Towards innovative Formation in interior design According to the application of Chaos Theory

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Abstract:
Over the years, many theories of learning have emerged, trying to explain the various movements and behaviors of objects around us, and find the relationship between these objects and their causes. Starting from the behavioral theory that studied the human behavior, passing through the theory of prediction where a compatible result could be predicted from any single action, till reaching the Chaos Theory.

As Being able to explain a number of issues that the previous scientific theories stood still without having any reason or definition for such issues, Chaos theory has attracted a great attention by its ability to find a link between disparate things, or anticipating the interrelationships among them, even if looking random, and following non-linear paths, but repeated in such an organized and nearly symmetrical way as if they were attracted back to a specific point of attraction.

In an attempt to reach the seemingly invisible system of phenomena, behaviors, or movements, The Chaos Theory try to construct some rules needed for its study and utilization of its applications. Representing the practical application of the Chaos Theory, Fractal Geometry could be used to formulate a wide range of design innovations in interior, furniture design and their complementary products either in the field of interior design or the field of product design.

Research Query:
To what extent is it possible to use the applications of Chaos theory in the interior, furniture design and their complementary products?

Research Objectives:
1. Defining of Chaos theory and Fractal Geometry as being the application of Chaos theory, and their role in interior, furniture design and their complementary products.
2. The way of using Fractal geometrical forms and their creative potentials in finding different and innovative solutions in interior, furniture design and their additives and complementary products leading to a non limited collection of modern and contemporary products

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Hypothesis:

Scientific studies of mathematical and philosophical theories could offer various, innovative solutions that could meet the user needs in the field of interior design & furniture and its complementary products.

Research Methodology:

Descriptive analytical method is used relying on the compiling, comparing and analyzing of information and facts in order to get acceptable perceptions, ideas and considerations.

Keywords: Chaos Theory – Interior Design – Innovative Formulation.

Introduction:

As the concept of chaos means disorganization, the chaos theory is completely far away from that.

By checking what surrounds our life, we could easily notice that nothing happens or exists in coincidence, anything or even simple things that seem to be chaotic, are subjected to accurate, complex calculations and certain laws, such as (rotation of the earth, the galaxy's attitude in the universe, the motion of electrons around the nucleus, the body's internal tissues and the growth of plants) everything that seem to be random in our eyes, is actually a part of a chaos system that the human mind is unable to perceive. (3)

1-Chaos theory:

In 1908 a scientist named "Poin Care" wondered about the reason which is responsible for the difficult and inaccurate prediction of the weather made by the meteorologists, he found that the neglecting of small fractions in mathematical equations is the reason for all that. In 1963 a mathematician called "Edward Lorenz" was able to prove that in a paper entitled "Deterministic Non periodic Flow" while he was trying to create a mathematical model to predict the weather. He found that small changes in the initial state of some systems (Chaotic systems) could lead to great changes in the final state, which he introduced as the "Butterfly effect". The concept is that the movement of a butterfly wing in China for example could lead to a hurricane thousands of kilometers away (U.S.A for example), and that is due to the complex meteorological system and his great effect on any of the factors no matter how weak or simple it was. Lorenz was able to define the Characteristics of chaotic systems as follows:

1-1 Characteristics of chaotic systems:-

- As the results (in many cases) can not be predicted accurately, due to the huge number of factors affecting the system, chaotic systems could be described as the systems that have a high degree of complexity.
- The abundance of inputs due to the huge number of factors affecting the chaotic systems.
- Sensitivity to variables no matter how simple they are.
- Even the shapes and figures that could be found in nature and seem to be chaotic, are directly subjected to mathematical equations.
- The used equations in the study of these systems refer to a type of mathematics which is defined as fractal mathematics.
- The ability to produce a very complex system from simple inputs.(Fig.1)

Plant leaves and shapes of butterflies

Lightning forms

Ground cracks

Fig. (1) Examples of chaotic systems that exist in nature

The most important characteristics of chaotic forms are self-adaptation, dynamism, flexibility, Nonlinearity, self-organization, self-similarity (Fractals) and Strange Attractors (2)

Some scientists and mathematicians cradled the emergence of "Chaos Theory" such as "George Cantor" the author of "The theory of Sets" and the one who was able to introduce the term "Infinity" as a mathematical term reaching the meaning of "Infinity" through what was defined as "Cantor Group" (Fig. 2 – Fig. 3). (6)

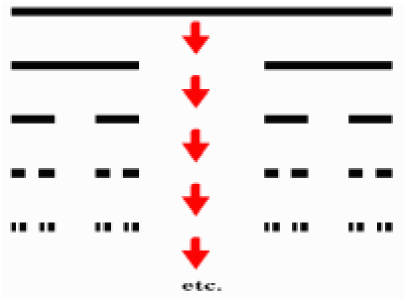


Fig. (2) A detailed diagram of Cantor set

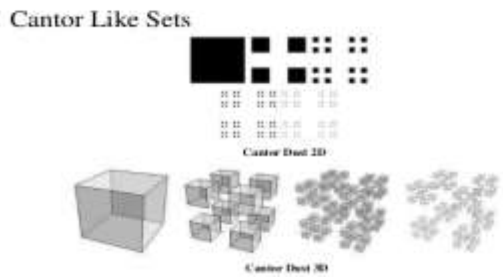
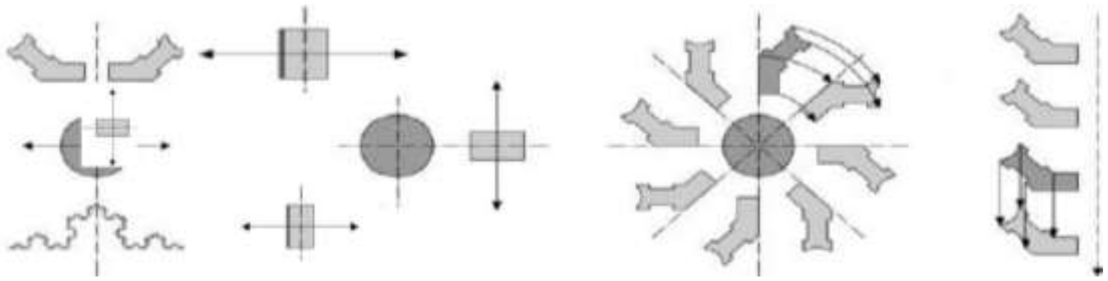


Fig. (3) A detailed diagram of Cantor set in 2D & 3D

In order to configure that group "Cantor group", a one unit line should be drawn, then divided into three sections, then the middle section should be deleted. After the deletion two lines appear. By repeating the previous steps on both lines and even the resulting lines until the difference between the line and the point could not be defined, leading to the creation of a standard Cantor set, but the question that still remains is how could we find the length of the rest of the points after deletion, whose lengths are equal to zero in the infinity.

Cantor set is a self similar, uncountable and totally disconnected number of parts (points) that are exactly similar to the original one (9). These properties are applicable in 2D or 3D figures (Cantor Dust 2D, 3D) as shown in Fig. 3.

These characteristics could be easily noticed in nature as the chaos is not entirely random but has an implicit system in its essence. The complexity of a chaos formal system exists through the fractional, nonlinear dynamics and transformations, while complexity could be self generated through repetition using a number of methods such as transition, rotation, deviation, resized repetition and reflection as shown in fig. 4.



Reflection relationship **Resize or rescale relationship** **Rotation relationship** **Transition relationship**

Fig. (4) Different examples of repetitive dynamic transformations (4)

As trees are not a triangle and clouds are not a square or a circle, the Euclidean geometry failed to describe various forms or figures in nature that seem to be irregular or chaotic, and the problem was how could we manage to do that?

Beniot Mandelbrot was the one who managed to give an answer to the previous question by introducing the concept of Fractal Geometry.

2- The concept of Fractal Geometry:-

Fractal is a branch of mathematics which is completely different from the Euclidean geometry that deals with complex shapes or figures having fractional dimensions.

The term fractal was derived from the Latin word "Fractus" which means fragmented or broken. Mandelbrot, the one who was interested in the architecture studies of chaotic phenomena such as beaches, mountains, clouds, etc., firstly introduced the term Fractal geometry by the mid-seventies of the twentieth century as being able to describe irregular or chaotic forms. He found that these forms are logic, they have rules and follow certain patterns; therefore they aren't random as they seem to be. (5)

-Thus, we can say that the Fractal geometry succeeded to give a methodological description and construct the first mathematical model for complex forms that are generated from the repetition of non-linear equations. (12). Despite these forms have an infinite circumference; they occupy a specific spatial space. (11)

-As it is tightly attached to the natural forms and various phenomena, Fractal geometry could be described as "The geometry of nature".

-Fractal geometry was defined in many different ways; one of the most important definitions is "A number of shapes that are generated due to the repetition of non-linear equations of simple geometric shapes such as the triangle, square and circle, these shapes are Classified in complex sets. (1). Fractal sets could be classified according to their presence as shown in the following diagram.

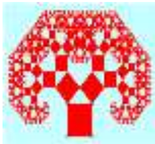
The organization of fractal sets according to their existence		
Nature Fractals	**Algebraic Fractals**	**Geometric Fractals**
Fractal forms are found around us in nature such as branching forms (blood vessels – trees – rivers – lightning…etc) which originate from the repetition of the branching process with different sizes  precise and creative spiral forms could be also found in snails &Aloe plants  	Fractal forms could be obtained from the repetition of simple mathematical equations for a number of times by the use of computers. These repetitions could occur in thousands of times forming an infinite number of creative fractal form  	Fractal forms could be obtained from repetition of addition or deletion or both of them on certain parts of a geometric shape for example the triangle of Sierpiniski. The repetition process takes place by the use of division and the Koch curve, in the branching form, where the middle third is substituted by an isosceles triangle that equals to that third. 
Diagram (1) the organization of fractal sets according to their existence in nature		

2-1- Characteristics of Fractals:

a. Self-similarity:

As the constituent parts of many of these forms are repetitions of the main form, therefore fractals are fairly symmetrical if not identical. The repetition of details occurs gradually in a descending way leading to an indefinite continuity. Self similar forms have the ability to preserve their own shapes even under the effect of different scales. Various types of similarity could be stated such as self-similarity, exact similarity, quasi &statistical similarity.

Categorization of fractals					
According to self-similarity			**According to the method of generation**		
Exact self-similarity	**Quasi self-similarity**	**Statistical self-similarity**	**Iteration fractals**	**Running time fractals**	**Random fractals**
The strongest type of self-similarity, which takes place by division of the original shape to smaller parts, these parts are exactly the same in shape as the original shape (triangle of Sierpiniski)	Fractals are nearly similar in various scales, it contains some non organized, smaller copies of the original shape as	The weakest type of self-similarity, where the repetition doesn't take place in a complete disciplined way. It is also called the self-similarity in nature as (earths cracks-fragmented rocks)	It depends on a clear Geometric substitution rule for every fractal as (the tree of Pythagoras)	A repetitive relationship for a point in the space. New details that are similar to the original shape when enlarged as (set of Hyper-engineering as Mandelbrot)	These fractals are characterized by statistical self-similarity as a part of the shape is statistically similar to the original shape as(beach shores)

	(Mandelbrot)  group				
Diagram (2) categorization of fractals according to self-similarity and the method of generation					

b. Fractal Dimension:

Fractal dimension indicates the extent of complexity of a form or shape. The more complex the shape is the greater fractal dimension it has. As any point has no dimensions, a line has one dimension, a 2D shape has 2 dimensions and a 3D shape has 3 dimensions, therefore the dimension in any closed system should be a positive integer. Although the dimensions in dynamic systems means the number of variables, it has a different, more complex form and meaning in fractals, that was the cause that let Mandelbrot make use of what he called Fractal dimension.

Fractal dimension couldn't be stated as a specific measurement but a repetition of similar forms on different scales, its curve is located in the fourth dimension 4D that contains the other three dimensions (First, Second, Third) and results from the following equation:

D = log (N) / log (r), where D = Fractal dimension, N = number of self-similar forms (the number of cells in which the figure is divided to) while r = amplification rate. (10)

c. Replacement rule:

When a certain fractal is formed or generated one of its constituent parts could replace any other generated fractal but in a more complex way than the previous one.

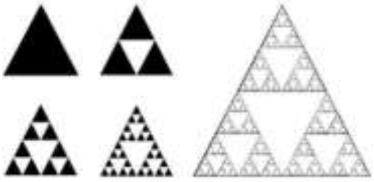
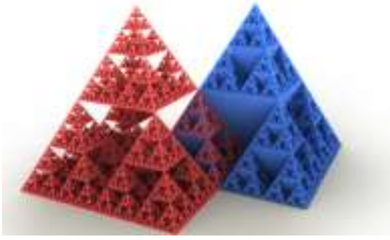
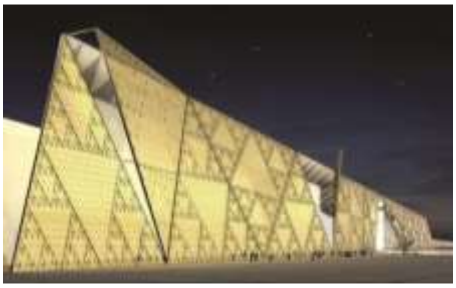
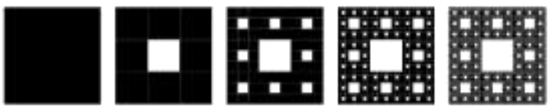
d. Iteration:

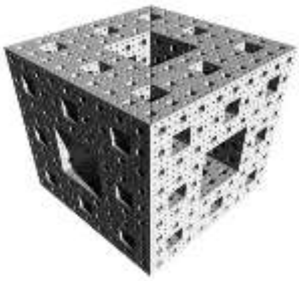
Fractal forms are generated due to the repetition of a particular shape or certain rule for several times. Every repetition output is used as the next repetitive input, and then the fractal is formed. The more the geometric repetitions are used, the more complex the shape becomes, the greater number of creative fractal forms we have as shown in Fig. (5-7).

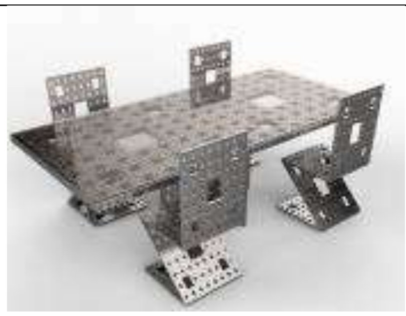
 **Fig. (5)**	 **Fig. (6)**	 **Fig. (7)**
Figures from (5 - 7) Some examples that achieve the concept of repetition in interior design & furniture		

3- The direct applications of Chaos Theory and Fractal Geometry in design:-

Fractals were directly used in various engineering designs as follows:

Fractals of the well-known repetitive function systems	**Direct applications in interior and furniture design**
Sierpiniski 2D triangle It is originated from a solid equilateral triangle where the inner triangle resulting from the intersection of the medians of the sides of the original triangle was removed, three inner triangles now exist, and by repetition we can get nine inner triangles, till reaching an infinite number of triangles after applying a number of repetitions. Fig.8   **Fig.9** **The 3D four faces pyramid of Sierpiniski**	 **The design of the triangle of Sierpiniski was used in the plastic facades of the Grand museum located in Giza Fig.10**  **As well as the decorations of a mosaic floor located at the Cathedral of ANAGNI in Italy which is inspired by the triangle of Sierpiniski Fig.11**
The carpet of Sierpiniski A fractal geometry self-similar repeatedly suspended form where a square is horizontally and vertically divided to three equal squares. By deleting the square on the middle, and after a number of repetitions the resulting form is as follows. **Fig.12**  **The 3D cube of Sierpiniski where the characteristics of repetition and self-similarity could be easily noticed.Fig.13**	**The direct use of the carpet of Sierpiniski in the design of floor forms.Fig.14**  **Also the carpet of Sierpiniski was used to design a dining table and chair by John Brevard as follows.Fig.15**





Cantor set

Firstly introduced by George cantor in the 19th century. His set depends on the deletion of the middle third of the straight line in each of the iterations(8) as it was previously mentioned. Fig.16

The analysis of Cantor set could be used in various design models, partitions and columns ornamentation.

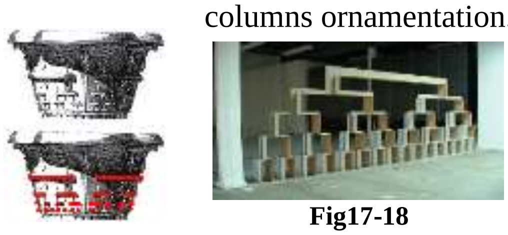


Fig17-18

Figures from (16 -18) Direct design applications for the models of Sierpiniski and Cantor

4- The role of Fractal Geometry in Environmental design treatments:-

Fractal geometry has had a tangible role in environmental design, for example, it has contributed to find a suitable and contemporary solution that could overcome the problems of glass buildings, and prevent the entrance of sun rays. An Islamic shading system (Mashrabeya) was used in the twin towers of (Albahr) located in Abu Dhabi,(13) that design was selected as the best of architectural design in terms of innovation and environmental standards. Fractal geometry was used in the design of solar umbrellas that have the ability to open and shut in an automatic way according to the sun's intensity. Despite of seeming to be so complex, the design of these umbrellas is actually constructed from the repetition of a simple fractal unit. By the use of these umbrellas, a contributable effect in protecting the building from sun and reducing the energy consumption was noticed. Fig.19

Fig. (19) Shows the twin towers of "Albahr" and the solar umbrellas that were constructed from fractal geometry

5- The role of computer techniques in the development of chaotic forms design thoughts:-

By the use of various design, drawing and sketching computer programs, it was available to have a great opportunity to navigate through creative design thoughts far away from the traditional Euclidean forms. Computer software has passed through two phases, **firstly**, it was considered as a design aid to the designer in the sketching process as it is quite easy to modify and save any changes upon the sketch.

Secondly, the digital modeling stage, in which the designer can use modeling that completely stimulates the real environment in the design process, with the ability to test and evaluate his designs anytime and even before implementation.

The most important features of using computer techniques in complex designs are:

Fluency: The ability to generate many design alternatives that suits the real environment.

Flexibility: The ability to generate or innovate a wide range of creative design ideas.

Originality: Singularity and non-imitation or repetition of consumed ideas (unique design).

6- **Applying the characteristics of chaos theory and fractal geometry on furniture and products models:-**

 **Fig (20) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of a door**	 **Fig.(21) Using of resized Iteration as one of the characteristics of Chaos theory in the generation of book shelves**	 **Fig.(22) Using of rotation Iteration as one of the characteristics of Chaos theory in the generation of a door**
 **Fig.(23) Using of deletion Iteration as one of the characteristics of Chaos theory in the generation of a coffee table**	 **Fig.(24) Using of deletion Iteration as one of the characteristics of Chaos theory in the generation of a buffet**	 **Fig.(25) Using of reflection Iteration as one of the characteristics of Chaos theory in the generation of a chair**

 **Fig.(26) Using of nonlinear Dynamic random Iteration as one of the characteristics of Chaos theory in the generation of a buffet**	 **Fig.(27) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of a buffet**	 **Fig.(28) Using of resized Iteration as one of the characteristics of Chaos theory in the generation of a buffet**
Figures from (20 - 28) Show various examples of doors, furniture units such as tables, chairs, counters, buffets, and cupboards all inspired by the main principles of chaos theory such as the complexity as well as the principles of fractal geometry such as iteration and self-similarity (exact - quasi – statistical).		

7- Applying the characteristics of chaos theory and fractal geometry on Walls cladding

 **Fig (29) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of wall treatments**	 **Fig.(30) Using of Additive Iteration as one of the characteristics of Chaos theory in the generation of partitions**	 **Fig.(31) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of wall treatments**
 **Fig.(32) Using of Division Iteration as one of the characteristics of Chaos theory in the generation of wall treatments**	 **Fig.(33) Using of Additive Iteration as one of the characteristics of Chaos theory in the generation of partitions**	 **Fig.(34) Using Division Iteration as one of the characteristics of Chaos theory in the generation of partitions**
Figures from (29 - 34) Shows various examples of the use of shapes or figures that seem to be chaotic or fractal in the interior design of either walls cladding, or partitions		

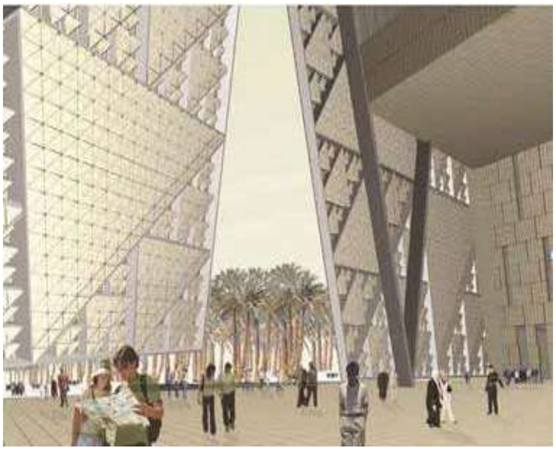


Fig. (35)

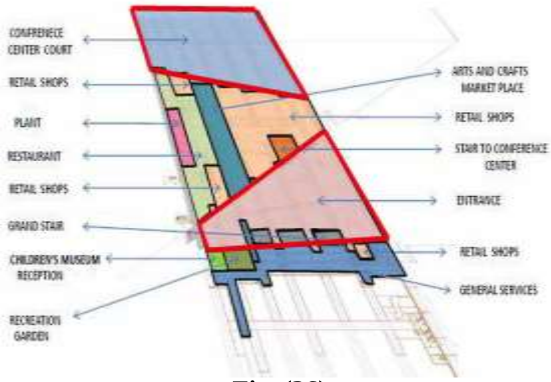


Fig. (36)

Figures (35 - 36) Show the direct use of fractal geometry (Sierpiniski Triangle) in the facades of the Grand museum in Giza as a plastic, aesthetic and environmental solution as well as the distribution of activities all-over the landscape

8- Applying the characteristics of chaos theory and fractal geometry on ceiling treatments:-

Fig (37) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of a Ceiling

Fig.(38) Using of deletion Iteration as one of the characteristics of Chaos theory in the generation of Ceiling

Fig.(39) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of a Ceiling

Fig.(40) Using of Dynamic Iteration as one of the characteristics of Chaos theory in the generation of a Ceiling

Fig.(41) Using of resized Iteration as one of the characteristics of Chaos theory in the generation of a Ceiling

Fig.(42) Using of Self-Similarity as one of the characteristics of Chaos theory in the generation of a Ceiling

Figures from (37 - 42) Show various examples of ceiling treatments that achieve the principles of both Chaos theory and Fractal geometry

Fig.(43) Using of Dynamic Iteration as one of the characteristics of Chaos theory in the generation of a Ceiling

Fig.(44) Using of resized Iteration & Self-Similarity as characteristics of Chaos theory in the generation of Ceiling & wall treatments

Fig.(45) Using of rotation Iteration as one of the characteristics of Chaos theory in the generation of a Ceiling

Figures from (43 - 45) Show various modern and contemporary examples of ceiling and wall treatments that achieve the principles of both Chaos theory and Fractal geometry

9- Nature as a source of inspiration for the interior design complementary products:-

As chaos theory is the responsible for the explanation of natural phenomena, their reasons, shapes and forms, therefore the inspiration of nature in order to design complementary interior design products could be stated as one of the most chaos theory outputs.

The following examples represent a number of nature inspired complementary light units, that seem to be chaotic in form but actually they refer to a system of high precision and creativity.

Fig. (46)

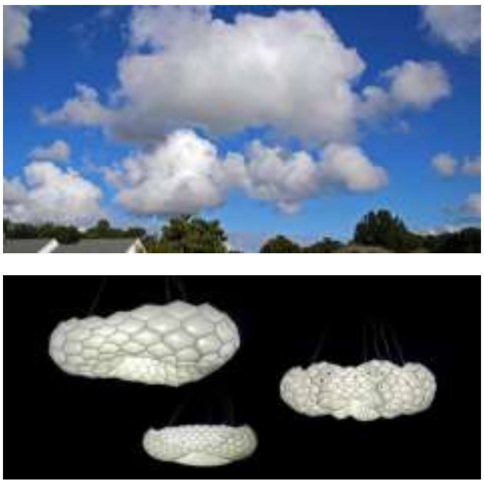


Fig. (47)

Figures from (46 -47) Show ceiling lighting modules that were inspired from organic forms as Pine and natural chaotic elements as clouds, having a fractal nature, which can be used as complementary products in interior design

Fig. (48)

Fig. (49)

Figures from (48 - 49) Show a number of Vertical lighting units that were inspired from natural elements that depend on simple repetition in the formation of their shapes in a fractal way such as pineapples and broccoli plant, these units can be used as complementary products in interior design

Fig. (50)

Fig. (51)

Figures from (50 - 51) Show some ceiling lighting units having either organic or geometric repetitive specific format cavities in their body in order to reflect shadows having the fractal nature when used as a complementary light source in interior design (7)

From the above we can deduce that the human consciousness is constantly developing and evolving with science, theories and their interpretations. This consciousness is always attached to the human cognitive, physical and design needs…etc. Many scientists were inspired by chaos theory and fractal geometry in their attempts to explain complex systems. Various innovative and creative designs that were obtained from their applications could be used in the fields of interior design, furniture design as well as the design of complementary products. In such a way the research methodology has been achieved from the possibility of scientific and applied studies of both mathematical and philosophical theories to contribute in the provision of creative and innovative solutions in interior design and its complements that comply with the user needs.

Conclusion:

1. Chaos theory and fractal geometry had a direct effect in the innovation of complex and creative forms and design solutions that could be modified by the use of digital computer techniques.
2. What takes place in the design process is just dissolving of systems and organizing of chaos, which could be described as a process of demolition and reconstruction, in order to obtain various innovative designs.

3. Fractal geometry could be stated as important resources for the design process, as it depends on repetitions, self-similarity and scale modifications in the generation of design innovations.
4. Contemporary and innovative designs could be obtained from the interference effect between interior design, product design, and scientific theories like chaos theory.
5. Fractal forms could be defined as an experimental entrance and a creative feature for both interior design and product design.
6. Fractal geometry plays a very important role in the improvement of creative design thinking.
7. As the principles of fractal geometry could be easily noticed in the most of the living organisms, and as the main target of bionic products is to simulate nature, therefore it is quite easy to say that bionic products follow the principles of fractal geometry.

Recommendations:

- The urgent need to make use of the applications of scientific, philosophical and mathematical theories in the fields of art and design, such as interior design, furniture and product design, due to their ability in innovating various solutions that are compatible with user needs.
- The necessity of teaching fractal geometry in various educational stages in order to develop the concept of creative thinking among students.

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