balance and responding to change and new situation [15].

• Converting: the converting is happening in the architectural structure due to the imbalance that happened in the system, which lead to turbulence by reorganizing it to be a higher level than the level of complexity, all this regulation is to produce a new system, this converting is happen by process called (the emanation), which effecting either in some part of system or a whole system, this called (return the structure of system) [15]. The converting is happen in contemporary architectural structure by using many mechanics such as (hiding, changes the structural network points or by using a simulating natural structures through using digital technology. The digital technology is implemented in the structures through the use of animation programs to adjust the
structure and also to choose the best solution to change the traditional structure in to new structure or also through a mathematical rules which considered the structural lines as a rules that may changes it to produce anew rules by adding or removing some element of the structure and by doing some of operations that change the structure such as (bending, folding and twisting) [38].

6.2.3 the repetitive system strategy in the architectural structure that took from nature:
These system is depend on the investment the nature and living components, where this strategy is known as "simulation strategy " to produce a biological strategy are production in two ways : the first way :is to benefit of outstanding properties and the structural composition of the structures that existing in nature to produce a structure with efficiency and aesthetic appearance .the second way :is to benefit of mechanical the natural structures and produce a structure that reflect the action of the living structure. The importance system that effected on the structure are:

6.2.3.1 the iterative system according Voronoi diagram:
This strategy aims to simulate the structural pattern ,which inspired from the natural word ,in order to develop the structural system and this made the structure very efficient and to use the materials and energy as well as to develop the regular structure ,through using a digital and the fractal engineering to get rid from the Euclidean geometry ,through investing the laws that control on the processes which happens in the nature and to use it in design many of structural elements, all these is done by known the structural of the organisms [39], this strategy is dependent on the :-I-the rules that exist in the mathematics and the engineering has taken from the bionics and the division of non-curved structures to curved structure and to link all of the structural units to mathematical equations [41].2-the graphs is done by determine a set of points and giving the information that related of the distance between them. This graphs is consider as a units of structures .therefore, the benefit of graphs is by using it to various geometrical shape, with different sizes and material, to produce patterns or structures fractal. The benefit of the voronoi is to determine the structural features, organize the space and achieving more effective and dynamic relationship between the components and elements of the architectural structure, as well as achieving the balance for forces and giving a several design options with hierarchical distribution [40] . the voronoi cell is contains of a polygon that containing a production point.all of the point of the polygon were located in the closest point of the production ,with two forms (two-dimensional voronoi),this form is use as a mechanism to achieve the self-organization through development the three – dimensional structure by giving every space in the scheme a point location and interfacial representation and the adjacent terminal such as a graph and to improve it by an algorithm called (kohonen). The kohonen algorithm is works on the processing, modification and improvement according to the structural reaction after using the Oasys gsas(analyzing structural program) then integrate the product in the processing programs [41]. Three-dimensional voronoi is using to produce a structural system by using the mechanism of complexity and transfer of the system from a standard iterative system to a complex adoptive system by considered each cell is a part of the structure system, which subject to modify and transfer ,through considered the edges of voronoi as the bridges and beams that linking the levels to calculate the wind load ,force value (horizontal and vertical) and displacement by using the structural analysis program. The system is improve by three strategies which is (the point –moving strategy, regression ratio algorithm and the harmonic algorithm) so the system changes after many operation to reach to the final form [21].

6.2.3.2 repetitive system according Lindermere system:
These system are aim to study the development and modeling of the plants and the simple organisms growth, because these system are structural and formal systems, where these systems are invested in the production and design of the architectural structure .the system is subject to many of iterative operations,
which is based on coding the elements as a letters, where this letters in initial string are replaced in paralleled with new once ,according with serial rules and laws ,which has taken from the biology (the current agrestic replaces the results of the operations that used before and this is called reproduce the series) Serrato43 . this process is made by two way:

- The first part is called the productivity processes of many of the element that using in (axiom system) while the initial strings, which is considered a first part of the system, rules, number of duplicates and the depth,all these processes are using in(dol system) [22].

- The second part is the process of translate icons and converting them geometrical forms as well as …translating this series to produce many of the density derivations and the replacement ,that lead to produce the diversity thus, many patterns of folded ,light and complex structures are producing ,by depending on the derivation production through using this rules [38].

6.2.3.3 Automato cellular:-
This sitratigy adopted by the genetic architecture, where it is based on a calculation method simulates the growth process of the organism to describe the complex system which is made up of simple elements and rules [43]. It is internally organized relations with time through the frequent replacement process called (Recursive) until reaching a specific situation that leads to develop architecture forms and structures [42]. The Automate cellular is made up from arranged net of cells each cell of these has limited number of cases. In order to make an Automate Cellular it has to be determined the situation of the central cell and its adjacent cells in addition to that the transition and transformation rules ,because each on has two cases (alive or died) (vacant or filled) the transition process starts with taking an initial situation from alive cell, this situation is subject to several rules for every successive generation and they determine which cell will survive or die, or new generation is born. So what determines the future of these cells is the situation of the adjacent cells. This is what is called (intertextuality) or (compass window) [38].These cells are being developed not based on the arrangement but by follow the system rule of the adjacent, what about the algorithm which is used in these systems ,it is determined by the many steps: Defining the cell size,and starting with a specific cell,and mentioning the rule which determines the next generation.Finally test the result pursuant to a series of iterations until reaching an acceptable result [38].

6.2.3.4 iterative system according to swarm system:-
The swarm system are depending on the collective active of self-organizing of decentralized systems. Although of there is no control centralization that dictates how to behave, however the system is consist of May of the elements and parts that interact with each other and with surrounding environment. The behavior and rules of the elements is made through the interaction of the elements in order to operate the system from the lower to top, so every elements either be more develops or more complexity of its behavior parts [42], the aim of using this type of the system is to describe the behavior of similar organisms and to create a pattern with specific rules of avoiding the collisions in speed and with drawl, so this creating a structure of mechanical simplicity and apparent complexity [38]. this system are depending on three mechanics :the separation ,each structure has the a ability to keep its identity. The cohesion, through coherence and gathering it with other nearby structure, where each structure is align with other structure. The communication and the connection between these structures are constructed the building structure (the movement of the point is determine the shape of the structure).the simulation was made by digital animation where this animation are translated into various engineering structures according to the connect and the cohesion [41] .

7. The first axis :vocabulary of the theoretical framework that taken from strategies iterative system. The source :( the researcher)
There are many vocabulary had taken from the theoretical framework that subtrahend in previous studies in table (1).

**Table 1.** The theoretical framework of the iterative system strategies, Ref: the researchers.

| Characteristic related to the system and the surrounding environment | Material technology | Characteristics of the iterative system that associated with the system |
| --- | --- | --- |
| 1-self-regulation | Material technology | Structure density increase |
| Fractional pattern | Distribution of load point |
| 2-the symmetry | Its type | Couple |
| Central | |
| radiation | |
| Its level | At The building level | |
| At the part level | |
| Its mechanism | The expansion | |
| Slandered hierarchy | |
| Two system merging | Optical manipulation |
| 3-domination | Iterative the element | Special size of duplicate element |
| Strategic location of duplicate element |
| 4-the unity | Replication of monolithic structural element | |
| Gathering units of different structural element |
| 5-standard hierarchy | Self-similar | Part level |
| Structure level |
| 1-the complexity | Combining two or more structural system | The structural system Manipulation |
| The algorithm | Achieve the balance | Coordinate element iterative |
| Expressive | Random element iterative |
| 2-the flexibility | The ability of the system to remain stable | Respond to external conditions |
| 3-the dynamic | Properties | instability feed back |
| changes | Balance status change |
| levels | The relation between the structural element | |
| a structural system depends on function |
| 4-the converting | Level | On the whole level |
| On the part level |
| Mechanism | Self-regulation |
| Concealment |
| Manipulation |
| Simulation |

| Th | 1-voronoi | The aim from this strategy | Visual simulation at the level of the external appearance |
| --- | --- | --- | --- |
| | | | Simulate mechanical properties in a living structure |
| 2-l-system | The aim behind this strategy | Mechanical properties in the living structure | Bio-medical simulation | Growth and development process in the living structure |
| --- | --- | --- | --- | --- |
| Mechanism | production | Replacement and interpretation rules |
| Tools | Mathematical method | Basic units iterative |
| Structures properties | According to aesthetic consideration | Form and structure integration |
| | According to structural consideration | Stable-coherent-steady |
| General properties | | Vivd-dynamic-stable |

| 3- the automated cellular | The aim behind this strategy | Simulation of growth –self-regulation –developed in the living structure |
| --- | --- | --- |
| Mechanism | Genetic algorithm | Manipulation of the parameters of the relationship between parts |
| | | Drag-rotate and bend of basic units and repeat it |
| Tools | Mathematical methods | Basic units iterative |
| Structures properties | According to aesthetic consideration | Basic units iterative -balance |
| | According to structural consideration | Stable-coherent |

| 4-the intelligence | The aim behind this strategy | External apparent level | Optical simulation |
### Table 2. Description of the selected samples.

| 1 - the project: Abdulla center for studies and petroleum research | The Designer: Zaha Hadid | Location: K.S.A | Code: A |
|---|---|---|---|
| Explanation of the description case |
| The project had been designed by Zaha Hadid in K.S.A, where had designed to produce energy consuming in an area with extreme with 10000 m² space. Zaha Hadid had designed this project by a series of crystal structures that inspired from desert landscape. this center is consist of five buildings, which gathered together by a central patio, where the benefit of the center in to link all buildings, the strategy that were used in this project is iterative strategy, which called cellular system (voronio) due to the possibility of expansion, by giving new cell, where the benefit of arrangement and shape in cells is to reduce the light and warm (Figure1). (https://www.researchgate.net) |
The airports project is one of the distinctive and unique designs, due to the integration of the structure that used it to support and look like the trees with the ceiling, as well as the functional side in this project is working better by providing the easy in guide travelers, employees and baggage. This building is specialized by the good ceiling of the hall with open space, which provious the ease and streamland movement for the travelers and ease to reach the baggage, the most important element in this project is the structural system (look like trees) due to that structural system is supporting the ceiling were divided into (12) rectangular clip with (34.4*26.6) measure, which compose as a bi-directional system of iron steel. Each area is supported by a steel tree, (where transfers the loads from the branches together in the trunk). The architectural structure is simulate the trees structure shape and its functional through the way of distributing and carrying the heavy loads, where the shape of the structure is come from the black forest that adjacent the building the roof of this design is characterized by a tendency in the direction that load to access to planes, all these is to dominate the branching structures with their gothic properties and its opposite with the floor granthic and trees. The building is a rectangular shape with three levels, where these columns are from a shape that look like a small waterfall that flows regularly, the pillars is consist of four tubular columns that lining with each other and spreads to from a branch tree in the three levels. Each of columns are from three branches with four secondary branches, all these is to support the roof, although these columns having an organic appearance however, these columns are distributed in a wonderful engineering shape to hold the loads of the roof. The branching system in this design are direct the forces to smaller points together in the trunk of the hard tubes, so the structure is consist of (12) columns that supporting the net. Figure (2) (Ahmeti, 2007, P. 28-40)
Figure 2. Stuttgart airport building, Ahmeti, 2007, P; 28-40

3- project : A proposal for designing the cultural center
Design : NL architecture
Location : Taipei
Code: C

Explanation of the description case

This project is specialized by its simplicity with dimensions 110*80*64 m, it can be considered an urban building to achieve some kind of interaction. The project is an open space, in the form of a hollow square rather than a solid block, so its design without a threshold. The building consists of 3 floors (mall, shops, halls, lounges, restaurant club, games area). The building is likened to a table with four different legs, where a horizontal plate, its may be considered a small skyscraper, that narrow in some and expand in some areas as for the structure, it is supported from the corners by various forms of solid blocks to give some kind of misfit symmetry and to give a form to the building look like a dome but orthogonal form (Figure 3). (https://www.yatzer.com/Taipei)
4- Project: prosho museum and research center  
Design: Kengo Kuma  
Location: Japan  
Code: d

| Explanation of the description case |
|-------------------------------------|
| The project has established with 424.55m2. This project is established to change the machinery architecture to the craftsman building, through simulating the flow of blocks of birds and fish, by using the digital technology, where this process is repeated several times, through visually test items, for any type of structures produced. The structural system in this design consists of two layers. The first layer is a concrete system, while the second layer is consist from natural material, to give the impression of the swarm and to form a mass that combines between the solid and transparent mass. The wooden structure is made from likeing of the molecules and particles movement to a element of the architectural structure and the liking between these particles is a system of this structure by using the traceability and communication to produce this structural system. (https://ookkuu.com/blogs/articles) |
8.4 Method of Measurement:
There are two axes to define this case: the first axis specializes in the vocabulary of repetitive systems within the simulation strategy that includes two types of measurement which divided into two cases:

- The first case is a qualitative case where the descriptive approach is depending on the value, if this value is in the elected sample (realized value = 1, unrealized value = 0), where this type is aimed to analyze the vocabulary of the strategy and rates of its achievement.

- The second case depends on the evaluation of the single axis achieved by using the digital scale.

The second axis is concerned with vocabulary related to the relationship of the structure form, shell, and this axis will depend on the result that first axis will provide.

9. Results, Conclusions
9.1 Results
9.1.1 Analyses and discussion of the first axis’s result:

9.1.1.1 The characteristics of the iterative systems that related to the same system:

The values of the sub-vocabulary for the samples have diversified. For the self-regulation single axis, it achieved (50%) through material techniques, using the fractional pattern at a rate of (25%), while the symmetry single is achieved a binary symmetry at rate of (50%) and central at rate of (25%) and on the level of part at of (75%), at the level of structure (25%). The domination single is achieved through the exceptional element size and at rate of (50%), whereas the strategy location not achieve any domination at rate (0%), while the single unit that achieved it by the iterative element with rate of (100%), and achieve the unity through gathering the unit to an architectural structure the rate of (50%). The hierarch single is achieved on whole and part levels at rate of (50%).

9.1.1.2 The characteristics of the iterative systems that related to the relationship between the system and surrounding environment:

The result has shown a diversity in the output properties, according to its mechanisms and tools. The building of the Stuttgart airport and the brochorw museum has achieved very high degree in the complexity, through amount of details of the structural element. While the petroleum research center has achieved a medium degree of the complexity, due to the diversity in the structural element, where the cultural project center not achieve any complexity. The conversion single has achieve a high degree and at two levels (whole and part), through the reflexive relationship on the rotation axis and by repeating the
element with a certain pattern, the petroleum project center has achieved a medium conversion degree with two levels (the whole and the part level) while the Stuttgart airport has achieved a medium conversion degree at the level of the whole while the culture project center not achieved any degree of the conversion. The single of the petroleum project center, Stuttgart airport and brochow has achieved a very high degree, through the linking between the elements. As for the flexibility degree the culture center has achieved a medium degree. the result of analysis showed the a achieve of the dynamics single and with high degree at the part level of the Stuttgart airport and with a medium degree to both of the culture center and brochow museum, as for apparent level the research center has achieved high degree in dynamic, while the other a above projects were not achieved any degree.

9.1.1.3 The iterative system strategies that taken from the nature:-
Voronio strategy has achieved the single of the simulation on apparent level with rate of(50%), with using of the structural improvement mechanism at rate (25%), as for its tools, the signal division of units and linking them with mathematical equations has achieved (50%), as well as, when the set of net has determine the rate was (25%). L system strategy has been achieved a simulation single of processes of the growth and development in the organism with rate of (50%) and the simulated of mechanical properties in the structure are rate of (25%). the mechanism of substitution and interpretation has achieved (25%) rate of elected sample, while the rate of using digital program was (75%). The automated cellular strategy has achieved a single simulation of growth processes by the self-regulation in the rate of (50%), as for using the mechanisms of the genetic algorithm and manipulating in parameters of the relationship between the parts, the drag mechanism, rotation and curvature at the rate (50%), while the tools of the genetic algorithm mechanism has achieved a single of the basic units at rate (100%), and the uses of the mathematical method at rate of (50%), the swarm intelligence strategy has achieved in the simulation single of the apparent level at the rate of (25%), and for (50%) bio simulation, its mechanism, the separation mechanism at rate of (25%), and for the alignment mechanism rate of (50%), mechanism of cohesion (100%), while the tools of the swarm intelligence, the animation programs have achieved at rate of (25%) and the structural iterative element at rate of (100%).

9.1.2 Analyses and discussion of the second axis’s result:-
The result which had taken from result of the first axis, where this result are related to the relationship the shape and the structure and its relationship to the skin. After analysis the changes and comparison of the elected project that is led to produce two levels:

9.1.2.1 First level: at the installation level:
A-analysis of the result that related to a variable organization depth of the architectural structure. Table (3):-
The result has shown different between the architectural projects, from depends on clarity of the architecture structure and hidden of the architecture structure. (2) samples have depended on clarity of the structure where appeared between show the architectural structure with clearly and between the opening on the nature at the whole and parts level, while (3) samples have depended on the hiding structure, so that indicate to (the diversity of the transfer of the architectural structure from the depth of the building to its surface, by show it in clear form or by being open to the nature).

| Elected sample | The organization depth |
|----------------|------------------------|
|                | Exposed structure | Hidden structure |
| First project  | 0                     | 1                  |
| Second project | 1                     | 0                  |
| Third project  | 0                     | 1                  |

Table 3. Ref: the researchers
B-analysis the result that associated with the integration variable between the architectural structure and the skin. Table (4)

The result have shown a different between the architectural structure and external cover system with dependence on the integration level. (1) sample has appeared in the unified integration level, while (2)样品 has in the continuous integration, (3) sample for contact integration, (3) samples for the interlocking integration, (2) samples for the separate integration. So, we conclude that the result are similar in the relationship between the architectural structure and the skin, addition to differ in the nature of their level.

| The elected sample | Unified | continuous | contact | interlocking | separate |
|--------------------|---------|------------|---------|--------------|----------|
| First project      | 0       | 1          | 1       | 1            | 0        |
| Second project     | 0       | 0          | 1       | 0            | 1        |
| Third project      | 0       | 1          | 1       | 1            | 0        |
| Forth project      | 1       | 0          | 0       | 1            | 1        |

C-analysis of the result that related to the singularity appearance of the architectural structure in the shape. Table (5)

The implementation result of this single have shown two levels: first level, the whole level has appeared (0) samples in move the architectural structure from the shape (separating in the meaning of both), while appeared (4) samples in the different of the architectural structure in the building materials and (2) samples of use of different technology. While the second level (the part level), there are (2) samples has shown the exaggerate in the size of the element, with (2) samples has shown also the exaggerate in the location of the element, and (3) samples has found different in measurement. All these shown (the different in the output of the distinguish method of architectural structure by the form).

| Elected project   | The distinguish method of the structure in the shape | The part level |
|-------------------|-----------------------------------------------------|----------------|
|                   | The whole level                                      | The part level  |
|                   | The displacement of the structure as a whole         | Exaggerate in size of element | Exaggerate in location of element | Different of measurement |
|                   | Variation in the nature of the building materials    |                |                            |                          |
|                   | Use of different technology                          |                |                            |                          |
| First project     | 0                                                    | 0              | 0                           | 1                        |
| Second project    | 1                                                    | 1              | 1                           | 1                        |
| Third project     | 0                                                    | 0              | 0                           | 0                        |
| Forth project     | 0                                                    | 1              | 1                           | 1                        |

D-result of the variable analysis that related to the type of mechanism to achieve the relationship between the form and the architectural structure. Table (6)

The implementation result has shown a different between the projects due to the mechanisms that the designer may takes it, all these is it active some relationship in the architectural structure and the shape. (2) samples has adopted the mechanism of the abstraction as for (4) samples has adopted of the mechanism of the repetition and (1) samples has adopted of the deletion mechanism. All these are associated with
hypothesis of this variable (the diversity of the mechanisms that the designer takes it, within each strategy to achieve the relationship between the architectural structure and the form).

Table 6. Ref: the researchers

| Elected project | Repetition | Deletion | Abstraction |
|-----------------|------------|----------|-------------|
| First project   | 1          | 0        | 0           |
| Second project  | 1          | 0        | 0           |
| Third project   | 1          | 1        | 1           |
| Forth project   | 1          | 0        | 1           |

9.1.2.2 The second level: the expressive level: in this level there are four patterns have been shown in the relationship between the structure and the shape (in general) and the structure and the skin (in particular). the concept of the meaning has been confirmed through the relationship between the architectural structure and the shape, this is due to the multiplicity of meaning and the diversity of the source. the result have been contributed in the determining a pattern of the meaning that related to the architectural structure, through its relationship with the context, location and the architectural function. (2) sample has appeared that the structure is separate from the context, while (1) sample the structure is connected with the context. As for the meaning of the site, has shown (3) samples for the functional and aesthetic meaning, over, the symbolism is not achieve any meaning in the structure. the meaning for the architectural functional of the structure has appeared (3) samples of meaning that taken from the structural clarity, (4) samples of meaning of the tectonic and (2) samples for both of meaning that was taken from clarity of the building materials and breach of the structure rules, through the shape of convey the powers. From one samples we conclude that there is a distinction in the meaning pattern, that associated with the architectural structure that was taken from the structural functional of the meaning pattern which related to the architectural structure but indirectly, whether had taken from context or location. Table 7.

Table 7. Ref: the researchers

| Elected project | Meaning from the context | Meaning from location | Meaning from the structural functional | Breach of structural rules |
|-----------------|--------------------------|-----------------------|----------------------------------------|----------------------------|
|                 | Separate from context | Nested with context | Aesthetic | Symbolism | Functional | Expressly Structural | Certify building materials | Tectonic | Shape style to transfer the powers | Building material properties |
| First project   | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| Second project  | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| Third project   | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Forth project   | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |

While the meaning that taken from the diversity of source, the result has shown a similarity between the samples, on the level of the formal perception of the architectural structure, where this result has adopted on outside of the field of the architecture which adopted it as a reference to the shape formulas, that
associated with the architectural structure which depended on vegetable forms one sample. One sample has been shown when adopted it on reference from inside architecture and one case from inside and outside the architecture field. table (8)

| Elected project | The nature of the formal conception of the architectural structure |
|-----------------|-------------------------------------------------------------|
|                 | Inside the architectural field | Outside the architectural field | Inside and outside the architectural field |
|                 | vegetarian | animal | organic | |
| First project   | 0          | 0      | 0       | 1       | 0       |
| Second project  | 0          | 1      | 0       | 0       | 0       |
| Third project   | 0          | 0      | 0       | 0       | 0       |
| Forth project   | 1          | 0      | 0       | 0       | 1       |

Table 8. the researchers

| Elected project | The relationship patterns between the structure and the shape |
|-----------------|------------------------------------------------------------|
|                 | hybrid | Chained(similar) | Separate | Combined |
| First project   | 1      | 0               | 0         | 1        |
| Second project  | 0      | 1               | 1         | 0        |
| Third project   | 1      | 1               | 0         | 1        |
| Forth project   | 0      | 1               | 0         | 1        |

Table 9. the relationship patterns between the structure and the shape of elected project, Ref: the researchers

10. Conclusion:
- The simulation is considered the one of self-adaptation of the biological system, by considering the nature as metaphor source. As for the architecture in general and the architectural structure in particular, the simulation comes in two ways, either visual on the level of the out appearance, or conceptual to trance the organism behavior, or biological simulation at the level of self-regulation and dynamics in the live structure. All these is for several goals that include a creating complexity at the virtual level, mechanical, Simplicity, organizing the parts of structure and to produce a structure with high efficiency.
- The iterative system are consider as a process of structuring, recycling, organizing and producing something, so the iterative system is using as a mechanism within the simulation strategy. The iterative system are represent one of the basic development processes that producing the shape or the appearance of the architectural structure. Its can considered the iterative system as a system with rules, that could from it to control on a specific situation. As well as, having the ability in regulation of its component and element with unorganized way.
- The iterative systems have contributed to produce, what known as the biological structures by two ways (the first way) is to benefit from the appearing properties and the structural composition of the structures that existing in the nature to result a structure with efficient and aesthetic appearance. (The second way) is to benefit from mechanics of the nature structures and also to produce a structure that reflect the action of the living structure. The both ways is being how to see the objects essence that is wanted to be inspired.
- When the strategy is using in the architectural structure, there must be an integrative relationship between the goal of the approved strategy, the mechanisms and its tools, so all these is done through of many vocabulary such as: The effect of the digital programs and systems directly on the goal of the strategy. Morover The different and diversities the aim of the strategy and its dependence on the technologies used Are lead to the diversity of mechanisms used.
There is a relationship between the architectural structure and the shape in two levels, the first is structural, through the regulation depth of the architectural structure by being apparent or hidden, that made through a priority of the appearance of the structure in form, and second is (a whole or part of structure level). Many levels have appeared through the integral relationship between the structural level and the skin are: There is functional coordination except that there is a separate Integration, in which each Systems are separate from the other system.

- The connected integration of the outer shell (the skin) that associated with the architectural structure And may execute some of functions, such as close- up or wind load distribution.
- The contiguous integration, in which the skin is used in the architectural structures and be flexible To fit with it.
- Interlaced integration in which the systems take the same space.
- The unified integration, in which the architectural structure is united with the outer casing (the skin), so cant distinguishe between them. While for the expressive level, there is four inspiration that associated with the architectural structure, and this relation is:
  - The type of the relationship (hybrid) in which a concept (appearance with substance) bing the Production diversified, due to the changes in the forms, source and treatment, where the architectural Structure is disappear to express (the structure and the skin for the same thing).
  - The similar relationship (chained) that the architectural structure, building materials and creating Method are the result of the functional requirements of the building that lead to structure is effecting on the skin or the skin is effecting on the structure, so the product is characterized by complexity and Contradiction.
  - The pattern of the merged relationship in which the architectural structure (the structureal system Pattern) is expressed through the shape and directly. The shape in which express it is done through Responding to the structural and functional requirements and also response by the building materials.
  - The pattern of separate relationship in which each system (the structural system and the skin System) is working separately, addition to keep them connected with the structural level.

All these relationships are characterized by many of qualities such as (dynamism, transformation, flexibility and complexity), where all these are getting through using the iterative system, the diversification of mechanisms and tools of the architectural structure.

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