New Design Ideas
Vol.2, No.2, 2018, pp.51-61

ADAPTIVE VERSUS RANDOM COMPLEXITY

Nikos A. Salingaros*

Department of Mathematics, The University of Texas at San Antonio, USA

Abstract. Human beings "feed" on visual complexity much as we feed on nutrients. But some types of complexity are useless, or can be harmful for us. Both "designed" minimalism and random complexity remove life-enhancing structural features from the built environment. Sustainable systems depend upon organized complexity, where different structural scales link together coherently. Adaptation generates useful complexity through feedback from the environment. The sequence of steps followed in adaptive design is traditionally tested by generations of human interactions. Adaptive computations search the space of possible geometries. Biology and computer science work in this way, using adaptation, not imposition, to find innovative solutions. Invented complexity, however, cannot reproduce the organized complexity found in nature, except in the most superficial, non-functional manner. Disorganized complexity is random, and humans cannot "plug into" such environments to feed life processes. Building the wrong type of complexity results in dysfunctional buildings and urban regions that waste enormous energy resources to maintain.

Keywords: *architecture, urbanism, complexity, design methods, emergence, computational design.*

Corresponding Author: *Prof. Nikos Salingaros, Department of Mathematics, The University of Texas at San Antonio, One UTSA Circle, San Antonio, Texas, USA, e-mail: salingar@gmail.com*

Received: *08 October 2018;* ***Accepted:*** *16 November 2018;* ***Published:*** *03 December 2018*

1. Introduction

Nature and the built environment are both complex. But they don't always have the same type of complexity. Portions of what we build share the organized complexity found in nature, and this affects our body and eventually our health positively. The greatest healing effects come from man-made environments of traditional and vernacular character (Kellert *et al.*, 2008; Mehaffy & Salingaros, 2015; Salingaros, 2016). Architects would love to know how to use mathematical knowledge to design complex forms. But complexity that responds to human society is not "designed" in the sense that one person, the designer, determines all details beforehand.

This paper proposes a clear, well-developed, and comprehensive framework on the topics of complexity, randomness, and adaptivity in design. I will discuss and try to strengthen insights obtained by Christopher Alexander and his collaborators (Alexander, 2001-2005; 2009). This research is useful for researchers and practitioners working on the intelligent process of creating adaptive geometries in place-making. The intent is to formulate design tools that lead to human wellbeing and life-enhancing environments.

Design as styling, typically conceived by architects as abstract art, is adaptively random: a pursuit dealing with appearance and not function of a building or urban space, or the needs of users. Using random input for generating a design might produce a visually striking ground plan or building shape judged as abstract sculpture. If that's what the client wants, then everybody concerned is satisfied, except perhaps the hapless user in many cases where client and user are different people.

Designed cities can be random but not look it, and are dysfunctional for tens of thousands of people. The problem here is deep, yet difficult to explain because of a visual contradiction. Neat geometrical ordering on a plan (the basis of industrial-modernist planning) is irrelevant to the evolved geometrical complexity of human-scale urbanism. Alignment and repetition, while visually ordered as seen from the air, are actually experienced as random by society and individual users (Salingaros, 2011; 2012). This design approach fragments social complexity by forcing it into a pre-determined physical framework. Energy cycles driving living processes actually fit within a very different complex geometry adapted to people's needs. The result cannot be drawn on paper or on a computer screen, but has to be derived from basic principles.

A city constitutes part of a dynamic complex system that includes human society and culture. If the urban fabric allows them, energy flows spontaneously generate frameworks and physical structures obeying the characteristics of complex systems. Their properties include linked hierarchical levels, internal and external connections, and redundancies that help in stability. Complex systems that promote human life are dynamic, responding to movements and processes, not static images. Organisms solved similar problems to the ones we face in generating an adaptive built environment. We can usefully apply those methods to completely re-design our cities and make them more adaptive.

2. How to build up organized complexity

Adaptive design organizes components as they are being generated. A responsive design process channels emergent complexity instead of trying to eliminate it. The method encourages complexity to be generated from adaptation, in responding dynamically to complex human needs. Nothing inessential is imposed top-down. Design is sensitive to feedback. One can forget about *designing* complexity in the built environment: the sequence of steps followed in adaptive design will generate it for you (Salingaros, 2012). By focusing on adaptation and organization in each design step, the result will adjust to human use and physiology.

The standard tools for organizing complexity (Alexander, 2001-2005; Salingaros, 2011; 2012; 2014) include the following:

Table 1. How to organize complexity

(i) Connect the parts of a system or structure through various geometrical means, most often with multiple and redundant connections.

(ii) Align adjoining flows so they reinforce each other and define their own natural paths (but don't force them to a rigid axis or grid).

(iii) Create many linked symmetries of different types as a response to activities on distinct scales (but don't impose a global overall symmetry).

(iv) Implement approximate spatial correlations using similarities at a distance and scaling symmetries (i.e. similarity under magnification).

(v) Only repeat things adaptively, i.e. adapt the prototype to the new situation, which makes the units vary with each repetition. Monotonous repetition without variety, on the other hand, lacks adaptation.

(vi) Build up a system or structure using a sequence of adaptive steps, where organized complexity arises from an evolutionary process with feedback. Don't build layers from a pre-determined blueprint.

(vii) Implement organized complexity as the result of adaptive dynamic processes rather than as the result of a conventional static appliqué of "art".

Adaptive design follows a step-by-step procedure, which seeks feedback from the design process at the same time as it is being carried out. Components arise from adapting design to human dimensions and movements, and to the psychological responses to spaces and uses. Adaptation therefore requires paying attention to all scales, and to our emotional/psychological reactions on each scale. This method is the antithesis of the standard top-down "design" emphasizing the largest scale, which is carried out all at once.

Begin by defining those forms and dimensions that are constrained by the project brief. Those are less flexible, or not changeable at all after construction. Continuously experience the shape or space using your own body, and with the help of other volunteers make possible adjustments during the design process, before anything is finalized (Alexander, 2001-2005; 2009). Use full-scale mock-ups from cheap materials that help the team of volunteers to *feel* the actual dimensions. Then decide on the next most-rigid part of the design and model that, again using feedback for further adjustments. Proceed downwards in this manner to the smaller and smaller scales, and don't hesitate to change what's on an initial drawing.

Because simplistic regularization (i.e. monotonous repetition) reduces the information content of a complex system, it is incompatible with adaptive design (Salingaros, 2011). Adaptation breaks monotony. In music, for example, each variation on a theme breaks the monotony of repetition, but it is not generated by arbitrary randomness. Instead, it follows an organizational framework. Both monotony and randomness are out of place in tonal music. How a variation departs from the basic theme may be unexpected. Yet coherent variations are carefully premeditated and controlled excursions into tonal possibilities, applying the constraints of organization and coherence. The same idea animates the development of adaptive design on both architectural and urban scales.

3. Why complexity needs to be organized

Organized complexity "feeds" life by building on a place's life-enhancing architectural features, understood as such by history of use, and tested by human action and interaction. Since humans are part of nature, our life is just another natural process of system organization and energy-flow optimization (Marshall, 2009; Salingaros, 2016). Cities were, until very recently, straightforward accommodations and extensions of social complexity. But humans cannot "plug into" randomness; thus built disorganized complexity cannot feed energy into life processes (Mehaffy & Salingaros, 2015). Our sensory and cognitive systems have evolved to process only information that is organized.

At the other extreme, the tedium felt in minimalist environments may be blamed on their lack of complexity (Salingaros, 2011; 2012; 2016). And yet, trying to “fix” such dead places by adding the wrong sort of (random) complexity only worsens their imbalance and lack of fit with social complexity. It is common nowadays to design and build *physical complexity* that does not match *social complexity*, and which injects no liveliness, vitality, or *life* into a place.

Iconic buildings, urban projects, and public sculptures that embody random forms are arbitrary whims, designed without human needs in mind. Those forms inserted into the built environment do not adapt to social complexity but impose themselves brutally over it. The disorganized complexity of those structures never feeds people’s emotional and informational needs (and if it does so, it’s only by accident). There is a basic mismatch in the *kind* of complexity we need, and what we experience. Apply the substitution test: *randomly complex designs can be replaced by one another, or even by a minimalist one, without making any difference, because their adaptivity to life is negligible*.

Design and construction were very different in the past. For millennia, the building process created organized complexity. Vernacular buildings were erected in ways that directly satisfied human needs, functions, psychological dimensions, etc. Their designers did not need to consciously adapt them, because all the building parts and the means of fitting them together in a way that worked best had been thought through already. Well-established building components and time-tested ways of composing buildings were adaptive. Responding to changes in human needs, building practice evolved going forward, yet never contradicted traditional adaptive geometries. For centuries, nothing was ever built or even conceived unless it facilitated connectivity, pedestrian flows, economy of movement, energy use, climatic needs, life functions, and the dynamic utilization of space as defined by human perception on the ground.

Typically, very few designs were conceived as abstractions on a drawing board. Only the most monumental of structures were designed with human functionality taking second place to aesthetic symbolism. Buildings and associated structures (e.g. urban space and street furniture) accommodated best to “feed” social complexity. Over time, built examples evolved into the complex forms of traditional architecture that we inherited. Those adaptive typologies would have continued to evolve adaptively had not disorganized complexity, in the guise of artistic novelty, interrupted a natural process that intuitively incorporated the DNA of successful adaptation (Marshall, 2009; Mehaffy & Salingaros, 2015).

Today we are used to exerting direct control over every aspect of our environment, and that includes our constructions. The design process has become terribly deliberate. But industry ignores the possibility of optimizing energy flow through organized complexity by adaptively evolving a design. Randomly-shaped iconic buildings as artistic whims provide the worst examples of energy wastage. Those are designed directly by sophisticated software that generates construction drawings and even building components, without much mental exertion, let alone real creativity. Design as sculpture, supported by engineers paid to push the structure to extremes, forgets the essential adaptive processes from our past.

4. Randomness and uniformity both destroy information

To get a handle on complexity, we need to distinguish between three varieties. *Organized complexity* is what adaptive design seeks, and what living processes "feed" upon. Then, there exist two distinct opposites that undo organized complexity: *extreme simplicity* or uniformity, and *disorganized complexity* or randomness. We need to avoid both. Neither of these extremes is recognized by our cognitive apparatus as representing a working complex system. [As complexity is not a linear problem, thinking of a model as one line with opposite ends is misleading: imagine rather a plane where we can plot different varieties of complexity (Salingaros, 2014).]

The first type of state that is the opposite of organized complexity is extreme simplicity (uniformity). Here we have a homogeneous state without variety. Extreme simplicity occurs when a system's various components are essentially copies of one component. Every piece is expected, and the ensemble carries no additional information beyond its elementary components. There is no complex structure, since every piece decomposes into its simplest components, which are all the same. Reductionistic simplicity results in uniformity. Even with possible correlations among its component pieces, there is insufficient variety to define a complex system (Salingaros, 2011; 2014).

The other distinct opposite state from organized complexity is disorganized complexity (randomness). In this state, many elements, not necessarily complex, lack mutual connections. Individual pieces do not link together into a working system. If they do work at some level, connections are weak and there is no coordination with the other levels of scale. Any organization that might be present within individual pieces is unexpected, because that was not a design goal. Randomness has no organization. A random state is heterogeneous without any correlations, consisting as it does of many different non-interacting pieces.

5. Lessons from living complexity found in nature

Humans have evolved to recognize and respond to complex systems in nature. Grasping informational messages from organized complexity is the foundation of our ability to survive. A non-system such as a built environment that celebrates unnatural or non-living qualities stops the energy flows that define organized complexity, and detaches us from the world. We pick up this fact instantly, simply from the configuration's obvious visible geometry. Directors have no problem designing an "alien" environment in a science-fiction film.

The physical structure of the universe offers the most basic example of organized complexity. Components of matter on different scales, from the subatomic to the microscopic to the macroscopic, bind coherently to define larger and more complex structures. Observed structures are the result of energy stability among all their components, which is a consequence of system organization (otherwise it wouldn't survive, and we wouldn't be seeing it).

Organic forms arose for the purpose of converting energy into information. Energy input from the sun, but also from some geothermal sources, drove organisms over eons of time to structure their bodies to utilize this energy. The energy goes into building and upkeep of the organism's complex structure. Energy flows lead to similar geometrical frameworks (evolved independently) for optimizing both the apparatus for living processes, and the utilization of energy. This is why the geometrical templates for life can be classified (Newman & Bhat, 2009). Evolved life forms share common elements of organization relevant to their design as given in Table 1: alignment, local symmetries, spatial correlations, and scaling symmetries (Alexander, 2001-2005).

Life thus defines a direction for the transformation or build-up of organized complexity: proceeding from simple or random states towards highly organized complex systems (Alexander, 2009). The same holds true for adaptive environments. Energy and information are locked up in either static systems, or in stable dynamic systems. The geometry of life also extends itself outside the body: whenever organisms are able to erect surrounding structures (animal architecture), those embody the same type of organized complexity as do living structures (Kellert *et al.*, 2008). This principle held true until humans violated it in recent times.

Metabolism consists of various energy cycles that transform organized complexity. Animals eating food digest complex organic matter that dissolves into slightly simpler components (nutrients), which are then re-assembled as essential components into the complex body of the animal. Animals feed on complex organic molecules, whereas unintelligent plants feed on minimalist chemical compounds. Chemical energy stored in the food is released and used to power the metabolism of the organism doing the eating. (Note the correlation between intelligence of an animal as a system working on a higher complexity threshold needing more complex food.)

Animals “feed” on organized visual complexity in their environment to navigate, find food, interact with other animals, etc. Our brain and nervous system are constantly processing information to make decisions. Lack of information, as in minimalism or uniformity, leads to inaction and isolation. Disorganized information, as in randomness, has no message because meaningful information can only be coded through organization. An animal reacts to random states with alarm and confusion, because they offer no basis for taking decisions.

The death of an organism marks the onset of decay, when more complex structures become less complex and less organized. The organism’s constituents break down into simpler chemical states either of more uniformity, or randomness. The system can no longer channel energy flows internally to maintain itself: it is dead. Energy is then captured by other systems nearby. When natural structures decay, scaling hierarchies and local symmetries dissolve, generating randomness as the level of organization decreases, and leaving components unrelated to each other. As those components decay further, they decompose towards minimal states, so that minimalist design is associated with death, not life.

6. Biological versus man-made information

The process of life also includes the urge to encode structural information about its material configurations. Documentation of organized complexity allows life to continue a virtual existence as an informational template. Useful mechanisms discovered by life forms survive by being encoded into their DNA, which permits the biological template itself to be perpetuated (reproduced) before the structural materials and repair processes come to the end of their natural life span. Templates for highly organized complexity survive in this way.

Turning to systems of man-made complexity, those may be viewed as sophisticated extensions of the life process. Humans have the innate urge to encode useful information into surrounding material structures, to save it for re-use. This phenomenon is responsible for the invention of writing as a means to preserve spoken language. Language is a complex invention of regularity and patterns that convey meaning. Words enabled our ancestors to communicate and cooperate among family members and the larger social group. The success of the relatively weak humans over other, stronger animals is as much due to social cooperation and coordination as it is to our evolved innate intelligence.

Recording observations of our natural environment required us to invent mechanisms of physical documentation: regular markings on bone and stone; paintings on cave walls; patterns on pottery; regular patterns of the sound of our voice that became language and song; and regular complex patterns of the movement of our bodies that became ritual dance, etc. Humans stored complex information whose decoding was vitally important for life. Discovered information responsible for social complexity goes far beyond immediate biological needs. This information was, until very recently, stored as the complexity of our built environment: in the geometry itself.

Written language in the West eventually decoupled from ornamentation. The unified practice continues in the Arab-Islamic world, however, where calligraphy is an indivisible part of architecture. When the built environment no longer carries meaning through organized complexity, it loses its nourishing function. This loss is a casualty of the surface appearance of design style. Since it no longer encodes information that nourishes human life, architecture has become random for the first time in human history. Until the 20^{th} century, designers instinctively and correctly shunned randomness, because that destroys the information encoded through ordered complexity. By erasing this information, our environment is fast becoming either minimalist (no information at all), or random (with lots of useless information).

7. Observed complexity in the built environment

As human beings, we find ourselves in a complex world that we did not create, but which we manipulate and transform in profound ways. We create our most natural complex systems more or less unconsciously, to negotiate the energy flows encountered in daily life. Successful buildings and streets are often outgrowths of their designers' understanding (conscious or not) of how complex systems actually work.

Traditional buildings and cities are created by forces analogous to those that drive natural and biological complexity. The traditional built environment was shaped adaptively over time to contain and help our movements, vital actions, and socialization. Here, *physical complexity* matches *social complexity*. A building or urban space itself doesn't change instantly in response to our needs, except when renovated. Yet we experience environments as expressions of ever-evolving techniques for designing them. Those techniques incorporate the knowledge acquired from the success or failure of their predecessors.

Adaptive design does not really copy nature's forms (biomimicry). Instead, we are hard-wired to reproduce nature's organized complexity in how we make things. When we do observe either extreme simplicity (as uniformity) or randomness (as disorganization) in traditional buildings and urban fabric, it is not imposed by "design". It is there because it is the simplest and easiest energy alternative within a larger system, or a byproduct of forces that have built up organized complexity elsewhere. Simplicity and randomness are left over after focusing on organizing complexity nearby. In nature as in traditional settlements, there are functional reasons for what is happening and where it occurs, and it does not arise from a designer's whim.

8. Adaptive complexity cannot be designed all at once

Architects and the educated public wrongly assume that complexity must be designed. That misconception affects human wellbeing negatively. Designed (i.e. invented) complexity cannot automatically produce the high degree of organized complexity found in nature. To do it right, we have to follow steps such as those listed in Table 1. We certainly want to employ complexity to generate a better, more adaptive environment. True sustainability depends upon creating complex systems where all of the different structural scales link together coherently. The "organized" part is their most vital characteristic, and the most difficult to achieve.

That doesn't stop architects from trying to design complexity, however. Computer programs generate complex, innovative shapes that look impressive on a screen. But those designs are random and superficial, satisfying style, not adaptation. They fail to embrace evolutionary responses to variable conditions on the ground. Many complex contemporary built structures interact with their users in a random, disorganized manner. The substitution test determines whether a structure is organized or random: *if any other component or structure could be erected in its place, then it is random and not adaptive*.

Let's look at any one of a number of recent award-winning buildings meant to be concert halls, government offices, museums of contemporary art, or public libraries along with their adjoining urban spaces. Their shapes are interchangeable (except maybe for specialized interior features). After such a virtual switch, the substitute building does not adapt any better to its site, nor to its surroundings. Its public urban space would be just as deficient (usually repelling instead of attracting pedestrians) after the substitution. The original did not adapt well to human use, and neither does any alternative designed according to contemporary fashion trends.

9. Human-computer interactions, and environmental reductionism

Many design disasters result from top-down thinking, where untested models are implemented by force on the population. Eventual failure from the point of view of their human users as a rule does not mean subsequent rejection of those dysfunctional models, because they continue to make money for some groups. This occurs the world over, fuelled by global finance and supported by ideologies concerned only with visual style. Greed and megalomania thwart adaptive design. The building process is driven by a total disregard for the delicate complexities of living society, coupled to a desire to get something built as a venture of financial speculation.

Human actions and movements, together with the structures that adaptively contain them, always link into one socio-geometric system. Ideally, physical space should match social space with the same type of complexity. Stylistically-driven simplification on a grand scale reduces the organized complexity of the built environment, however, with serious negative effects. One example is bulldozing the complex supporting frameworks of traditional neighborhoods to erect repeating blocks of high-rises that look simple from an airplane. To accomplish the same task or goal as before, human actors must now expend far more energy in negotiating their daily actions. The built complexity was changed without noticing the disastrous consequences. If people are unable or unwilling to assume the additional energy burden, useful activity may cease (Salingaros, 2011; 2012). In this example, complexity tries to shift, but cannot.

This, sadly, is the legacy of industrial-modernist planning the world over. Misguided governments impose formal plans as tools of social engineering. The large-scale footprints and infrastructure are wrong because they exclude human-scale activities, thus starving social complexity. Yet, because of the scale of existing built structures such as tower housing, it is nearly impossible to fix the errors through plastic deformations. Humanity is thus saddled with dysfunctional urban regions that will keep society fragmented and waste energy for decades or centuries (Marshall, 2009; Mehaffy & Salingaros, 2015).

Whenever planners eliminate the small and intermediate scales from the built environment, system complexity is lost. The analogy with computers, where software and hardware take on increasing complexity burdens to simplify the human-computer interface, doesn't hold. Computers are designed to execute specific functions; therefore, the objective of simplification in a computer is easier use, not reduced capability. Users of information and communication technology demand being able to do what they always did and more, and in an easier, faster, and more efficient manner.

In the analogous physical situation, complexity cannot shift over. Contrary to the user-driven evolution of computers, geometrical simplification has killed off formerly lively and vibrant community life. The evolved kind of organized complexity in the built environment feeds living processes. Replacing human-scale intricate urban fabric by giant, faceless, mono-functional blocks erases organized complexity. Simplistic top-down urban design replaces the components and variety of healthy individual and social life with deadening, homogeneous sterility. It proves extremely difficult for a person to exist in anything more than a disconnected minimal state.

10. Adaptivity and computational irreducibility

Biology and computer science shed light on the type of sequential computations that create organized complexity. These play an essential role in generating healthy buildings and cities (Alexander, 2009; Salingaros, 2012). Each step that creates adaptive complex structure corresponds to some design operation akin to a computation. The key here is that we perform one design step at a time, with continuous feedback.

A computational model of the urban fabric fixes the degree and adaptivity of the computations involved. How do we judge the computational content of different situations? How much computation is required to design complex urban fabric? The answers are known from the theory of complex systems. A system is constructed by following a sequence of steps. In simple systems one can use a formula to shortcut to the final state. We don't need to duplicate the amount of computational effort involved in the system's own design, since in most cases we get the form directly. This is true for physical systems that are examples of what are called "computationally reducible systems" (Mehaffy & Salingaros, 2015).

Most of what is built today in the "official" sector applies a standard formula. It is computationally simplistic. Such environments are usually mediocre or even dysfunctional for the user, but they generate easy profits for the speculative investor and construction companies. Such design and planning formulas have become institutionalized. For this reason, decision makers simply repeat the same formula everywhere throughout the world to create more dysfunctional urban fabric.

Adaptive systems are not simple, however. A living system's overall complex form develops by changing its state, and since every complex system has a hierarchy of distinct scales (from small to large), the system changes on various different levels of scale simultaneously. Computation of the final state requires the same computational effort as the system has gone through to create itself. Such a system is called "computationally irreducible" (Mehaffy & Salingaros, 2015; Wolfram, 2001). In irreducibly complex systems, there is no formula or shortcut for finding the final state. When designing a complex system, therefore, taking a shortcut by applying a generic form compromises system coherence and functionality. (But extractive industry unconcerned with human welfare seeks the opposite: to build the same form everywhere regardless of context.)

An adaptive design process consists of a large number of steps, each using feedback to influence the final product. This method is well known in adaptive software design (Highsmith, 2000). When the goal is left more loosely defined, the designer may concentrate on adjusting the sequence of steps, to guarantee the development of a coherent emerging system. Every design decision is then guided by its affect on the evolving whole as it exists at that instant (Alexander, 2001-2005; 2009). This means that a design must communicate with each of its components (usually in the mind of the designer). Any help in visualizing the connections, such as drawings, miniature models, computer visualizations, or full-scale mockups, will help to decide on what to do next.

The essential difference between following a template and the computational design method is that a planned, imposed result considers deviations from the plan as mistakes, whereas an interactive computation uses a process with feedback to enhance the existing whole. Deviations from plan ought to be welcomed: those are necessary but we still have to choose among them. Positive deviations respond to input from the configuration during its development. In a guided computation, the end result is neither fixed nor entirely predictable, yet it turns out to be highly adaptive and coherent.

11. Conclusion

We need to know how to build complexity into artificial systems that is similar to that of living systems. Only a special type of organized complexity helps to adapt the built environment to human needs. This paper clarified the differences among three types of complexity: (i) organized complexity, (ii) extreme simplicity, and (iii) disorganized complexity. Whenever we find the second and third varieties built into urban form, the urban fabric is dysfunctional and inhuman. Complexity cannot be designed in the sense that architects understand the term: it must be allowed to evolve step-by-step from a flexible design process. Organized complexity "feeds" living structure in cities that privilege the scale of the human being. This is seen in traditional urban morphologies, yet planning has not implemented them for decades.

The results outlined here represent an "intelligent" search for the most adaptive forms in design. A computational process applies towards the adaptive design of cities. Complexity is embodied in different natural and artificial systems all around us, yet we have been building the wrong type of complexity into our environment for about a century, with disastrous consequences for sustainability. Creating organized complexity follows analogous processes to how an organism achieves its form and structure. We are able to use insights from biology and computer science to revolutionize architecture and urban design. Design that adapts essentially to human life will hopefully replace the industrial-modernist typologies that society has been fixated upon for decades.

Acknowledgment. This article includes, in revised form, material that appeared in *ArchNewsNow*, May & September 2015.

References

Alexander, C. (2001-2005). *The Nature of Order, Books 1-4*, Center for Environmental Structure, Berkeley, California. *Book 1: The Phenomenon of Life*, 2001; *Book 2: The Process of Creating Life*, 2002; *Book 3: A Vision of a Living World*, 2005; *Book 4: The Luminous Ground*, 2004.

Alexander, C. (2009). Harmony-Seeking Computations, revised and expanded version of a Keynote Speech at the International Workshop "The Grand Challenge in Non-Classical Computation", University of York, UK, April 2005. www.livingneighborhoods.org/library/harmony-seeking-computations.pdf

Highsmith, J.A. (2000). *Adaptive Software Development*, Dorset House Publishing, New York.

Kellert, S.R., Heerwagen, J. & Mador, M., Editors (2008). *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*, John Wiley, New York.

Marshall, S. (2009). *Cities, Design & Evolution*, Routledge, London, UK.

Mehaffy, M.W. & Salingaros, N.A. (2015). *Design for a Living Planet: Settlement, Science, and the Human Future*, Sustasis Press, Portland, Oregon and Vajra Books, Kathmandu, Nepal. www.zeta.math.utsa.edu/~yxk833/DFALP-online.html

Newman, S.A. & Bhat, R. (2009). Dynamical patterning modules: a 'pattern language' for development and evolution of multicellular form, *International Journal of Developmental Biology*, 53(5-6), 693-705.

Salingaros, N.A. (2011). Why Monotonous Repetition is Unsatisfying, *Meandering Through Mathematics*, 2 September 2011. http://meandering-through-mathematics.blogspot.com/2011/09/why-monotonous-repetition-is.html

Salingaros, N.A. (2012). Urbanism as Computation, Chapter in: J. Portugali, H. Meyer, E. Stolk & E. Tan, Editors, *Complexity Theories of Cities Have Come of Age*, Springer, Berlin, 245-268. http://zeta.math.utsa.edu/~yxk833/urbanism-computation.pdf

Salingaros, N.A. (2014). Complexity in Architecture and Design, *Oz Journal*, 36, 18-25. http://zeta.math.utsa.edu/~yxk833/ComplexityinArchitecture.html

Salingaros, N.A. (2016). *Biophilia and Healing Environments*, Off the Common Books, Amherst, Massachusetts. Published online by Terrapin Bright Green LLC, New York. Ten-part series originally published online by *Metropolis* in 2015. https://terrapinbrightgreen.com/report/biophilia-healing-environments/

Wolfram, S. (2001). *A New Kind of Science*, Wolfram Media, Champaign, Illinois. http://livingneighborhoods.org/library/harmony-seeking-computations.pdf