

Softwares as powerful tools in modern biophilic and human-friendly architectural design: visual and tactile aspects

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In the modern era of increased stress levels in all aspects of human lives, the built environment plays a significant role, both negatively and positively. Cities and buildings account for a major portion of CO₂ emissions, waste production, noise, traffic jams and energy consumption. On the other hand, besides the well-known and necessary eco-friendly measures, a smart built environment can be among the top positive stimuli for humans in regard to the connection of the environment and human psychology. Numerous design techniques that use nature and nature-like forms in its core, commonly known as biophilic design, are proven to have positive effects on the human brain, namely the relaxation and stress-relief centres. This paper aims to research and present the possibilities in creating a human-friendly and biophilic visual and tactile built environment that is made possible through use and development of softwares and technology. A special focus is given to application of fractal geometry in 2D and 3D architectural features and ergonomic urban furniture based on parametric modelling. Keywords: architectural design, biophilic design, software, fractal geometry, ergonomics.

Introduction

Centuries ago, the greatest theoretician of architecture, Vitruvius, said the never forgotten sentence: "Firmitas, Utilitas, Venustas". Architects have always struggled not only to obtain, but also to define the Venustas, i.e. delight.

People are aware of the immense power of Venustas on the mind's well-being. The Golden Ratio was, for centuries, the key to obtaining Venustas. Ancient Greek art and architecture relied on this proportion. The proportion itself relied on nature.

This magical number, 1.61, is deeply carved in snail shells, pineapples, human face and body, the Great Pyramid of Giza, the Parthenon, Vitruvian man, Mondrian's paintings, etc. People always strove to create delightful objects for a single reason: its beneficial effect on humans and the environment. Architects have tried to create a measure that would combine form and function in architecture.

Le Corbusier succeeded by creating the Modulor as a measure of mathematical proportions in the human body that could be universally applied to everything a human creates, including architecture. It is based on achievements of the Ancient civilizations and the Renaissance that put a man into the center of the Universe, declaring him a measure of all things.

More importantly, it puts the man's needs into the focus of attention, with one sole purpose: creating a better place to live in.

This paper presents the possibilities of using developed technologies, mainly softwares, in producing architectural works with biophilic, and the effects that relieve stress on humans, through visual and tactile examples.

Use of softwares in creating and analysis of visual biophillic patterns

Stress relief is one of the burning issues in psychology, medicine and wellness today. The exact pathways of the environment's subconscious influence as stimuli on processes in human brain are still somewhat unknown. However, the influence of the built environment and art on human behaviour is certain and its specific forms do help relieve stress. Many studies have, as expected, shown that natural or natural-like environment is highly more preferable than standard, built environment [Kaplan and Kaplan 1989], since they help reduce physiological stress [Ulrich 1993] and increase concentration levels and focus [Kaplan 1995].

A very interesting recent study on human EEG response to viewing fractal patterns showed that certain fractals generate responses in the frontal brain region which makes them adequate for relaxation [Hagerhall et al. 2008]. The amazing capability of the human brain to associate one thing with another, even before the conscious levels of our minds become aware of it is the key to using nature-like forms in any kinds of design. This was proven by a study where patients in a hospital were surrounded by nature-like images. The levels of stress and anxiety were significantly lower than in patients surrounded by a typical hospital environment [Ulrich 1993]. This miraculous characteristic is the catch that is somewhat neglected in contemporary art, architecture and urban design, au contraire to the fact that it used to be one of the strongest design pillars of the ancient world. Fractal geometry, that became known under that name relatively late in science (by Mandelbrot in the 1970s), is today proven to be the core of the design in many structures that have mesmerized masses with their beauty and delight for centuries, starting with the Mesoamerican pyramids, through ancient mosaics, Islamic ornaments and remarkable Hindu temples, Gothic architecture elements, to Le Corbusier and Wright (present in different fractal dimensions).

Use of softwares in analyzing and creating fractal geometry patterns in design

The role of ornaments in architecture has many aspects; aesthetic, symbolic, cultural, psychological. A mathematician Benoit Mandelbrot said that "Clouds

are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line" (Mandelbrot in Bovill, 1996, 4). This sentence picturesquely encompasses different areas where fractal geometry can be found: "visual qualities as art, their (fractal) relationship to explain natural processes, music, medicine, and in mathematics" (Pickover 1996). Despite the fact that Mandelbrot (1977) coined the term in the 1970s, from "the Latin adjective fractus, which has the same root affixation as fragment and means 'irregular or fragmented'; it is related to frangere, which means 'to break.', mathematicians have introduced functions and constructed patterns based on fractal geometry even before.

Another explanation of the fractal dimension is that "it is a statistical quantity that gives an indication of how completely a fractal appears to fill space, as one zooms down to finer scales." (Xiaoshu Lu, 2012). In mathematical language, "fractal dimension shows the relationship between the scaling factor and the number of smaller pieces that the original construction is divided into" (Batty and Longley, 1994), or:

$$D = \frac{\log(a)}{\log(\frac{1}{s})}$$

where a is the number of pieces and s is the reduction factor. (Sala, n.d.)

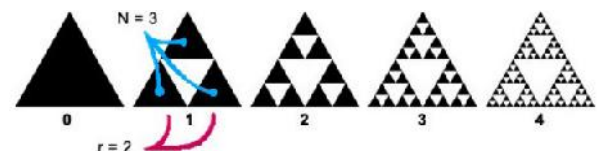


Figure 1: Creation of Sierpinski's triangle, source: Fractal Foundation (n.d.) <http://fractalfoundation.org/OFC/OFC-10-3.html>, retrieved on 04.11.2016

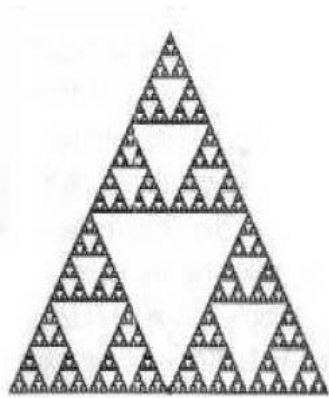
The above figure represents the N, number of parts and r, scaling factor. N equals to 3 and r equals to 2. From a simple equation we get the fractal dimension of the Sierpinski's triangle:

$$D = \frac{\log(N)}{\log(r)} = \frac{\log(3)}{\log(2)} = 1.585$$

The presence of fractal geometry in architecture is widespread, not only in terms of its fields, but also with respect to civilizations.



(a)



(b)

Figure 2.: a) Fractal geometry-based mosaic from the floor of the cathedral of Anagni (1104) b) Sierpinski gasket; Source: N. Sala, Some News About The Fractals, 1997, resource available online from: [http:// www. arch. unisi.ch/fractals/fract1e.htm](http://www.arch.unisi.ch/fractals/fract1e.htm)

Figure 2. shows cathedral of Anagni's "floor mosaic showing the fractal at its fourth stage of iteration" (Sala, 1997) and Sierpinski gasket fractal.

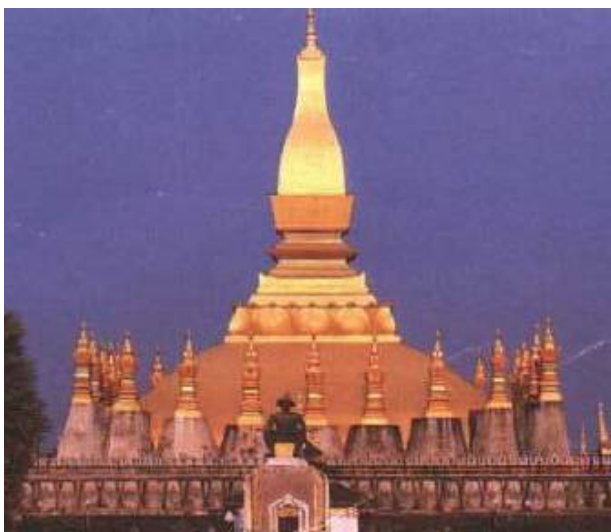


Figure 3.: The Sacred Stupa Pha That Luang in Vientiane, Laos, source: Marefa (n.d.). Retrieved 17.11. 2016, from <http://www.marefa.org/index.php/>

Figure 3. is an example of fractal – based temple architecture, where the fractal principle is evident in the repetition of the same element in different scales. In his work, *Fractals and the Birth of Gothic: reflections on the biologic basis of creativity*, Goldberger (1966) discusses the relationship between fractals and Gothic art and architecture and their common features.

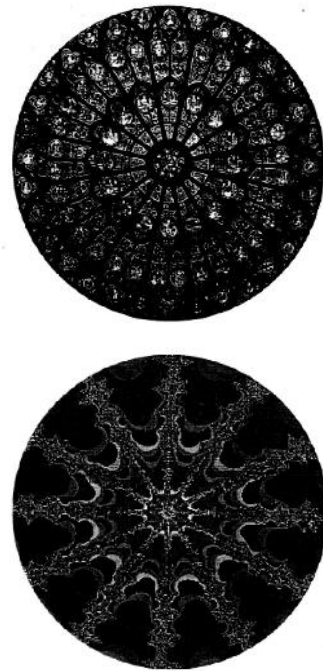


Figure 4.: a) North transept rose window, Notre-Dame de Paris, b) 12-fold symmetry in portion of Mandelbrot set magnified by a factor of 37 trillion, source: source: Goldberger, A. (1966). *Fractals and the Birth of Gothic: reflections on the biologic basis of creativity*. Stockholm Press 1359-4184

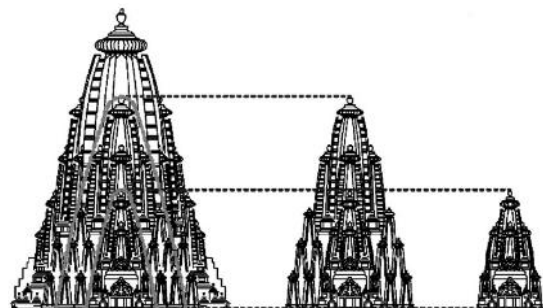


Figure 5.: Hindu temple fractal geometry characteristic, source: Joye, Y. (2011). *A Review of the Presence and Use of Fractal Geometry in Architectural Design*. *Environment and Planning B: Planning and Design Environ Plann B Plann Des*, 38(5), 814-828. doi:10.1068/b36032 (credits to Iasef Md Rian)

Xiaoshu Lu (2012) describes the application of fractals in Persian art: "In the Middle East, fractal patterns have been adopted widely in designing stucco, a typically Persian art form for the decoration of dome interiors."



Figure 6.: Stucco dome interior in a private house in Kashan. Four attractors around the main one in the center, source: Xiaoshu Lu, D.C.C. (2012). Fractal Geometry and Architecture Design: Case Study Review. Chaotic Modeling and Simulation (CMSIM), 311-322.



Figure 7.: Jami Masjid Champanar, source: 10 Famous Stone and Rock Indian Sculptures. (n.d.). Retrieved 17.11.2016, from <http://hubpages.com/art/Famous-Stone-and-Rock-Carvings-in-India>

Kumar (2001) discusses the position of a man in a mosque: "While praying in a traditional mosque, the Muslim in a sense returns to the bosom of nature, not externally but through the inner nexus which relates the mosque to the principles and rhythms of nature."

The role of ornaments in mosque interior is multiple, but mostly symbolic, as Nasr (1990) describes Shah mosque in Isfahan, Iran, as if "an echo from Heaven [were] to remind earthly man of his heavenly origin." Both practice and theory have shown that fractal geometry has beneficial effects on human brain and behaviour.

The application of different softwares for the generation of fractal geometry – based design, and the analysis of fractal dimensions of the existing ornaments enables the creation of patterns and design elements on the principles of fractal geometry, as well as analysis of their effects on humans in a significantly shorter period of time when compared to managing this process manually. The example below shows a software-generated ornament based on fractal geometry:

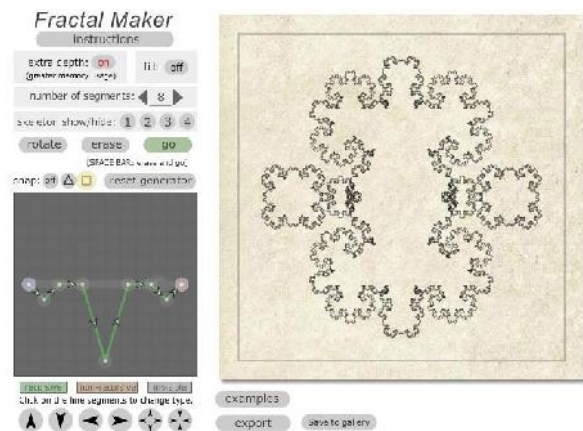


Figure 8: Applying basic fractal geometry principles to create a simple ornament in Fractal maker software (Author)

Another example of the practical use of fractal geometry analysis softwares is the analysis of the existing ornaments visual values. First, one sample, a drawing of an ornament on a dome of Sheikh Loft Allah Mosque in Isfahan, Iran, was analysed in ImageJ, image processor software, using FracLac, fractal analysis plug-in.

Box Counting analysis was conducted in order to obtain the fractal dimension of this ornament, with the aim of proving its fractal nature.



Figure 9: Ornament of the dome of Sheikh Lotf Allah Mosque, Isfahan, Iran (Kuppel der Moschee, orientalische Ornamente aus Isfahan, Iran (Depositphotos). Available from: <http://de.depositphotos.com/17420297/stock-photo-dome-of-the-mosque-oriental.html> [accessed on 08.10.2016.]

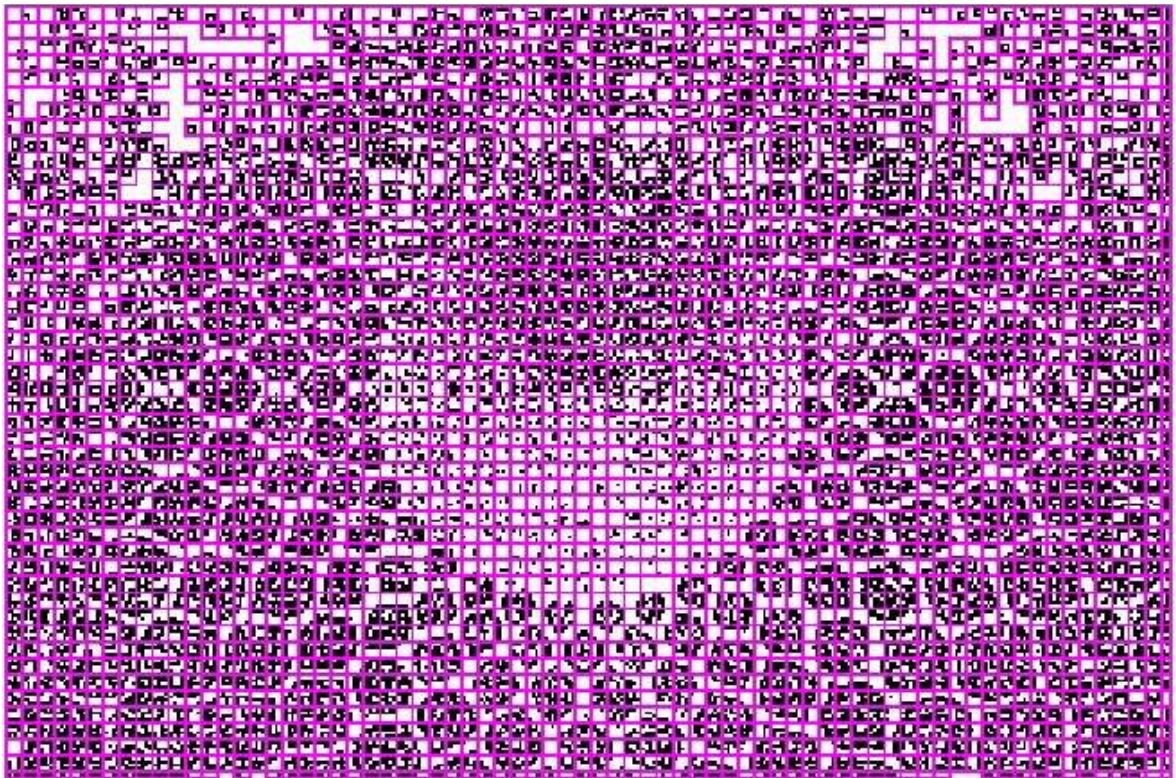


Figure 10: Box counting analysis in Image.J software (Author)

The fractal dimension of this ornament obtained through box counting analysis performed in ImageJ software is 1.8823. Afterwards, the obtained value can be compared with different ornaments' values and analysed in terms of visual complexity, which is of crucial importance in architectural aesthetics.

The importance for humans is reflected through the relation between fractal geometry and the brain. According to the previously cited research by Joye, such visual patterns have beneficial effects on human brain and behaviour.

The use of softwares in designing the tactile aspect of human environment – parametric and ergonomic furniture design

Ergonomics represents a personalized answer for human comfort in different situations and parametric design, i.e. today, the use of different softwares that ease this process is widespread in different branches of architecture, interior design, urban furniture etc.

The term “parametricism” implies that all architectural elements are becoming parametrically malleable, adaptive to each other and to the context, and thus capable of relating and interacting with each other (Schumacher).

Just like natural systems, parametric compositions are highly integrated so that they cannot be easily decomposed into independent subsystems – a major point of difference in comparison with the modern design paradigm of the clear separation of functional subsystems.

(Schumacher, *The Autopoiesis of Architecture*. 2012). One of the most successful examples where parametric modelling was applied in architectural features is the Ricchezza Pavilion, where the parametric design was used to create both intimate and ergonomic furniture and space.



Figure 11.: Parametric design; Pabellón Ricchezza image courtesy of BarriosEscudero

Another good example from the urban furniture design that best explains the purpose and benefits of this method is the Hong Kong “Urban Adapter” project, where parametric modelling, softwares and creative architects' ideas were merged to produce a functional answer to changeable site conditions. Variable site conditions are entered into the software and act as input data. This is why designs created in such ways are flexible, adaptable and sustainable.



Figure 12.: 3D visual representation of the part of the Urban Adapter project

Conclusion

In today's architecture, interior, furniture and urban furniture design, urban planning, spatial planning, restoration and conservation of monuments, softwares are inevitable and very helpful tools. They save time and energy, and enable the creation of realistic renders and animations of designed solutions, but also provide a deeper insight into long-term effects on humans and the environment. Some

of those aspects are certainly visual and tactile ones, such as nature-like forms in design, the application of fractal geometry principles and analysis of visual values of fractal and fractal-like forms, as well as increasingly popular ergonomic urban furniture design. Advanced use of numerous softwares of this kind can help solve problems designers face in a fast, reliable, functional and creative manner.

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Softveri kao moćan alat u modernoj biofiličnoj arhitekturi i dizajnu prilagođenom čovjeku: vizualni i taktilni aspekti

SAŽETAK

U modernom dobu u kojem stres vlada u svim aspektima života, izgrađeni okoliš igra bitnu ulogu, kako negativnu, tako i pozitivnu. Gradovi i zgrade su glavni emitenti CO₂, proizvođači otpada, buke, saobraćajnih gužvi, te najveći potrošači energije. S druge strane, pored dobro poznatih i neophodnih mjera za smanjenje zagađenja, pametni izgrađeni okoliš može biti među najznačajnijim pozitivnim stimulansima za čovjeka, što se tiče povezanosti životne sredine i psihologije čovjeka. Dokazano je da brojne tehnike u dizajniranju koje se oslanjaju na principe prirode, poznate kao biofilični dizajn, imaju pozitivne efekte na centre u ljudskom mozgu odgovorne za relaksaciju. Cilj ovog rada je istražiti i predstaviti mogućnosti u oblikovanju izgrađenog okoliša prilagođenog čovjeku, sa biofiličnim elementima, sa vizualnog i taktilnog aspekta, korištenjem visoke tehnologije i softvera. Poseban fokus je na primjeni fraktalne geometrije u dvodimenzionalnim i trodimenzionalnim arhitektonskim elementima i dizajnu ergonomskog urbanog mobilijara pomoću parametarskog modeliranja.

Ključne riječi: arhitektonsko projektovanje, biofilični dizajn, softver, fraktalna geometrija, ergonomija.