Geoinformatics for Geosciences

Advanced Geospatial Analysis using RS, GIS, and Soft Computing

Edited by

Nikolaos Stathopoulos, Andreas Tsatsaris and Kleomenis Kalogeropoulos

Earth Observation Series

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Chapter 3

A new kind of GeoInformatics built on living structure and on the organic view of space

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3.1 Introduction

The great architect Christopher Alexander had some remarkable insights about architecture, which applies equally to geography. Over the past century, geography (or architecture) has always been a minor science, seeking application of the physical sciences such as physics and anthropology. In the next two centuries, geography (or architecture) might become a major science, a sort of complexity science, when the deep question of space has been properly understood (Grabow, 1983). The deep question touches the very nature of space or the organic or third view of space, as formulated by Alexander (2002–2005, 1999), that space is neither lifeless nor neutral but a living structure capable of being more living or less living. Living structure is such a structure that consists of far more small things (or substructures) than large ones across all scales ranging from the smallest to the largest (scaling law, Jiang, 2015), yet with more or less similar-sized things (or substructures) on each of the scales (Tobler's law, Tobler, 1970). It is initially the deep question or the very notion of a living structure or the organic view of space that triggered us to develop this chapter.

The third view of space differs fundamentally from the first two views of space: Newtonian absolute space and Leibnizian relational space, which are framed under Cartesian mechanical worldview (Descartes, 1637/1954). The mechanical worldview is so dominated in science and in our thinking as if it were the only mental model, or even worse it may be considered to the world itself. It is a powerful model about our world, for what we human beings have achieved in science over the past 100 years is largely attributed to the mental model. However, the mechanical mental model is limited when

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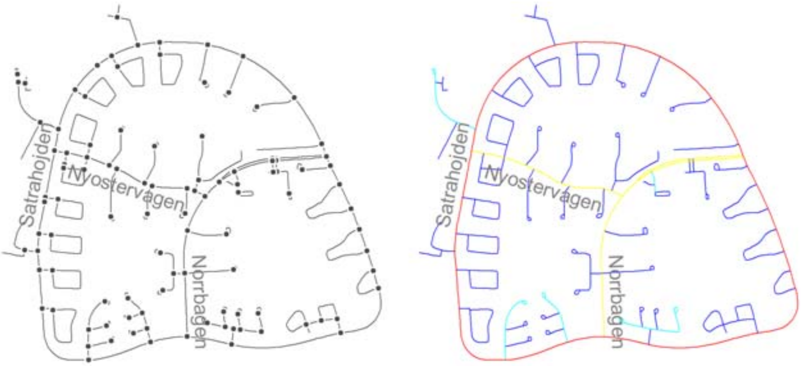
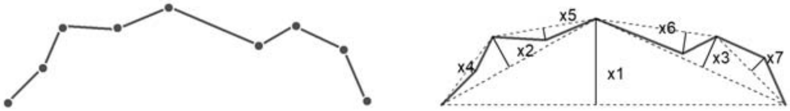
comes to design or creation, as the goodness of designed or created things is sidelined as an opinion or personal preference rather than a matter of fact (Alexander, 2002–2005). Under Newtonian absolute and Leibnizian relational views of space—a geographic space is represented as a collection of geometric primitives such as points, lines, polygons, and pixels (c.f., Fig. 3.1 for illustration), which tend to be "*cold and dry*" (Mandelbrot, 1982), so it is not seen as a living structure.

The mechanical world picture has two devastating results according to Alexander (2002–2005). The first was that the "I" went out of the world picture and the inner experience of being a person is not part of this picture. The second was that the mechanical world picture no longer has any definite feeling of value in it, or value has become sidelined as a matter of opinion



(A) Representation of street segments

(B) Representation of natural streets



(C) A curve as a set of line segments

(D) A curve as a set of bends

FIGURE 3.1 Nonliving versus living structure views of geographic features. *Note*: Conventionally, a street network is represented as a set of geometric primitives, which are not the right things or substructures (A), whereas it is more correctly perceived as a collection of named streets, which are the right things or substructures for seeing the street network as a living structure (B). Each street is colored as one of the four levels of scale: blue for the least connected streets, red for the most connected street (only one), and yellow and turquoise for those between the most and the least connected. A coastline is conventionally represented as a set of line segments, which are not the right things or substructures (C), but it is more correctly perceived as a collection of far more small bends than large ones, which are the right things or substructures for seeing the coastline as a living structure (D). It is because the notion of far more small bends than large ones occurs twice: (1) $x_1 + x_2 + x_3 > x_4 + x_5 + x_6 + x_7$, and (2) $x_1 > x_2 + x_3$.

rather than as something intrinsic to the nature of the world. The organic world picture first conceived by Whitehead (1929) extends the mechanical world picture to include human beings as part of the organic world picture. The same worldview has been advocated by quantum physicist Bohm (1980) among many others. Under the organic worldview, we human beings are part of the world rather than separated from the world. In other words, the physical world or the universe is organ-like rather than machine-like (Whitehead, 1929). It is under the organic world picture that Alexander (2002−2005, 1999) formulated the third view of space. Under the third view of space, value lies on the underlying configuration of space and the goodness of space is no longer conceived as a matter of opinion, but a matter of fact. The shift from the opinion view to the fact view or from the mechanical worldview to the organic worldview represents something fundamental (Kuhn, 1970) in our thinking about geography, for design or how to make living or more living space is at the forefront of geographic inquiry.

We in this chapter attempt to setup a new kind of GeoInformatics on the notion of living structure and on the third or organic view of space. Living structure is said to be governed by two fundamental laws: the scaling law and Tobler’s law. Among the two laws, the scaling law is the first, or dominant law, as it is universal, global, and across scales, whereas Tobler’s law is available locally or on each of the scales. Conventionally, GeoInformatics has been viewed as a minor science or an applied science that seeks to use or apply major sciences for understanding geographic forms and processes. In this chapter, we argue that the new kind of GeoInformatics is a major science, a science of living structure, not only for better understanding geographic forms and processes but also for better making and remaking geographic space or the Earth’s surface toward a living or more living structure.

The remainder of this chapter is organized as follows. Section 3.2 introduces the two fundamental laws of living structure that favor statistics over exactitude. Section 3.3 illustrates how living structure differs from nonliving one under two different worldviews. Section 3.4 presents two design principles—differentiation and adaptation—to make or transform a space to be living or more living. Section 3.5 further discusses the new kind of GeoInformatics and its deep implications. Finally in Section 3.6, the chapter concludes with a summary pointing to a prosperous future of the new GeoInformatics.

3.2 Two statistical laws together for characterizing the living structure

The notion of living structure applies to all organic and inorganic phenomena in the scales ranging from the smallest Planck’s length to the largest scale of the universe (Alexander, 2002−2005, 2003), so do the scaling law and

Tobler's law. The applicability implies that there are far more small particles than large ones, far more rats than elephants, far more small stars than large ones, far more small galaxies than large ones, and so on. This chapter deals with a range of scales of the Earth's surface between 10^{-2} and 10^6 m. Table 3.1 shows how these two laws complement rather than contradict to each other from various perspectives (Jiang & Slocum, 2020). It is wise to keep the scaling law as the dominant one, as it is global or across scales, whereas Tobler's law is local or on each scale. In conventional GeoInformatics, Tobler's law is usually overstated as the first law of geography, and it implies that the Earth's surface is in a simple and well-balanced equilibrium state. However, we know that the Earth's surface is unbalanced and very heterogeneous and every place is unique (Goodchild, 2004). Dominated by the scaling law or the nonequilibrium character, the new kind of GeoInformatics aims not only to better understand the complexity of the Earth's surface but also to make the Earth's surface a living or more living structure. For creating living structures, two design principles—differentiation and adaptation—will be introduced later on.

Unlike many other laws in science, these two laws are statistical rather than exact. The statistical nature is more powerful than the exactitude one. Below, we cite three sets of evidence in science and art to make it clear why exactitude is less important. First, Zipf's law (Zipf, 1949) is also statistical rather than exact. It states that in terms of city sizes, the largest city is about twice as big as the second largest, approximately three times as big as the third largest, and so on. Here twice, three times, and so on are not exact but statistical or roughly. Among the two sets for example: [1, 1/2, 1/3, …, 1/10] and [$1 + e_1$, $1/2 + e_2$, $1/3 + e_3$, …, $1/10 + e_{10}$] (where e_1, e_2, e_3, … e_{10} are very small values), the first dataset does not follow Zipf's law, whereas the second does. Zipf's law is a major source of inspirations of fractal geometry (Mandelbrot, 1982). In his autobiography, Mandelbrot (2012) made the

TABLE 3.1 Two complementary laws of geography or living structure.

Scaling law	Tobler's law
There are far more small things than large ones across all scales, and the ratio of smalls to larges is disproportional (80/20).	There are more or less similar things available at each scale, and the ratio of smalls to larges is closer to proportional (50/50).
Globally, there is no characteristic scale, so exhibiting Pareto distribution, or a heavy-tailed distribution, due to spatial heterogeneity or hierarchy, indicating complex and nonequilibrium character.	Locally, there is a characteristic scale, so exhibiting a Gauss-like distribution, due to spatial homogeneity or dependence, indicating simple and equilibrium character.

following remark while describing the first time he was introduced to a book review on Zipf's law: "*I became hooked: first deeply mystified, next totally incredulous, and then hopelessly smitten ... to this day. I saw right away that, as stated, Zipf's formula could not conceivably be exact.*" A dataset following Zipf's law meets the scaling law, but not vice versa, which means that the scaling law is even more statistical than Zipf's law. Zipf's law requires a power law, whereas the scaling law does not.

The second evidence is not only statistical but also geometrical. The leaf vein shown in Fig. 3.2 (Jiang & Huang, 2021) apparently has far more small substructures than large ones from the largest square to the smallest white spots. Carefully examining the structure of the leaf vein, it is not difficult to find that there are four different levels of scale according to the thickness of their outlines. In contrast, the Sierpinski carpet also has far more smalls than larges; that is, far more small squares than large ones, exactly rather than statistically (Sierpínski, 1915). Let us carefully examine the exactitude of the carpet. The largest square is in the middle of the carpet of size 1/3, which is surrounded by eight squares of size 1/9, each of which is surrounded by eight squares of size 1/27, each of which is surrounded by eight squares of size 1/81. Thus there are two exponential data series, each of which is controlled by some exact number. The size of squares is exponentially decreased by the exact number 1/3 (1/3, 1/9, 1/27, 1/81), whereas the number of squares is exponentially increased by the exact number 8 (1, 8, 64, 512). Clearly there are far more small squares than large ones exactly rather than statistically.

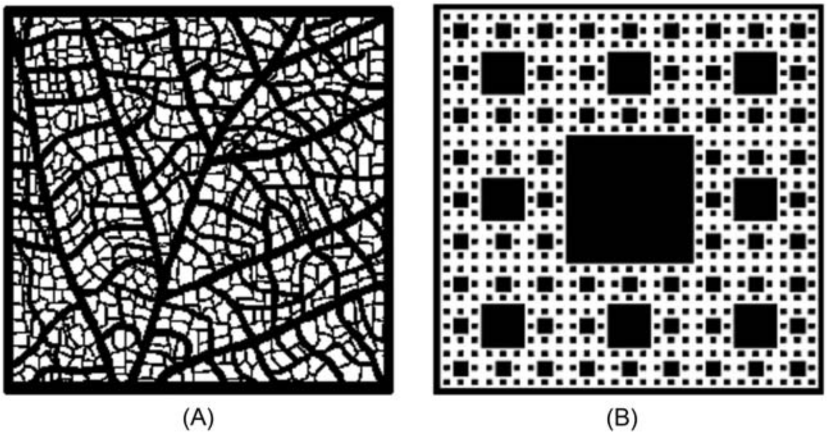


FIGURE 3.2 The leaf vein looks more living or more structurally beautiful than the stiff Sierpinski carpet. *Note*: The leaf vein (A) and the Sierpinski carpet (B) both meet the scaling law and Tobler's law, but the leaf vein is more living than the Sierpinski carpet. This is because the squares of the Sierpinski carpet on each scale are precisely the same rather than more or less similar, thus violating Tobler's law to some extent.

Because of the exactitude, the Sierpinski carpet is less living structurally than the leaf vein.

French painter Matisse (1947) made a famous statement about the essence of art: "*Exactitude is not truth.*" In terms of exactitude, a photograph is far better than a painting. However, the value of a painting lies not in its exactitude, but in something else, which is not only inexact but also distorted or exaggerated. The distorted or exaggerated nature is often used in drawing a cartoon. A human face is a living structure governed by the scaling law and Tobler's law, with the recurring notion of far more smalls than larges. The eyes, nose, mouth, and ears are the largest features and are therefore the most salient; each of them—if examined carefully—is a living structure again, with the recurring notion of far more smalls than larges. All human faces are universally beautiful in terms of the underlying living structure, despite some tiny cultural effects on their beauty.

The scaling law and Tobler's law are really two fundamental laws about livingness or beauty. They can be used to examine many patterns or structures (e.g., Wade, 2006; Wichmann & Wade, 2017) for understanding not only why they are beautiful but also how beautiful they are. For example, the leaf vein is living or beautiful because of the recurring notion of far more small structures than large ones. This way, through these two laws, the livingness or beauty of a structure or pattern can be objectively judged. Importantly, the livingness judged through these two laws can be well reflected in the human mind and heart, thus evoking a sense of beauty. This point will be further discussed in the following.

3.3 Living versus nonliving structure: the "things" the two laws refer to

The two laws introduced above have a common keyword—"things": (1) more or less similar things on each scale and (2) far more small things than large ones across all scales. What are the "things" the two laws refer to? In general terms, the things that collectively constitute a living structure are the right things, whereas the things that collectively do not constitute a living structure are not the right things. For example, if the leaf vein was saved as a gray-scale image with 1024 by 1024 pixels, each of which has a gray scale between 0 and 255, careful examination of these pixel values would show that they do not have far more light (or dark) pixels than dark (or light) ones. This way, we would end up with an absurd conclusion that the leaf vein is not a living structure. In fact, the pixels are not the right things, or the pixel perspective is not the right perspective for seeing the living structure.

In addition to the perspective discussed above, the scope also matters in seeing a living structure. A tree has surely far more small branches than large ones across scales from the largest to the smallest, whereas branches on each scale are more or less similar. Thus the tree is no doubt a living structure, not biologically but in terms of the underlying structure. However, its leaves can be both living and nonliving structures depending on the scope we see them. It is a living structure, if we go down to the scope or scale of intra-leaves, each of them has multiple scales (as shown in Fig. 3.2). It is a nonliving structure, if we on the other hand concentrate on inter-leaves, they are all more or less similar sized, being the smallest scale of the tree. In addition, the leaf vein shown in Fig. 3.2 is not a complete leaf, but part of it, with the large enough scope for us to see the living structure. All geographic features are living structures, if they are seen correctly with the right perspective and scope.

Let us further clarify the term "things" or substructures through two working examples: a street network and a coastline (Fig. 3.1, Jiang & Slocum, 2020). Conventionally, in geography or GeoInformatics, the things often refer to geometric primitives such as pixels, points, lines, and polygons. There is little wonder that Tobler's law is seen pervasively, as there are more or less similar-sized things seen from the perspective of geometric primitives. For example, a street network has more or less similar street segments, or all the street junctions have more or less similar numbers of connections (1−4) (Fig. 3.1A). A coastline consists of a set of more or less similar line segments (Fig. 3.1C). Unfortunately, all these geometric primitives are not the right things for seeing the street network or coastline as a living structure. There is little wonder, constrained by the geometric primitives, that living structure was not a formal concept in geography or GeoInformatics.

A street network is more correctly conceived of as a set of far more short streets than long ones or a set of far more less connected streets than well connected ones (Fig. 3.1B). The street network has four levels of scale, indicated by the four colors, far more short streets than long ones across the scales, and more or less similar streets on each of the four scales. A coastline is more correctly represented as a set of far more small bends than large ones (Fig. 3.1D). The coastline has three levels of scale, indicated by three sets of bends: [x_1], [x_2, x_3], and [x_4, x_5, x_6, x_7]. The notion—or recurring notion—of far more smalls than larges should be the major criteria for whether things are the right things that enable us to see a living structure or whether we have the right perspective and scope for seeing a living structure.

The "things" that collectively constitute a living structure are also called centers (Alexander, 2002−2005), a term that was initially inspired by the notion of organisms conceived by Whitehead (1929). Centers or organisms are the building blocks of a living structure, and their definitions are somewhat obscure. Instead, in this chapter, we use substructures to refer to the right things for seeing a living structure. This way, a living structure can be stated—in a recursive manner—as the structure of the structure of the structure, and so on. The things or substructures constitute an iterative system. To make the point clear, it is necessary to introduce the head/tail breaks (Jiang, 2013), a classification scheme for data with a heavy-tailed distribution.

For the sake of simplicity, we use the 10 numbers [1, 1/2, 1/3, . . ., 1/10] to show how they are classified through the head/tail breaks (Fig. 3.3, Jiang & Slocum, 2020). The dataset is a whole, and its average is about 0.29, which partitions the whole into two subwholes: those greater than the average are called the head [1, 1/2, 1/3] and those less than the average are called the tail [1/4, . . ., 1/10]. The average of the head subwhole is about 0.61, and it partitions the head subwhole into two subwholes again: those greater than the average are called the head [1] and those less than the average are called the tail [1/2, 1/3]. Instead of expressing the dataset as a set of numbers, we state the 10 numbers as an iterative system consisting of three subwholes recursively defined: [1], [1, 1/2, 1/3], and [1, 1/2, 1/3, . . ., 1/10]. Instead of perceiving these numbers as a set of 10 numbers, we consider them as a coherent whole, consisting of three subwholes including the whole itself. Or alternatively, these numbers as a coherent structure consists of three substructures including the structure itself. The dataset [1, 1/2, 1/3, . . ., 1/10], because of its inherent hierarchy of 3, is more living than the other dataset [1, 2, 3, . . ., 10] that is without any inherent hierarchy, or violates the notion of far more smalls than larges.

Now let us apply the recursive way of stating a whole or structure into the street network illustrated in Fig. 3.1. Seen from above, the sample street network consists of 50 streets at four hierarchical levels indicated by the four colors: red (r), yellow (y), turquoise (t), and blue (b). Instead of stating the street network as a set or as four classes, we state it as an iterative system consisting of four subwholes or substructures that are recursively defined:

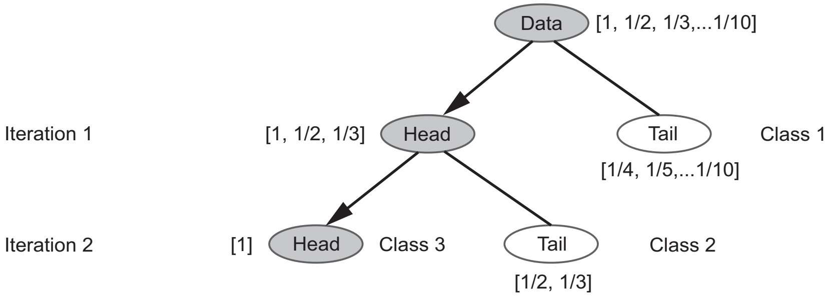


FIGURE 3.3 Head/tail breaks with a simple example of the 10 numbers. *Note*: The 10 numbers [1, 1/2, 1/3, . . ., 1/10] are classified into three classes: [1/4, 1/5, . . ., 1/10], [1/2, 1/3], and [1], which can be said to have three inherent hierarchical levels. The dataset, due to its inherent hierarchy, is therefore more living or more structurally beautiful than another dataset [1, 2, 3, . . ., 10], which lacks any inherent hierarchy or violates the scaling law.

[r], [r, y_1, y_2], [r, y_1, y_2, t_1, t_2, t_3, t_4, t_5], and [r, y_1, y_2, t_1, t_2, t_3, t_4, t_5, b_1, b_2, b_3, . . ., b_{42}]. In the same way, it is not difficult to figure out the three recursively defined subwholes for the coastline: [x_1], [x_1, x_2, x_3], and [x_1, x_2, x_3, . . ., x_7]. This living structure representation is recursive and holistic, so it differs fundamentally from existing representations that tend to focus on segmented individuals or mechanical pieces. An advantage of the living structure representation is that the inherent hierarchy of space is obvious. To this point, we have seen clearly how the right things constitute an iterative system, being a living structure consisting of far more smalls than larges.

3.4 Two design principles: differentiation and adaptation

In line with the two laws of living structure, there are two design principles—differentiation and adaptation—for transforming a space or structure to be living or more living. The purpose of the differentiation principle is to create far more small substructures than large ones, whereas the adaptation principle ensures that the created substructures are well adapted to each other, for example, nearby substructures are more or less similar. These two design principles ensure that any geographic space would become living or more living from the current status. Importantly, goodness of a geographic space is considered as a fact rather than an opinion, as mentioned above. These two design principles are what underlie the 15 structural properties (Fig. 3.4) distilled by Alexander (2002–2005) from traditional buildings,

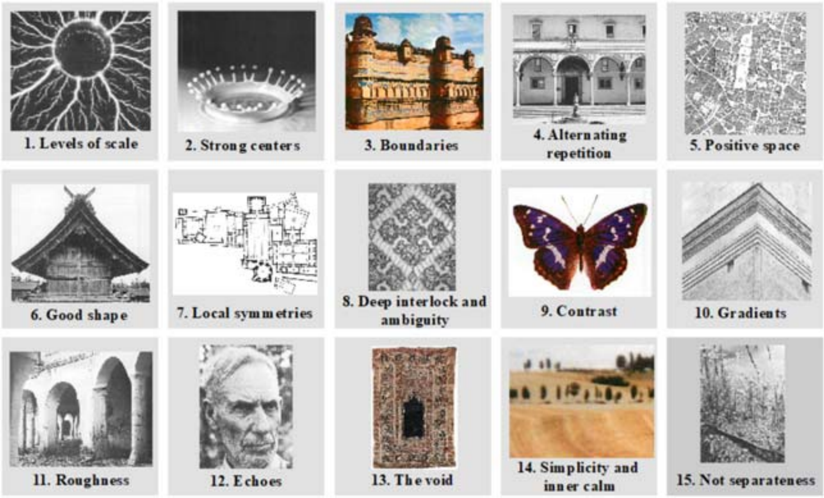


FIGURE 3.4 Fifteen properties in natural and human-made things. *Note*: The fifteen properties exist pervasively in physical space, not only nature but also in what we human beings make and build. The two fundamental laws and the two design principles are distilled from these 15 properties.

cities, and artifacts. The 15 structural properties can be used to transform a space or structure into living or more living structure. Interested readers should refer to Alexander (2002–2005), specifically Volumes 2 and 3, for numerous examples. In this section, we use two working examples—two paintings and two city plans—to clarify these two design principles.

The two paintings shown in Fig. 3.5 are not very living, as they meet only the minimum condition of being a living structure with three or four inherent hierarchical levels. Painting (A) by Dutch painter Piet Mondrian (1872–1944) is entitled *Composition II*, with the three colors of red, yellow, and blue, whereas painting (B) is modified slightly from painting (A) by the author (Jiang & Huang, 2021). Fig. 3.5 demonstrates that how these two paintings are evolved—in a step-by-step fashion—from an empty square. Structurally speaking, painting (B) is more living than painting (A). It can equally be said that structure (G) is more living than structure (F), which is more living than (E), which is more living than structure (D), which is more living than structure (C). Thus, among all these structures or substructures, the empty square is the deadest, while structure (G) is the most living. On the one hand, there is the recurring notion of far more newborn substructures than old ones; on the other hand, within each iteration, there are far more

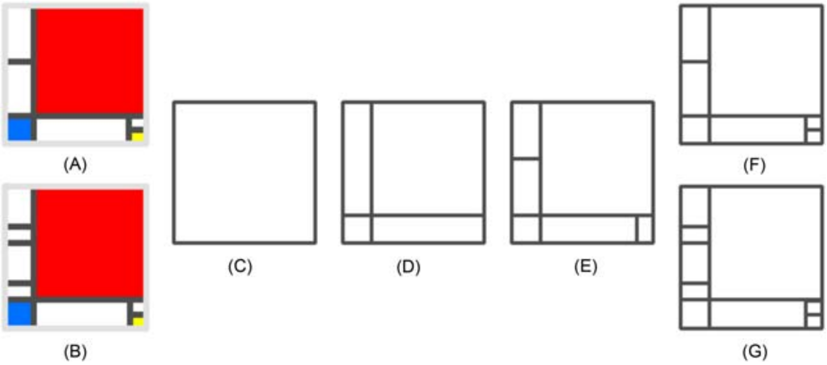


FIGURE 3.5 Living and less-living structures and their differentiation processes. *Note*: The two paintings—*Composition* (A) by the Dutch painter Piet Mondrian (1872–1944) and *Configuration* (B) modified from *Composition* by the author of this chapter—meet the minimum condition of being a living structure. Both paintings can be viewed to be differentiated like cell division from the empty square (C), so they are featured by the recurring notion of far more newborn (newly generated) substructures than old ones. More specifically, there are far more newborns than old one from (C) to (D), and again from (D) to (E), except from (E) to (F) in which there is a violation of far more newborns than old ones. However, there is again far more newborns than old one from (E) to (G). On the other hand, in each iteration, there are far more small substructures than large ones. Thus the painting *Configuration* is more living or more beautiful—structurally—than the painting *Composition*. If the reader prefers *Composition* over *Configuration*, do not be panic and your preference is likely to be dominated by nonstructural factors such as cultures, faiths, and ethnicities. However, the kind of beauty determined by the underlying living structure accounts for the feelings shared by most people or peoples.

small substructures than large ones. Seen from the comparison, it is not hard to understand that one structure is—objectively—more living than another.

The goodness or livingness of a space—or a city in particular—is a matter of fact rather than an opinion or personal preference, based on the underlying living structure. More specifically, the goodness of a space depends on substructures within the space, as we have already seen in the above discussion. The goodness also depends on larger space that contains the particular space. This way of judging goodness or order of things is universal across all cultures, faiths, and ethnicities, not only for natural things but also for what we make or build. This is probably the single most important message in the masterful work *The Nature of Order* (Alexander 2002–2003, 2005). This is a radical departure from the current view of space in terms of its goodness, judged by various technical parameters such as density, accessibility, and greenness. The living structure constitutes the foundation of the new kind of GeoInformatics this chapter seeks to advocate and promote.

The living structure perspective implies that a geographic space is in a constant evolution from less living to living or more living. Importantly, a geographic space or its design and planning process is an embryo-like evolution rather than LEGO-like assembly of prefabricated elements (Alexander, 2002–2005; Jiang & Huang, 2021). Note that the evolution view differs fundamentally from the assembly view, with the former being organic or natural, while the latter being mechanical or less natural. The living structure perspective implies also that a structure or substructures must be seen recursively. For example, conventionally painting (A) is seen as composed of seven pieces, but it is more correct to say it consists of 18 (1 + 4 + 6 + 7) recursively defined structures or substructures (Fig. 3.5). Instead of being nine pieces for painting (B), it is more correct to say that it consists of 20 (1 + 4 + 6 + 9) recursively defined structures.

Using the recursive perspective, it is not hard to understand why traditional city plans are usually more living than modernist counterparts. For example, with the city of London plan, the notion of far more small substructures than large ones recurs five times, so there are six hierarchical levels, whereas for the Manhattan one, the notion of far more small substructures than large ones recurs twice, so there are only three hierarchical levels (Fig. 3.6). Thus the city of London city plan is more living—structurally or objectively—than the Manhattan one. There have been many human perception tests supporting the conclusion that traditional city plans are more living than modernist counterparts (e.g., Alexander, 2002–2005; Wu, 2015), indicating over 75% agreement between the human perception and the reasoning based on the two laws. There may be some people (fewer than 25%) who prefer modernist buildings because they look new and luminous or for whatever personal reasons. A recent biometric investigation (Salingaros & Sussman, 2020) has provided further neuroscientific evidence that traditional façades are more “engaging” with people than contemporary façades.

FIGURE 3.6 Why the city of London plan is more living than the Manhattan one. *Note*: The city of London plan (the left) is obviously a living structure, for it meets scaling law, or the recurring notion of far more small substructures than large ones across the six hierarchical levels, shown in colors in those reduced panels to the left (Jiang & Huang, 2021). The part of Manhattan plan (the right) is less living, with only three inherent hierarchical levels to the right. Additionally, the number of substructures for the city of London is almost twice that of Manhattan, which is another reason why the left plan is more living than the right one.

Space has a healing effect, and this insight into space has been well established in the literature (e.g., Ulrich, 1984). Human beings have an innate nature of loving lifelike things and processes such as forests and weathering. This affinity to nature is termed by the eminent biologist Wilson (1984) as biophilia. The biophilia effect has been used to help create living environments by integrating lifelike things such as light, water, and trees (Kellert et al., 2008). It should be noted that a true biophilia goes beyond the simple integration of natural things but to create things that look like nature structurally (Salingaros, 2015). Jackson Pollock (1912–56) once said that he was not interested in mimicking nature, yet his poured paintings capture the order of nature. In this connection, living structure or the recurring notion of far more smalls than larges, as Alexander (2002–2005) has argued, appears to be the order that exists not only in nature, but also in what we make or build. The order—or living structure—constitutes the core of the new kind of GeoInformatics.

3.5 The new kind of GeoInformatics, its implications, and future works

The new kind of GeoInformatics laid down in the chapter is established on the third view of space or on the solid foundation of living structure. The new kind of GeoInformatics is inclusive of a wide range of conventional disciplines, including for example architecture, urban design and planning, urban science, and regional science, all to do with how to transform our cities and communities to be more livable, more living or more beautiful. Thus the new kind of GeoInformatics is a science of living structure, not only for better understanding geographic forms and processes but also—more importantly—for better making and remaking geographic space to be living or

TABLE 3.2 Differences between the conventional and new GeoInformatics.

Conventional GeoInformatics	New kind of GeoInformatics
Mechanical worldview of Descartes	Organic worldview of Whitehead
First and second views of space of Newton and Leibniz	Third view of space of Alexander
Understanding geographic forms and processes	Understanding + making living structures
Tobler's law dominated	Scaling law dominated
A minor science or application of other major sciences	A major science or a science of living structure

more living (i.e., sustainable spatial planning or design). Table 3.2 lists the differences between the conventional GeoInformatics and the new kind. The new kind of GeoInformatics goes beyond the two cultures under which science is separated from art (Snow, 1959), toward the third culture (Brockman, 1995) under which science and art is one. In the rest of this section, we further discuss on implications of the new kind of GeoInformatics and future works to be done.

It is important to note that the concept of living structure is part of physics, part of mathematics, and part of psychology. As a physical phenomenon, living structure pervasively exists in physical space or in any part of space or matter, and the physical phenomenon constitutes part of physics, or part of quantum physics to be more precise rather than that of classic physics. In this connection, living structure has another name called wholeness that is essentially the same as implicate order (Bohm, 1980). Living structure can be defined mathematically, but the mathematics is a nonlinear mathematics rather than a linear mathematics. The physical or mathematical structure can be psychologically or cognitively reflected in the human mind and heart, triggering a sense of livingness or beauty. Living structure is to livingness or beauty what temperature is to warmth. Given this, human-related research such as spatial cognition, mental map, human way-finding, and even perception of beauty must consider the underlying living structure.

The new kind of GeoInformatics has huge implications on design and art, because goodness of art or design is no longer considered to be an arbitrary opinion or personal preference, but a matter of fact. It is essentially the underlying living structure that evokes a sense of goodness or beauty in the human mind and heart. Thus there is a shared notion of quality or goodness of art among people or different peoples regardless of our culture, gender, and races. Goodness can be measured and quantified mathematically, and the outcome has over 70% agreement with people perception (e.g., Salingaros & Sussman, 2020; Wu, 2015). In this regard, the mirror-of-the-self experiment (Alexander, 2002–2005) provides an effective measure for testing people on their judgement on goodness of things. In this experiment, two things or pictures (e.g., those pairs in Figs. 3.2 and 3.6) are put side by side and human subjects are asked to provide their personal judgment to which one they have a higher degree of belonging or wholeness. The experiment is not kind of psychological or cognitive tests that seek intersubjective agreement, but rather on degree of livingness, something objective or structural. This kind of experiment, as well as eye-tracking and other biometrics data (Sussman & Hollander, 2015), will provide neuroscientific evidence for living structure, thus being an important future work in the new kind of GeoInformatics.

The new kind of GeoInformatics is a science of living structure, substantially based on living structure that resembles yet exceeds fractal geometry (Mandelbrot, 1982). Like conventional GeoInformatics, fractal geometry belongs to the camp of mechanical thought. For example, the commonly used box-counting method for calculating fractal dimension is too mechanical, as the boxes defined at different levels of scale are not the right things (or the right perspective) for seeing living structure (c.f., Section 3.3). As we have illustrated in Figs. 3.1 and 3.2, we adopt an organic rather than mechanical way of seeing living structures. Fractals emerge from an iterative process, but the iterative process is often too strict or too exact. The real world is indeed evolved iteratively, but it is not as simple as fractals, neither classic fractals nor statistical fractals. Nature—naturally occurring things—has its own geometry, which is neither Euclidean nor fractal, but a living geometry that "*follows the rules, constraints, and contingent conditions that are inevitably encountered in the real world*" (Alexander, 2002–2005). The major difference between fractal and living geometries lies probably on the two different worldviews. More importantly, goodness of a shape is not what fractal geometry concerned about, but it is the primary issue of living geometry.

Geographic information gathered through geographic information technologies has provided rich data sources for studying living structures on the Earth's surface from the perspectives of space, time, and human activities. This is particularly true for big data emerging from social media or the Internet. The big data are better than government owned or defined data for revealing the underlying living structure for two main reasons. First, big data have high resolution (like GPS locations of a couple of meters) and finer time scales (down to minutes and seconds for social media location data). Thus they are better than government data for revealing living structure at different levels of scale. Second, government-defined spatial units, such as census tracts, are too rough or too arbitrary for seeing living structure. Instead, we should use naturally defined spatial units such as natural cities and auto-generated substructures (Jiang & Huang, 2021; Jiang, 2018), which are all defined from the bottom up, rather than imposed from the top down, thus making it easy to see living structures. While working with big data, we should try to avoid using grid-like approaches such as the digital elevation model. Although the digital elevation model has far more low elevations than high ones, the grid approach is not the right perspective for seeing living structures. Instead, we should use watersheds or water streams which are naturally or structurally defined. All these topics will be studied in the future for the new kind of GeoInformatics.

3.6 Conclusion

This chapter is intended to help set GeoInformatics on the firm foundation of living structure, based on the belief that how to make and remake livable spaces—or living structures in general—should remain at the core of the new kind GeoInformatics. Considering a room, for example, we should first diagnose whether it is a living structure. If not, try to make it a living structure; if it is already, try to make it more living. This pursuit of living or more living structure extends from our rooms, gardens, buildings to streets, cities, and even the entire Earth's surface. The new kind of GeoInformatics should not just be a minor science—as currently conceived under the Cartesian mechanical worldview—that seeks to apply other major sciences or technology for understanding geographic forms and processes (or city structure and dynamics in particular). This is because these major sciences have not yet solved the problem of how to do an effective making or creation. Instead, the problem of making or creating is commonly left to art, design, or engineering, where there is a lack of criteria for judging the quality or goodness of the created things. In this chapter, the new kind of GeoInformatics is built on the criteria of living structure, not only for understanding geographic forms and processes but also for transforming geographic space to be living or more living.

The new kind of GeoInformatics is founded on the third or organic view of space, under which space is conceived as neither lifeless nor neutral, but a living structure capable of being more living or less living. The third view of space reveals that the nature of geographic space is a living structure or coherent whole, and its livingness or the degree of coherence can be quantified by the inherent hierarchy or the recurring notion of far more smalls than larges. Throughout this chapter, we have attempted to argue that the scaling law should play a dominant role for it is universal, global, and across scales, whereas Tobler's law is available on each of these scales. These two laws are the two fundamental laws of living structure. To make a space living or more living, we must follow the two design principles or, more specifically, a series of biophilia design principles or the 15 structural properties. There are three fundamental issues about a geographic space (or a city in particular): (1) how it looks, (2) how it works, and (3) what it ought to be. A short response to these three issues is that a geographic space should look and work like a living structure and ought to become living or more living. Facing various challenges of our cities and environments, the new kind of GeoInformatics provides new concepts, questions, and solutions to tackle problems and to make and remake cities and communities to be more livable and more beautiful toward a sustainable society. It is time to transform conventional GeoInformatics into the new kind of GeoInformatics, a science of living structure for the Earth's surface.

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