

Complexity and Biourbanism Thermodynamical Architectural and Urban Models integrated in Modern Geographic Mapping

Dr. Eleni Tracada

University of Derby, Derby, United Kingdom

Dr. Antonio Caperna

Università Tre, Rome, Italy

Abstract

Vital elements in urban fabric have been often suppressed for reasons of 'style'. Recent theories, such as Biourbanism, suggest that cities risk becoming unstable and deprived of healthy social interactions. Our paper aims at exploring the reasons for which, fractal cities, which have being conceived as symmetries and patterns, can have scientifically proven and beneficial impact on human fitness of body and mind. During the last few decades, modern urban fabric lost some very important elements, only because urban design and planning turned out to be stylistic aerial views or new landscapes of iconic technological landmarks. Biourbanism attempts to re-establish lost values and balance, not only in urban fabric, but also in reinforcing human-oriented design principles in either micro or macro scale. Human life in cities and beyond emerges during 'connectivity' via geometrical continuity of grids and fractals, via path connectivity among highly active nodes, via exchange/movement of people and, finally via exchange of information (networks). All these elements form a hypercomplex system of several interconnected layers of a dynamic structure, all influencing each other in a non-linear manner.

Sometimes networks of communication at all levels may suffer from sudden collapse of dynamic patterns, which have been proved to be vital for a long time either to landscapes and cityscapes. We are now talking about negotiating boundaries between human activities, changes in geographic mapping and, mainly about sustainable systems to support continuous growth of communities. We are not only talking about simple lives ('Bios') as Urban Syntax (bio and socio-geometrical synthesis), but also about affinities between developing topographies created by roadways and trajectories and the built environment. We shall also have the opportunity to show recent applications of these theories in our postgraduate students' work, such as a 3D model as a new method of cartography of the Island of Mauritius, with intend to highlight developments in topography and architecture through a series of historical important events and mutating socio-political and economical geographies. This model may be able to predict failures in proposed and/or activated models of expansion, which do not follow strictly morphogenetic and physiological design processes. The same kind of modelling is capable to enable recognition of 'optimal forms' at different feedback scales, which, through morphogenetic processes, guarantee an optimal systemic efficiency, and therefore quality of life.

1. Introduction to Biourbanism and its principles

Either by observing satellite images of the surface of our planet or by reading modern geographical representations of it, we soon become aware that, some important features of urban fabric especially have been lost for good; modern urban design and planning turned out to be not only stylistic aerial views, but, also, as some author puts it “tumour imagery” and in particular, when we manage to observe the randomness of expansion of modern cities on our planet during the last couple of decades.ⁱ Satellite pictures reveal frightening images of urban sprawl, which can easily overlap and be assimilated to enlarged imagery of terminal illness viruses. This may prove that, modern cartography and mapping could easily develop into three-dimensional mapping or modelling, focusing and mainly distinguishing between good quality fractal dimensions of urban forms and random and disorderly developments of urban space.

Biourbanism attempts to re-establish lost values and balance, not only in urban fabric, but also in reinforcing human-oriented design principles in either micro or macro scale. Biourbanism as a discipline (and a School) operates as a catalyst of theories and practices in both architecture and urban design to guarantee high standards in services, which are currently fundamental to the survival of communities worldwide. By considering as top items in its agenda the humankind well-being and the dynamics of the urban organism, the discipline of Biourbanism approaches sciences and ecosystems in a particular way and with intend to appreciate “optimal forms ... at different scales which, through morphogenetic processes, guarantee an optimum of systemic efficiency and quality of life of the inhabitants” of the built environment.ⁱⁱ In fact amongst the main aims of Biourbanism, we can see “the identification and actualization of

environmental enhancement according to the natural needs of human beings and the ecosystem in which they live” and “deepening the organic interaction between cultural and physical factors in urban reality”, such as “the geometry of social action, fluxes and networks study.”ⁱⁱⁱ Therefore, it is evident that, this multifaceted discipline has to study and manage complex systems of geometrical patterns, which are very often generated during very diverse human interactions with both natural and built environment.

Urban space is often related to information theory, as its use is concurring to the information field generated by surrounding surfaces and also how this information can be noticed and accepted by human beings navigating through it. It is thought that successful spaces should offer tangible information from local structures, such as those for standing and sitting and also that, the total information field in turn determines the optimal positioning of pedestrian paths and nodes. Thus, human life in cities emerges during ‘connectivity’ via geometrical continuity of grids and fractals, via path connectivity among highly active nodes, via exchange/movement of people and, finally via exchange of information (networks). It is also evident that, 2D information, such as a plan has only a minor relevance during the processes of perceiving and receiving information from complex 3D surrounding surfaces created by architecture. Architecture acts as an extension of the human mind to the environment. Therefore, we build 3D structures to connect with them by being conscious to our immediate surroundings. If the human mind does not detect any connections, the next impulse we get automatically is to leave that alien environment. People define their living space by connecting to solid boundaries as well as through physical contact. As we should show later the ideal boundary for urban space is a fine fractal emergence. Hence, urban space is more sophisticated mathematically than the

formal geometry of a plan proposed by urban planners today.

Urban space encloses built environment, being defined by boundaries/filters and open interactive and multifaceted areas, being originated by these bounding fractal skins of the surrounded buildings. By referring to architectural scales inside the built environment, we discover that natural complex systems (to which both architecture and urban space relate closely) have hierarchical structure, as we shall explain further, regardless if they are biological or inanimate. The hierarchical structure of natural complex systems has been explained by several authors since late 20th Century. But, a systematic analysis was proposed mainly by Christopher Alexander in his *Nature of Order* and in Nikos Salingaros further criticism, especially in his books *A Theory of Architecture* and *Principles of Urban Structure*.

Material stresses into inorganic crystalline materials create fractures that show as regular patterns usually prevent a long-range ordering from continuing through out microscopic forms. Smoothness and uniformity, which are the main visual characteristics of long-range ordering, are unfamiliar to natural materials, because they do not survive on the largest scale. In nature, structural qualities exist on a variety of levels of scale, from the macroscopic to the microscopic (intermediate scales); physical forms possess natural scaling hierarchies as a result of internal and external forces. Natural biological forms, such as

communities of organisms in an ecosystem, organs, cells, etc usually reveal a definite scaling hierarchy in decreasing order of size with more structure as the scale becomes smaller. This is the most important manifestation of biological survival, to which 'Bios'=Life relies on. Thus, Biourbanism digs deeper into these hierarchies to find out laws which should govern the growth of urban fabric in modern cities in a more comprehensive way.

Amongst findings on architectural scales and natural forms, we find that, structurally coherent units will define a particular scale at different sizes; these scales are distinct and nested in a complex structure that exists in large scale. Some natural shapes and forms on the surface of Earth can be seen now at different scales by enlarging and/or reducing available satellite imaging as we shall see further. The same principles of coherent structural units at different sizes apply to the built architectural forms. According to Nikos Salingaros, '*architectural scales arise from the materials, structures and functions of a building and their distribution expresses an architect's organizational ideas*'.^{iv} In fact, throughout the history of architecture, methods used to define scales, include symmetry, which is noticeable in repetition of a symmetrical pattern from small scale to large scale and vice versa. And certainly, design units cooperate to achieve scaling coherence when a distinctive feature connects them visually, for example, if they have got similar texture or colour.

2. Complexity and thermodynamics of architecture: life

The fact that often architecture influences people's lives in a very conventional way cannot be denied. Thus, as a discipline,

architecture should strive to guarantee physiological comfort, without being deprived of its powerful psychological dynamics. It is obvious that, by conversing with human body and psyche at the same time, architecture should be considered a

multifaceted discipline, which deals with a large spectrum of issues related to humankind populating our globe. Moreover, we can suggest that, the permutation of the natural environment to offer more space to the urban sprawl today is not a completely new phenomenon; it has been often dictated by pre-established laws of nature rather than laws made by people during urbanisation processes.

At all times, architecture has been very close to both arts and sciences. Furthermore architecture is considered as an expression and application of geometrical order, although it is not often clear, how structural order can be achieved. A set of empirical rules has been analysed and included in Christopher Alexander's *Pattern Language* in 1977; he proposed a set of geometrical rules that govern architecture, which should derive from biological and physiological principles. According to Alexander's hypothesis and further criticism from Nikos Salingaros, structural order requires that, forms be subdivided in a certain manner and the subdivisions be made to relate to each other. Volumes and surfaces interact in a way that mimics the microscopic interaction of elementary particles, or better, the biological growth and multiplication of cells. Hence architecture is reduced to a set of rules, which are analogous to the laws of physics. As we should see further, human sensory systems respond to both tectonics and visual designs; these two aspects of the built form define structural order and they differentiate by scale.

As a matter of fact, structural order of architecture depends upon human perception. Thus, it cannot be judged strictly from abstract formal criteria, as the observer becomes part of and also influences the behaviour of.

As Salingaros affirms *'Scaling symmetry creates coherence; similar shape when a fractal's particular details are magnified;*

the brain handles information encoded in a fractal than if random.'^v This means that, architecture exists because of the existence of the humankind and cannot be isolated into an abstract world. In his *A Theory of Architecture*, Nikos Salingaros revises the 'fifteen properties' of Alexander's *The Nature of Order* in Book 1 in order to formulate a set of three laws, easier to be remembered and also synthesised to approach structural order slightly differently:

Law 1. Order on the smallest scale is established by paired contrasting elements, existing in a balanced visual tension.

Law 2. Large-scale order occurs when every element relates to every other element at a distance in a way that reduces entropy.

Law 3. The small scale is connected to the large scale through a linked hierarchy of intermediate scales with a scaling ratio approximately equal to $e = 2.7$ ^{vi}

According to Salingaros, *'entropy'* is the technical term for randomness or disorder, *'scaling'* links components of different sizes and *'hierarchy'* refers to the rank-ordering of all those sizes.^{vii} In physics, *'order of the small scale'* consists of paired elements with the opposite characteristics bound together. *'Coupling'* separates opposites found closely, so that they could not overlap and, as a result, they should not be able to vanish. This close separation of the opposites creates a dynamic tension. Also in physics, keeping units of the same type next to each other does not result in binding. Salingaros affirms that *'coupling'* of opposites applies to architecture as he expresses it in the Law 1 above. Thus, structural order on the smallest scale can result by coupling basic elements, contrasting in colour and geometry and often achievable with materials. During this process of ordering contrasting coupled scale pairs, we also find them interlocking. The concept of

contrast appears in different scales. For example, contrast prevents detail from filling all the space. High detail couples with plain, empty regions, as it is evident in built areas and finishes, which are necessary to complement the areas, which are sparsely built and finished. Each component of a contrasting pair needs to encompass an equal degree of coherence and complexity. According to Salingaros, coupling for interiors and exteriors of a building, *'does not occur via a glass curtain wall, but through the geometry of its plan, as it is formed so as to enclose outdoor space. This process leads to the definition of urban space.'*^{viii}

Again in physics, order on the large scale means that, non-interacting objects are simply juxtaposed and nothing occurs. An interaction encourages rearrangements, which lead to a reduction of the entropy/disorder, such as alignment along one axis. According to Law 2, *'large-scale order occurs when every element relates to every other element at a distance in a way that reduces entropy.'*^{ix} As a result similarities and symmetries appear between different sub-regions; large-scale order occurs by ordering colour and/or geometry. Structural order may result when a long-range interaction appears via intentional orientation and similarity of spatially separated units, such as tectonic elements. In small-scale order, coupling units touch each other, whereas in large-scale, we order units, which are not next to each other. By reducing entropy/disorder, we help people to perceive a structure; by contrast, a complex structure can be recognized, if it appears to be coherent by means of connections and symmetries.

Human beings conceive a structure as a whole; they find it extremely frustrating when a structure appears as a large number of scattered and unrelated pieces. Again in physics, thermodynamic entropy relates different arrangements of the same number of particles according to the

probability of occurring, whereas, according to Salingaros:

... entropy applies to structural order in a slightly different way ... structural order in architecture is inversely proportional to the entropy of a fixed number of interacting components. The higher the entropy (geometrical disorder) among the components at hand, the lower the structural order. Conversely, the lower the entropy, the higher the structural order. The entropy of a design could be lowered instead by reducing the local contrasts, but it also reduces the structural order ... (thereby reducing architecture to an empty minimalism).^x

Structural order is achieved by having units on a common grid; continuity of patterns across structural transitions raises the degree of connectivity. If one repeats the same minor pattern on different regions, those regions are tied together. This method was discussed by the author of this paper and her students at Masters Level recently; some students produced new mapping of vast areas by including a variety of degrees of connectivity – see further. In the absence of a physical force between areas, visual similarity connects two design elements or parts of a building through common colours, shapes and sizes. In this case, structural order harmonises local contrasts without reducing them to an empty minimalism in any way. By insisting on visual purity, we do not achieve refinement necessarily. Visual purity can destroy the connection process, because connections represent smaller scale structures (paired elements with the opposite characteristics bound together and complementing each other as in Law 1).

The third law of structural order proposes the scaling similarity by imposing a hierarchical linking between Laws 1 and 2; that means the different scales need to be close enough in size, so that they can

visually relate to each other. The linking is achieved through structural similarities, such as repeating forms and patterns. However, in physics, matter is not uniform; it looks totally different if magnified by a factor of 10 or more. The scaling ratio for which two distinct scales are still related empirically is found to be around 3, as in some part of the fractal geometry. In fact self-similar fractal patterns which most closely resemble natural objects have scaling ratio equal to 2.65, supporting the universal scaling ratio of 2.7 proposed by the hierarchical linking via Law 3. This hypothesis reveals a basic scaling phenomenon seen in biological structures. The secret of biological growth is scaling, either via a Fibonacci sequence or via an exponential sequence, which is generated by $e = 2.7$. Ordered growth in fractals is possible only if there is a simple scaling, so that the basic replication process could be repeated to create structure on different levels. Different scales must

exist, and they must be related, preferably by only one parameter, which is the scaling ratio $e = 2.7$; this parameter fits both natural and manmade structures, such as buildings and other artefacts. People react positively to ordered natural growth:

Monotonous repetition is a problem. Suppose we have a large number of identical smaller parts; triggers comparison, a combinatorial process that generates fatigue; monotonous repetition is thus not only boring, it can actually be stressful. ... We are interested in a very different [not algorithmic only] combinatorial complexity. ... Neural system evolved to cope with the natural world; expends energy to arrange data from senses into coherent patterns; tries to group similar pieces into larger wholes (Gestalt); keeps working to find some grouping.^{xi}

3. Fractal interfaces and Architectural Harmony and Life

Nature follows fractal geometrical patterns and several times these impressive illustrations attract the attention of artists and photographers; the harmony of the natural shapes has evolved for hundreds or may be thousands of years in some parts of the surface of Earth to remind us that, nature prefers organised complexity to guarantee its biological life. Several authors recognise the fact that, there is a revolution in course in the methods used by sciences to understand nature:

A remarkable revolution is under way in the design sciences today –fueled by powerful new insights into the workings of nature, and articulated by the burgeoning science of complexity.

New terms tantalize us with their suggestion of innovative directions and new possibilities: self-organization, biophilia, generative design, and much more.^{xii}

The Island of El Trocadero shown above is an 'island associated with the channel of the same name formed by fluvial-marine deposits of a sandy mud nature, which give rise to wetlands under tidal influence.'^{xiii} This magnificent fractal landscape, entirely created by nature, shows that the main laws related to the balance between entropy and scaling (with reference to Nikos Salingaros' theories explained before) are continuously evident in natural environment. Thus, they could be easily incorporated into the artificial manmade environment at any time. Mathematics in nature should be not only the accepted

way forward to verify the validity of new proposed urban development, but also to identify links to previous conurbation,

which may have been temporarily lost and/or preserved as 'hidden' agenda of entropic growth.



Figure 1. Island of El Trocadero, Puerto, Real, Cádiz – photograph by Héctor Garrido/CSIC ©

Many authors, like Christopher Alexander believe that the texture of space is governed by fractal structures, as a projection of what nature offers us and by fractal qualities, as historical urban fabric mostly enclose them. According to several authors, like Alexander and Salingaros Group, although urban space and architectural emergences in it could be complex and fractal, the processes which generate successful spaces should be summarized in only three axioms dealing with urban space *'bounded by surfaces that present unambiguous information'*, its spatial information field should define *'the connective web of paths and nodes'* and the *"core of the urban space is pedestrian."*^{xiv} As we can understand, the axioms provide the basics for urban planning by referring to more basic level rather than large-scale decisions often revealed by complex network grids. Thermodynamics in architecture are related mainly to *'bounding surfaces'* or better, to structural pieces surrounding an open space, so that

they present the maximum information to the people who use that geometrical urban space. Thus, the urban spatial boundaries act as generators of *'positive space'* stimulating the human senses. Therefore, the geometry of these boundaries should guarantee coherence in positive urban space.

Initially and towards the end of the 20th century, some authors, like Michael Batty, in 1994, prove that successful urban forms should be fractal, although they refer mainly to large-scale urban design based upon pathlines' connectivity. However, by considering urban space as defined by special boundaries, which transmit specific information (exterior architectural elements) and by enhancing the information field through geometric subdivisions, we can provide building surfaces with fractal scaling, from the size of the buildings down to the materials. Christopher Alexander has always insisted that, open and concave urban space should be formed by surrounding

buildings, not vice-versa. A 'typical town is not a pattern of streets, but a sequence of spaces created by building'^{xv} as Gordon Cullen observes in his *The Concise Townscape* in 1961 and Salingaros quoted in his *Principles of Urban Structure*.

As we saw before, architectural scales in the built environment play an important role in order to define distinct and coherent scales at different sizes. As several authors affirm, a design with natural scaling hierarchy influences the viewer, because it facilitates the process of human cognition. We are able to perceive a complex structure by reducing it to a number of distinct levels of scale. Human beings have a basic biological need to organise complex distributions of units into hierarchies, as a means of avoiding information overload. Back in 1987, Fischler & Firschein, who began considering the effects of computation to the human eye and brain, affirmed that the mind groups similar units of approximately the same size into one scale. Then, it looks for similarities or links between all the different scales. It is evident that, fractal self-similar shapes, forms and structures can be also perceived and grouped at different sizes and scales by human mind easily, since the mind has evolved in response to patterns found in nature and the natural scaling hierarchy of fractality. Thus, within the human perceptive mechanism, a certain set of rules for recognising hierarchical cooperation is hard-wired; the eye gets signals and the brain analyses them according to these set rules of hierarchical self similar patterns, which can easily be mapped, or better, be visually identified as such and thus, further evolving to 2D or 3D imaging via algorithmic computation and modelling nowadays.

We have accepted that, architecture affects humankind in a conventional way in terms of physiological comfort. It is though quite intriguing what some authors, like Salingaros try to do by examining how

the small and large scales contribute to the success of a building independently of the hierarchical mechanisms of coherence; he uses methods of quantifying architecture according to geometrical and visual content and he also claims that, it is possible to compare two buildings based on intrinsic, computable values of their design. The same author also insists that, these quantifiable values can influence the importance and feeling of a building (how good it feels to its residents). Salingaros wishes to give us more architectural tools for dealing with and understanding the organisational component of design. These latest points of his work have reinforced the author's of this paper belief that, in teaching studio design practices to students in Higher Education at all levels, from Level 4 to Level 7 (Masters) at least, theories and histories of architecture should provide empirical tools to design; these tools should be reinforced further by robust series of quantifying tools linked to both design and relevant sciences, such as maths and biology.

Thus, in order to organise fundamental qualities that govern the geometrical coherence of architectural forms, Salingaros has set a simple mathematical model, which draws on analogies of thermodynamics and can be considered as an innovative approach to design. Two distinct qualities have been identified and he has explained how to measure them. Small-scale structure is described as the architectural temperature T . The higher the architectural temperature, the higher the intensity of the design and the degree of visual stimulation, thus, more colour, differentiations, detail and curves, fractility, etc. Another measure, the architectural harmony H has been identified with the degree of symmetry and visual coherence of forms; harmony H measures visual organization, such as the absence of randomness. Harmony is a property of the larger scales and carries its traditional meaning, whereas the architectural temperature T is a new method of

describing familiar concepts in architecture.

The second part of Salingaros' model relates the perceived '*architectural life*' and '*architectural complexity*' to a variety of combinations of T and H.

The architectural life L is defined as $L=TH$ and the architectural complexity C as $C=T(10-H)$. The architectural life L refers to the degree that one recognises in a building and those critical qualities that make it seem alive. According to Christopher Alexander's theories, these are the same qualities that connect us with a building in the same way that we connect emotionally to trees, animals and people. The feelings generated by a high degree of complexity may correspond to interest, excitement and perhaps anxiety in some specific cases. Therefore the architectural life L and architectural complexity C are two independent measures that determine how we feel about a building. This establishes a connection between scientific quantities based on measurements and intuitive artistic qualities based on feelings. The third and final part of the model reveals how to fill a building with life by adjusting individual constituents of forms; this model may be valuable for analysis, design and construction by controlling the interplay between architectural life and architectural complexity in new build.

In his discussion about architectural design, Salingaros starts with the perception of uniformity and tries to explain why a form differentiating in terms of the geometry and colour follows the laws of physics, when we consider uniformity. In physics, uniform states in fluids and gases are associated with low temperatures. Raising the temperature often breaks the uniformity, leading to gradients and convection cells; this suggests that, we refer to the degree of detail and small-scale contrast in a design as the architectural temperature T. The architectural temperature is determined by

several critical factors, such as the sharpness and density of individual design differentiations, the curvature of lines and edges and the colour hue. Salingaros distinguishes five elements T1 to T5 that contribute to T. Each quality is measured on a scale by assigning a value of 0 to 2 according to a rough judgement, with very little or none=0, some=1, considerable=2. Thus, the following table is proposed:

T1= intensity of perceivable detail

T2= density of differentiations

T3= curvature of lines and forms

T4= intensity of color hue

T5= contrast among colour hues ^{xvi}

The architectural temperature T is the sum of all the above estimates. Each component assumes values between 0 and 2, so that the quantity T would range from 0 to 10. Thus, $T=T1+T2+T3+T4+T5$.

Salingaros explains what the result has been according to his mathematical computations against emotional response, etc. An important observation was that, buildings and artefacts with high architectural temperature throughout history usually satisfy a profound innate need in human beings.

Also architectural harmony H, associated with visual organisation, is measured as the sum of five components and measures in reality the lack of randomness in design. Thus, $H=H1+H2+H3+H4+H5$. The same values 0 to 2 are considered and the table should be:

H1= reflectional symmetries on all scales.

H2= translational and rotational symmetries on all scales.

H3= degree to which distinct forms have similar shapes.

H4= degree to which forms are connected geometrically one to another.

H5= degree to which colors harmonize.^{xvii}

There are some interesting observations made by several authors on Architectural Harmony and Pattern Recognition (especially in Fractal Patterns), which become obvious in Salingaros' critical and mathematical analysis. For example, there is a deep connection between architectural harmony and information in thermodynamics, carried over to architecture. Any symmetry in a design, for example, reduces the amount of information necessary to specify shapes. Juxtaposing different materials can lower the architectural harmony H by breaking the continuity of a surface. Disconnected forms positioned near each other across an interface or gap may create uncertainty and, as a result, they lower the architectural harmony. When the basic attachments of a form to other forms are missing, the brain continues to seek visual information which might establish the necessary connections. If these attachments are not obvious, then, we perceive only an incoherent entity. Usually recognition is frustrated whenever structural information is missing, or on the other hand, when structural information is overwhelming. The architectural harmony of multiple structures, which are unrelated by either symmetry or scaling, could be raised through intermediate regions of connections. A geometrical connection relates two separate forms and will become a boundary for both of them.

4. New mapping and harmonious landscapes – Conclusions

All the theories, practices and computations mentioned above were taught by the author of this article to her students through Designing Environments, a module at Level 7, in MSc in Sustainable Architecture and Healthy

Several authors, including Salingaros agree that, the best geometrical connections are offered by fractal regions and even mathematical linear elements, such as paths, mainly being defined by the differentiation between contrasting or distinct regions. By discussing the Theory of the Urban Web, Salingaros again refers to a successful path, *'if it coincides with the boundary of an area such as the edge of a building ..., thus combining two ... urban elements: path and edge ... paths and edges are potentially one unit.'*^{xviii}

Architectural Life of a building $L=TH$ (Life equals temperature times harmony); this takes values from 0 to 100 (T and H taking values from 0 to 10). A low value for Life L *'means that people may not connect to that building on the same emotional level that they would with a living organism (i.e., a tree, an animal or a human being).'*^{xix} The optimum value for the architectural harmony is below its theoretical maximum. Every great building has some degree of randomness/disorder; randomness is required to define new scales, or to create new couplings/fractal boundaries. Architectural complexity C equals temperature times randomness (disorder), $C=T(10-H)$; it also takes values between 0 and 100. The impression of a building's complexity can range from very low $C=0$ (dull), to medium C (exciting), to very high (incoherent). Thus, too much complexity detracts from a building's adaptivity to humans, as it extends from positive excitement into anxiety.

Buildings in the first semester of the academic year 2011/2012.

The students had produced both theoretical schemes and proposals of design and have written critical essays/papers on a topic related to the materials taught and discussed during peer reviews. Not only architectural complexity was investigated during peer

reviews, but also harmony and viability of urban space were considered in connection with infrastructures and geographical randomness, which affects both cityscapes and landscapes. Some empirical models were also produced, such as the model shown in Figures 2 & 3 below, with intend to produce composite three-dimensional mapping.

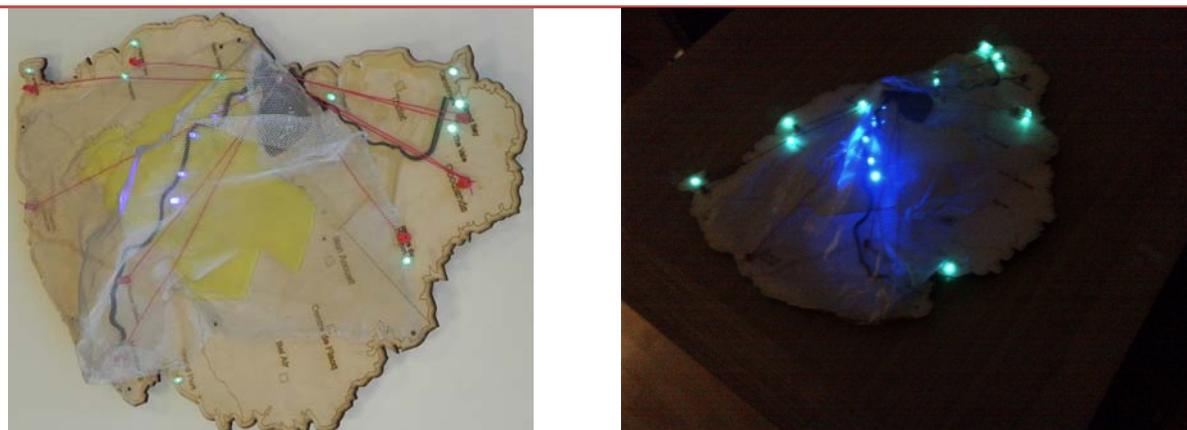
The idea is to include not only recent information, but also to juxtapose missing links (often historical) of both networks of connectivity and fragmented or lost fractal boundaries in urban space in order to stimulate further discussions. Public opinion should be listened before proceeding to sustainable community participation solutions of economical growth, which should interrelate firmly to future intensive and often random models of urban sprawl. The word 'life' was extended from the architectural life of a single building to the urban space as a multiple of architectural buildings, which integrate themselves with the rest via coherent fractal intermediate regions. The graphs of economical growth were also juxtaposed to other emergences inside the

spaces to enhance randomness, conflicting with the 'harmony' of developments proposed by local and state governments.

The author wishes to conclude with the following:

An alternative terminology more appropriate to complexity theory is to call architectural life L the 'degree of organized complexity' and the architectural complexity C the 'degree of disorganized complexity'. Most people understand complexity as being of the disorganized variety, whereas in fact there are two distinct types of complexity: organized versus disorganized. Biological forms are highly complex, and at the same time marvellously organized, thus establishing the relationship between life and organized complexity.^{xx}

Perhaps built environment should be following closely laws of biological complexity to be able to reassure people that an evolution of more inclusive cities through human-oriented spatial and urban designs could be easily achieved.



Figures 2. & 3. Model of the Mauritius Island, by Madhoor Bissonauth Prits for Module Designing Environments, taught by the author in autumn 2011 for MSc courses in the School of Technology, University of Derby.

References

- ⁱ Hern, W, 2008, 'Urban Malignancy: Similarity in the Fractal Dimensions of Urban Morphology and Malignant Neoplasms', *International Journal of Anthropology*, vol. 23, no. 1-2, pp. 1-19, available at www.drhern.com, accessed on 12/11/2011
- ⁱⁱ Caperna, A, 2010, 'Biourbanism', available at <http://www.biourbanism.org/p2p-urbanism/>, accessed on 15/03/2012
- ⁱⁱⁱ Caperna, A, 2010, 'Biourbanism', available at <http://www.biourbanism.org/p2p-urbanism/>, accessed on 15/03/2012
- ^{iv} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p66
- ^v Salingaros, N A, 2010, *Twelve Lectures on Architecture*, Umbau-Verlag, Solingen, p39
- ^{vi} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p30
- ^{vii} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p30
- ^{viii} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p33
- ^{ix} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p33
- ^x Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p34
- ^{xi} Salingaros, N A, 2010, *Twelve Lectures on Architecture*, Umbau-Verlag, Solingen, p31
- ^{xii} Mehaffy, M & Salingaros, N, 2011, 'Frontiers of Design Science: Self-Organisation' available at <http://www.metropolismag.com/pov/20111101/frontiers-of-design-science#more-21697>, accessed on 23/03/2012
- ^{xiii} This image was at first seen in <http://fractaldonana.blogspot.com/>, accessed on 12/11/2011. Then, by searching on the photographer's name (Héctor Garrido) we came across an article talking about findings through scientific photography ; this article is 'La piel de Doñana' by Juan Manuel Garcia Ruiz, published in the newspaper El Pais on 26th October 2008 and also accessed at http://elpais.com/diario/2008/10/26/eps/1225002414_850215.html. El Consejo Superior de Investigaciones Científicas (CSIC) in Spain owns mostly the copyright of this magnificent archive of Doñana Biological Station photographs, which show natural fractality at its best.
- ^{xiv} Salingaros, N A, 2005, *Principles of Urban Structure*, Techne Press, Amsterdam, p42
- ^{xv} Salingaros, N A, 2005, *Principles of Urban Structure*, Techne Press, Amsterdam, p53
- ^{xvi} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p107
- ^{xvii} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p110
- ^{xviii} Salingaros, N A, 2005, *Principles of Urban Structure*, Techne Press, Amsterdam, p32
- ^{xix} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p115
- ^{xx} Salingaros, N A, 2008, *A Theory of Architecture*, 2nd edn, Umbau-Verlag, Solingen, p118
-