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Paper: **SIMULATING THE ORGANIZATION OF MULTI-CELLULAR ORGANISMS WITHIN THE FRAMEWORK OF SPATIAL RELATIONS IN ARCHITECTURE**

Topic: Architecture

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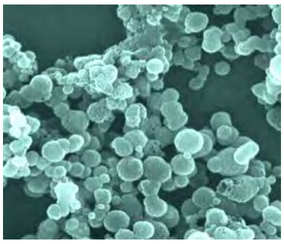
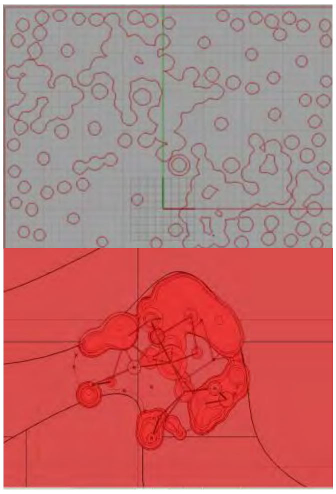
[2] Gary William Flake, “The Computational Beauty of Nature”, MIT Press, Cambridge MA, 1998

[3] Image http://www.dailygalaxy.com/my_weblog/2007/11/x-cells-five-su.html

Abstract:
The design approaches inspired by nature throughout history, has become more significant and complicated in today’s architecture. Thanks to the advances in biology and its interactions between different fields, the nature can be used with its complexity in design. Within the use of computational theories and advance techniques in design field, the morphological processes of cellular organisms such as emergence, growth, and selection in natural sciences can be analyzed and used at a certain level in architecture. Considering the 21st century’s global changes, understanding and emulating these chaotic processes seems one of the effective ways of designing more sustainable future. One of the reasons for that is there are some remarkable resemblances in morphological processes in nature and human civilizations. In this study, it is aimed to focus on some of these chaotic processes in an architectural frame by simulating the organization of single and multi-cell organisms in nature within a spatial framework.



Nanobacteria-like particles from human blood [3]



In nature, with a specific genetic code, the basic structure of a living system, a single cell, combines with its likely neighbors and creates tissues. As these tissues become organized with their neighbors and create clusters by their particular obligations given by their genetics, they generate the parts of a living system. Considering these neighborhood relationships between cells and tissues of cell organisms, it is possible to say that these connections between units which differ from cell to cell or tissue to tissue are the essentials for survival of an organism. There are different roles of these connections between these similar units and clusters which help to create a sustainable arrangement. Indeed, that is a common point between architectural design and biology. For the reason that, in architecture, we also need an effective organization and strong relationships between spaces for efficiency in our design. From smallest to largest scales in design, organizations of spatial relationships are the most key facts of a sustainable design. Thus, this study offers some architectural living models within the physical and social relations of design units in different-scales, by simulating the organization of cellular living systems.

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Simulating the Organization of Multi-cell Organisms within the Framework of Spatial Relations in Architecture

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Abstract

The design approaches inspired by nature throughout history, has become more significant and complicated in today's architecture. Thanks to the advances in biology and its interactions between different fields, the nature can be used with its complexity in different stages of design. Within the use of computational theories and advance techniques in design field, the morphological processes of cellular organisms such as emergence, growth, and selection in natural sciences can be analyzed and used at a certain level in architecture. Considering the global changes of the 21st century, understanding and emulating these chaotic processes seems one of the effective ways of designing more sustainable future. One of the reasons for that is there are some remarkable resemblances in morphological processes in nature and human civilizations. In this study, it is aimed to focus on some of these chaotic processes in an architectural frame by simulating the organization of single and multi-cell organisms in nature within a spatial framework. In nature, with a specific genetic code, the basic structure of a living system, a single cell, combines with its likely neighbors and creates tissues. As these tissues become organized with their neighbors and create clusters by their particular obligations given by their genetics, they generate the parts of a living system. Considering these neighborhood relationships between cells and tissues of cell organisms, it is possible to say that these connections between units which differ from cell to cell or tissue to tissue are the essentials for survival of organisms. The different roles of these connections between these similar units help to create sustainable arrangements. Indeed, that is a common point between architectural design and biology. Similar to nature, in architecture, we also need effective organizations and strong relationships between spaces for efficiency in our design. From smallest to largest scales in design, organizations of spatial relationships are the key facts of sustainability. Thus, this study focuses on the physical and social relations of design units in several scales by simulating the organization of cellular living systems.

1. Introduction

For efficiency, aesthetical concerns, and sustainability of production, the use of nature and natural forms can be seen in many fields as well as design. From structure to ornaments, nature has been used in several ways for different purposes of architectural design so far. However, for the 21st century, nature is considered more with its scientific values and is applied in design more comprehensively. Thanks to the advances in biology and its interactions between different fields, nature can be analyzed and used with its complexity in design. Within the use of computational theories and advanced techniques in design field, the morphological processes of living organisms such as emergence, growth, and natural selection of forms can be analyzed and used at a certain level in architecture.

Considering the global changes of the 21st century, the understanding and emulating these chaotic processes and adapting them into design process appears to be one of the efficient solutions for designing more sustainable future. One of the reasons for adapting these natural concepts to architecture is the similarities between the morphological processes of nature and civilization of humans. Especially, as dynamics of nature, the organizations of living systems are highly related to the logic of human civilizations. Both organizations form through their functions, capacities and relationships between their members and the environment over time. Therefore, if some of these strategies are described at a particular level, they can be applied in design field to create effective solutions for architectural design.

2. The Development of Living Systems as Natural Forms

2.1 Chaos and Complexity of Natural Forms

Natural forms are often developed as organization of units in variety of scales through time. All living units, emerge, organize and survive or die depending on environmental circumstances and their design principles given by genetics. These morphological processes mostly rely on the chaos and complexity as two significant features of natural events. These features usually can be seen as determining facts of the emergence and the self-organization progresses of units. As generative progresses of nature, emergence and self-organization of forms are often as chaotic developments within different complexity levels in time. All natural forms occur in chaotic order in variety of scales, changes gradually or instantly through time. While some of these developments and their changing values can be recognized as physical forms, some of them cannot be tracked due to timing and different scales.

Although the emergence and organization of units seem complicated and random, there is always a chaotic order of predefined spatial relationships of units with several constraints and no randomness in these progresses. According to Flake, “Chaotic systems can be easily mistaken for randomness despite the fact that they are always deterministic. Part of the confusion is due to the fact that the future of chaotic systems can be predicted only on very short-term time scales. Chaotic systems possess a form of functional self-similarity that shows itself in fractal strange characters. This fractal functionality, combined with chaotic unpredictability, is reminiscent of the uncertainty found in computing systems."[1] No matter how complicated that the natural systems are defined, the constraints of systems may also change in short term or long term, due to their given genetic information and environmental circumstances and cannot be followed completely. However, most of the changes of these constraints depend on the basic elements' genetic description adaptation to environmental circumstances. Therefore, in order to determine the chaotic order and complexity of systems over time, it is important to describe the basic elements of these systems and expose the relationships between their affiliated units and the environment. When these progresses and adjustments of these features adapted to into architecture, they do not have to be taken as complicated as nature. Although, best results of design developments would come with adapting the exact logic of nature, it is not easy to identify the whole complexity and basics of natural forms and adapt them into architectural design directly. Though, it is possible to identify the physical formation of natural forms by analyzing the organizations of their simplest structures as 'cells' and adapt them at a certain level into architecture. In order to create 'living solutions', the spatial arrangements of units both in nature and architecture should be in specific order which changes quickly or slowly depending on selection of units through time. To adjust these features of living forms to architectural design development, the development of cell-organisms as living systems can be examined and deliberated within several physical constraints.

2.2 How Cells Create Tissues and Natural Forms

In order to adjust the strategies of morphological progresses of living organisms within several constraints to architectural design, basic structure of these living forms should be examined in particular points to determine the most important ones. In nature, with a specific genetic code, the basic structure of a living system, a single cell, combines with its likely neighbors and creates tissues or living systems depending on their genetic design information. As they (tissues) become organized with their neighbors and create clusters by their particularly given obligations, they generate the parts of a living system. Considering these neighborhood relationships between cells and tissues of organisms, it is possible to say that these connections between units which differ from cell to cell or tissue to tissue are the essentials for survival of an organism.

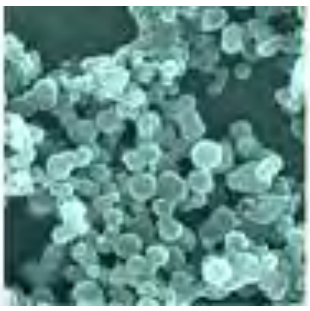


Fig.1 nanobacteria-like particles from human blood as uni-cell organisms
Fig.2 human body and inner parts as multi-cell organisms

In a biological description, cell organisms, "exist at the subcellular level; i.e., the basic functions that are divided among the cells, tissues, and organs of the multicellular organism are collected within one cell. The development of multicellular organisms is accompanied by cellular specialization and division of labor; cells become efficient in one process and are dependent upon other cells for the necessities of emerge and organize, according to their genetic information."[2]

Within this view, the significant similarities can be realized between the development of living systems and architectural organizations. Just like the logic of nature, in architectural design, we also consider the relationships of each unit within physical and social functions of spaces and organize our living environment with the same strategy. Every unit of design forms by these relationships with environment and other members of the system. The most important point of these types of design development, it helps to identify the physical and social relationships between spaces and spatial values of spaces. As a common point of architectural design and biological design, each connection of these similar units and clusters has specific roles and help to create sustainable arrangements. Also, each complex system represents the heterogeneous organization of nature.

Therefore, one of the ways of creating socially and physically sustainable living environments is to create complex and integrated systems through these heterogeneous organizations. The term 'heterogeneous' is considered as one of the characteristics of complex systems of nature. Hensel and Menges suggest that "The complex is heterogeneous, with many varied parts that have multiple connections between them, and the different parts behave differently, although they are not independent."[3] In architectural design, heterogeneous spaces can be formed by the defined relationships between users, functions, materiality and the environment. To create heterogeneous solutions for the design, the order of chaos and level of complexity must be defined in specific constraints. In this study, to generate these spaces through nature's logic, the progress of space development in architecture is considered as living organisms in variety of scales. From smallest to largest scales, defining the spatial relationships of architectural units like natures logic is one of the possibilities to reach a sustainable arrangement of architectural forms.

3. Architectural Spaces as Living Organisms

Although, there are numerous known and unknown features of emergence and organization of natural forms, the basic principle of most of these chaotic structures depend on the complex physical relationships of their simplest units. These morphological processes generally are contingent on the inner and outer relationships of their simplest parts and manipulated by their genetics, and environmental circumstances. Some of the principles of these living solutions can be adapted and applied to architectural design process at certain levels. Like living organisms, the emergence and growth of human civilizations follows the same logic of nature's relationships, only in simpler and slower way. According to Weinstock, "All forms of nature and all forms of civilization have 'architecture', an arrangement of material in space and over time that determines their shape, size behavior and duration, and how they come into being."[4] However, once the nature's logics are applied to design process, one must be aware of dealing with the complexity and chaotic order of nature's progress. Besides, to adapt not only the form, but also the logic of nature in design, the progresses should be simplified to its organization principles.

Even though, the units form freely by their functions within spatial constraints, they are not entirely independent. The cells are formed by the environmental and other units also. According to Flake, "… the complex systems that we simulated included insect colonies, flocking groupings, greedy game players, ecosystems, and statically wired neural networks. Clearly, the natural phenomena that these systems resemble exist on very different spatial and temporal scales. Moreover, the components of these systems also have varying amounts of sophistication: from single cells all the way up to relatively smart animals. However, each of the complex systems has a global behavioral pattern that depends directly on how closely and precisely the components are 'wired' together…..Systems that are tightly constrained fall into persistent static patterns. In between are systems that exhibit global patterns that are more than either of the extremes."[5] Considering this, it can be said that all complex systems in nature are wired (have networks) due to their different spatial and relational values. When these connections are tightly constrained to each other, they create more static patterns; otherwise, they create more flexible forms. The principle of nature relies on the functional and relational communications between its components. Therefore, one of the best solutions to define these functional and relational communications of space is to use network strategies.

3.1 Connecting Spaces by Networks Strategies of Nature

While the term 'network' is generally stated in communication field, the strategies of network systems, the logic of network has been widely used in several disciplines as well as in architecture. The term network is defined as "an abstract organizational model, in its broadest sense concerned only with the structure of relationships between things, be they objects or information, which can be applied to the organization of anything from friends lists to genetic algorithms to global military operations."[6] In general view, networks are the invisible connections between simplest units of forms and show how these units are related and connected to each other. It is possible to say that the morphological process of living organisms are formed by the constraints of networks, reflections of environmental conditions and genetics.

In order to adjust the systems of living organisms to design development and create heterogeneous spaces, the features of the systems can be limited to several constraints such as functional arrangements and distance relations of units through time by network systems. To control the emergence and organization of architectural spaces, several invisible 'wires' can be exposed or created between design units by applying network strategies to process. However, it is not entirely possible to control and limit the morphological process of living organisms, and civilization of humans with several limitations. Though, it is possible to create somewhat predicted solutions for growth of architectural element and to design well-organized and heterogeneous systems for living.

Since the emergence and organization of all forms are based on chaos and complexity in nature, there are numerous features manipulating these progresses. Although it is not possible to adjust all these characteristics of nature's design, some of them be simplified and manipulated in architectural design process. In this view, in order to create functionally and socially efficient heterogeneous spaces, creating connections between units within the physical and relational features and living environment is one of the characteristics of natural formation.

4. Case Study

4.1 Emergence and Growth of Living Spaces

When adapting the organization of cells into architectural design process, the arrangements of relationships between cells can be described in building scale within different functions or specifications such as living units working units or private/public spaces or deeper conditions depending on the strategy level. Also, is important to consider the importance of the scale of relationships during the arrangement progress like in natural formations. Within this framework, in order to simulate the organization of organisms as architectural spaces, two different strategies were used in different scales. In this study, considering these connections of living organisms, the emergence and organization of forms were practiced in different scales as uni-cell and multi-cell systems organization in architectural framework. In both examples, the formations of architectural forms were based on the characteristic relations and connections and distances of units.

4.2 Simulating Spaces as Uni-cell Organisms

In the first example, the organization of spatial units was simply constructed on the relativity of the units. This progress can be embodied as an organization of uni-cellular organisms in biology. Similar functions and forms create bounds to determine their neighbors. However, they do not create static forms. The replacement of the units will not affect the whole living form. Therefore, to define different relations of spaces with different functions, the connections of relative units were limited to distance between similar functions and degree of relativity.

The background of this example can be thought as placement of temporary living units such as emergence shelters. To adjust the order of chaotic organizations of living organisms, the relative families were arranged by their sizes, by the connections between units through specific order. Through this order, the organization can be manipulated to architecture in simpler way and will not be described as a random progress. Because, there is always an order behind the organization of living units mostly shapes in time and it is not easy to follow. For the design development, as an initial step, the physical features of design area were defined within several constraints such as max height, spatial boundaries, conserved areas etc… By some scripting, the outlines of the largest forms (common spaces) were placed by computer in design area with several possibilities (fig.3). Then, these possibilities were eliminated through the defined network values. In this case, the network values were described as distances of relationships. The use of networks helps to eliminate the best related units from numerous possibilities.

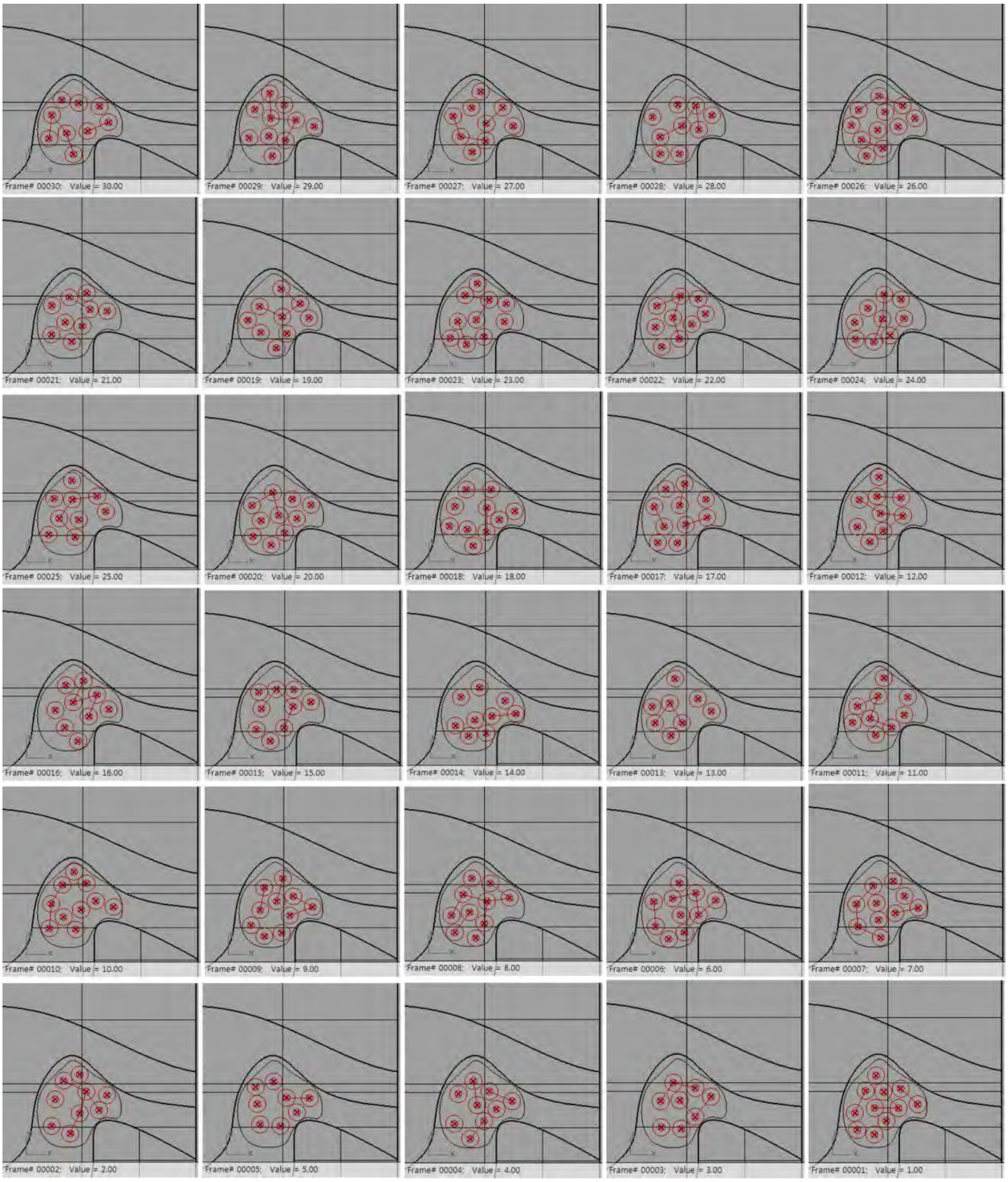

Fig.3 several possible arrangements of design units.

For the next step, the emergency shelters modular arrangements were located starting from the pre-defined common spaces to design boundaries by computer (fig.4). Finally, these shelters were connected through different lengths of network wires to eliminate the non-related (dead) units once more. The units with more than three wires were represented as families with children and others were described as two member families. The purpose of doing this is to create physical connections through social relationships of units in certain scale.

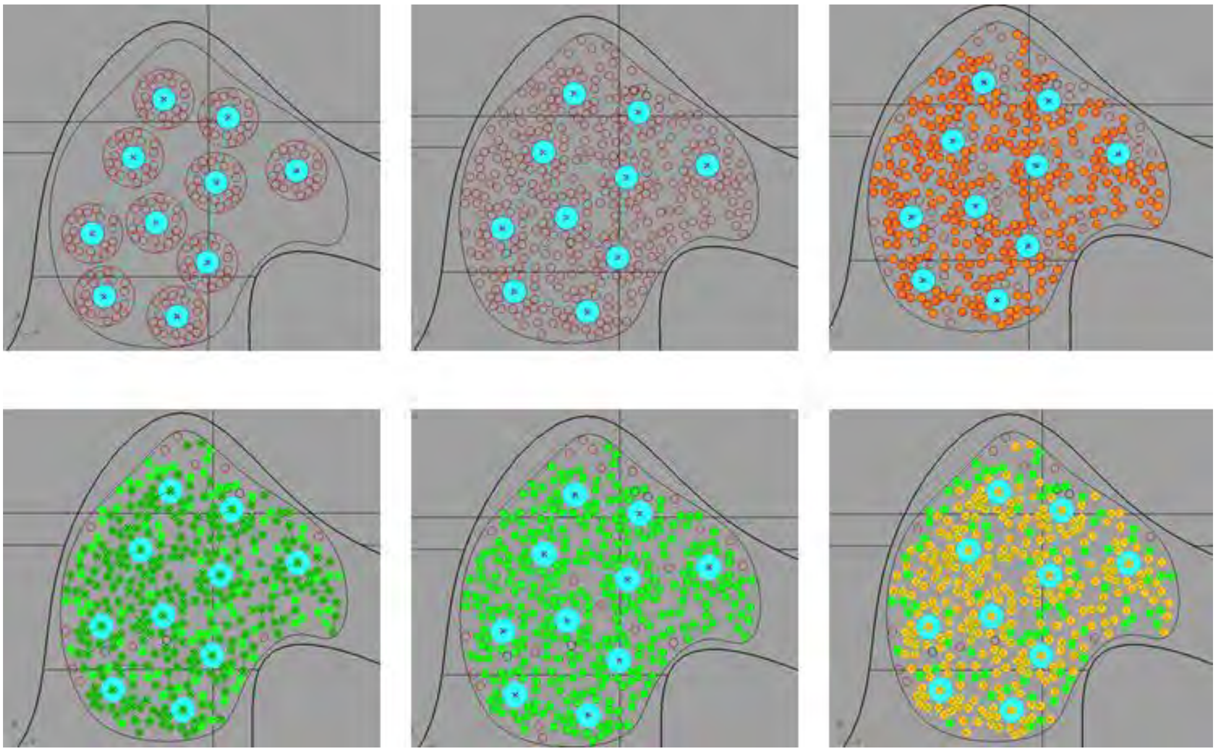

Fig.4 the stages of units' organization in functional order

As a conclusion of first example, the placement of units was generated through the neighborhood relationships. Within this strategy, the sustainability of social relationships can be provided by settling the similar families in specified points. Although there are numerous possibilities for placement emergence points of units, it is up to designer to pick one of them in the beginning and foresee the best efficient solution.

4.3 Simulating Spaces as Multi-cell Organisms

In the second trial, partially different strategy has been followed to create architectural forms with deeper complexity. In order to reduce the randomness placement of units and create the system works as whole, the organization of multi-cell organisms were adjusted as a design strategy. This time it is aimed to create more integrated spaces with different sizes contingent on their distance connections.

The background of the project was setup to create several units in different sizes, functions and distances. As a first step of this case, in order to grow the units in predefined spatial boundaries, several points were described with specified as cores of design units like in the first example. Once more, the network systems were used in specific orders to show the pre-defined invisible relationships of design cells (fig.5). Unlike the first example, the selection of living units were held in bigger pool in 3D frame and constrained by the volume requirements. Within the specific limitations, the end points of these network wires were grouped in 3D frames to support the relationship of similar functions (fig.6).

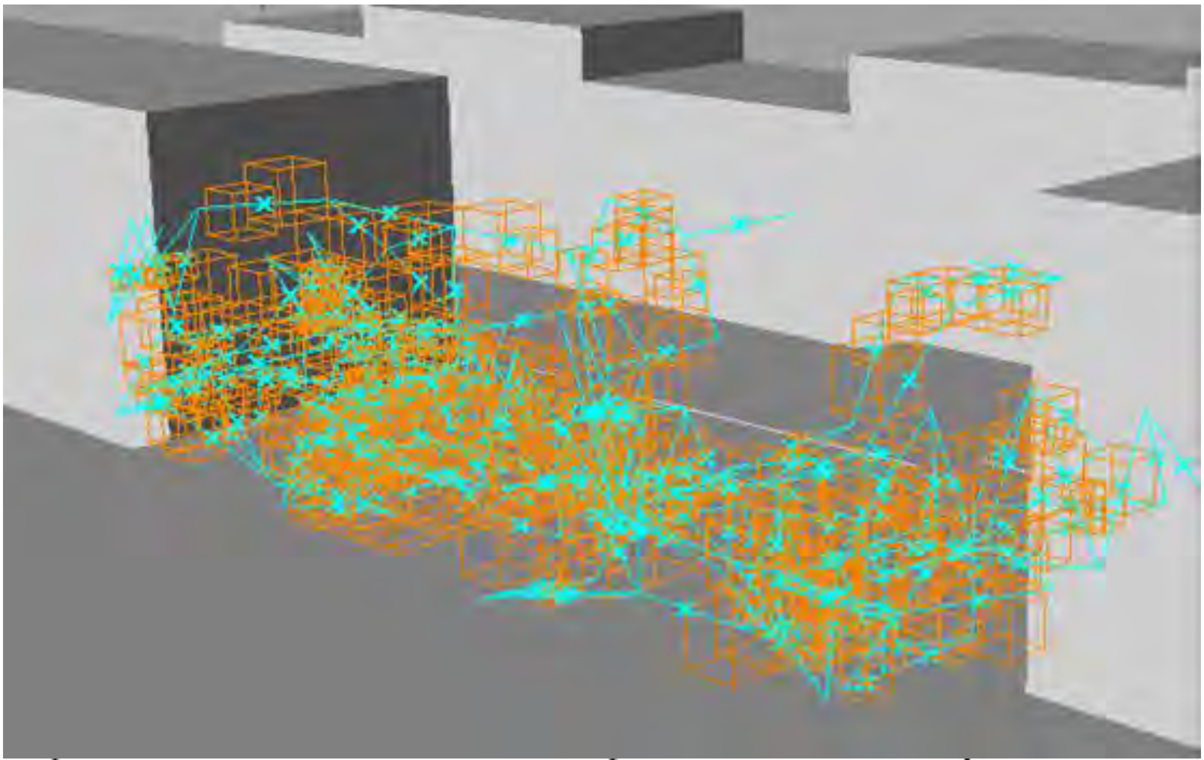

Fig. 5-6 the instant frame of the placement of relative spaces by network connections with specified parameters (volume and distance limits)

After grouping these space cores, the same strategy was applied for each function with different parameters (fig.7). Then, the frameworks of units were drawn to determine the growth of forms in 3d. With this strategy, the architectural spaces were placed in specific order and sized by their relations with other units. Then the groups were eliminated from (dead) non-related units and unwanted volumes by their defined constraints.

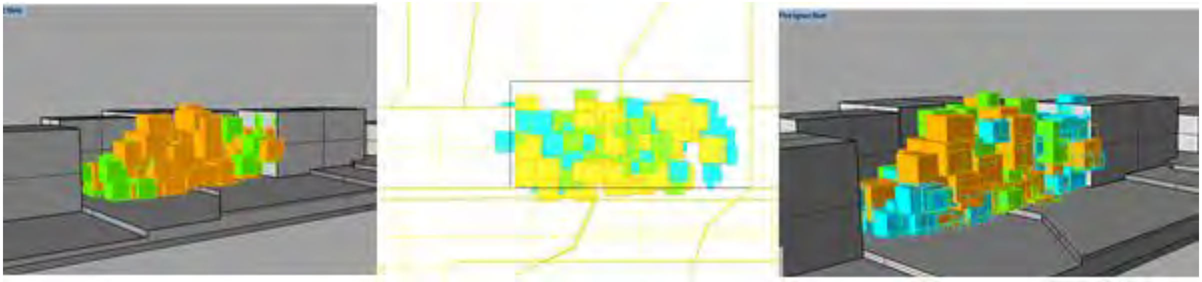

Fig 7 the placement of different space units through specified parameters

After calculating the efficient solutions (defined volume parameters by requirements for each) of each function and size, the instance forms were eliminated. By this procedure, the emergence point of each unit was positioned contingent on the other units and grew or died (disappeared) until reaching the defined requirements by designer with other related units of design.

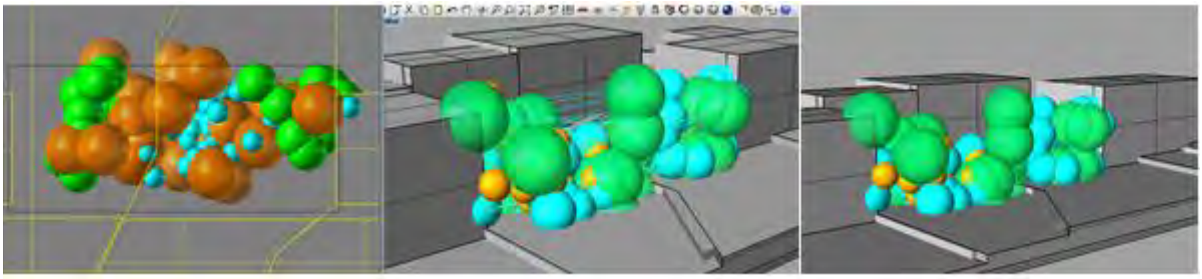

Fig.8 the several possibilities of architectural formations depending on specified parameters.

Conclusion

Although, several constraints were applied to manipulate the design progress, almost infinite possibilities can be generated by the nature's design logic. As reflections functional and social relationships between units, network systems, help to manipulate the complexity and chaotic order of design elements in architecture. By these invisible structures, morphological progress of design elements can be positioned in correlation with other members and particular order. Within this framework, the functional and social connections of design elements through their characteristics, helps to design many unique and efficient solutions. Revealing these connections and adapting them to requirements of physical values help to control the design development in a definite level.

The adjustments of morphological processes such as emergence, organization and natural selection into architecture, can help to design functionally efficient and more integrated heterogeneous spaces. Besides, through these approaches for design arrangements in architectural frame, nature can be measured in architecture not only as a dynamic form, but also as a mentality of the dynamic form.

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Images

Fig.1 http://www.dailygalaxy.com/my_weblog/2007/11/x-cells-five-su.html
Fig.2 http://www.dreamstime.com/stock-image-human-stomach-image2512651