Physica A 463 (2016) 475–484

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

A complex-network perspective on Alexander's wholeness

Bin Jiang

Faculty of Engineering and Sustainable Development, Division of GIScience, University of Gävle, SE-801 76 Gävle, Sweden

HIGHLIGHTS

- The complex network perspective enabling us to see things in their wholeness.
- Two types of wholeness or coherence at each scale and across all scales.
- The commonly perceived whole in comparison with the wholeness as a recursive structure.
- Differentiation and adaptation as effective design principles for living structures.

ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form 6 June 2016
Available online 26 July 2016

Keywords:
Theory of centers
Living geometry
Christopher Alexander
Head/tail breaks
Beauty

ABSTRACT

The wholeness, conceived and developed by Christopher Alexander, is what exists to some degree or other in space and matter, and can be described by precise mathematical language. However, it remains somehow mysterious and elusive, and therefore hard to grasp. This paper develops a complex network perspective on the wholeness to better understand the nature of order or beauty for sustainable design. I bring together a set of complexity-science subjects such as complex networks, fractal geometry, and in particular underlying scaling hierarchy derived by head/tail breaks — a classification scheme and a visualization tool for data with a heavy-tailed distribution, in order to make Alexander's profound thoughts more accessible to design practitioners and complexity-science researchers. Through several case studies (some of which Alexander studied), I demonstrate that the complex-network perspective helps reduce the mystery of wholeness and brings new insights to Alexander's thoughts on the concept of wholeness or objective beauty that exists in fine and deep structure. The complex-network perspective enables us to see things in their wholeness, and to better understand how the kind of structural beauty emerges from local actions guided by the 15 fundamental properties, and in particular by differentiation and adaptation processes. The wholeness goes beyond current complex network theory towards design or creation of living structures.

"Nature, of course, has its own geometry. But this is not Euclid's or Descartes' geometry. Rather, this geometry follows the rules, constraints, and contingent conditions that are, inevitably, encountered in the real world."

[Christopher Alexander et al. (2012)]

1. Introduction

Nature, or the real world, is governed by immense orderliness. The order in nature is essentially the same as that in what we build or make, and underlying order-creating processes of building or making of architecture and design are no less important than those of physics and biology. This is probably the single major statement made by Alexander [1] in

E-mail address: bin.jiang@hig.se.

http://dx.doi.org/10.1016/j.physa.2016.07.038

his theory of centers, in which he addressed the fundamental phenomenon of order, the processes of creating order, and even a new cosmology—a new conception of how the physical universe is put together. In the theory of centers or living geometry [2], the wholeness captures the meaning of order and is defined as a life-giving or living structure that appears to some degree in every part of space and matter; see Section 3 for an introduction to wholeness and wholeness-related terms. As the building blocks of wholeness, centers are identifiable coherent entities or sets that overlap and nest each other within a larger whole. Unlike the previous conception of wholeness focusing on the gestalt of things [3], the wholeness of Alexander [1] is not just about cognition and psychology, but something that exists in space and matter. Different from the wholeness in quantum physics mainly for understanding [4], Alexander's wholeness aims not only to understand the phenomenon of order, but also to create order in the built world or art. The wholeness is defined as a recursive structure. Based on this definition, Jiang [5] developed a mathematical model of wholeness as a hierarchical graph with indices for measuring degrees of life or beauty for both individual centers and the whole. This model helps address not only why a design is beautiful, but also how much beauty it has. However, this previous study had some fundamental issues on the notions of centers and wholeness unaddressed. Specifically, what are the centers, how are they created, and how do they work together to contribute to the life of wholeness? In addition, the wholeness remains somehow mysterious, particularly within our current mechanistic worldview [1]. To address these fundamental issues, this paper develops a complex-network perspective on the wholeness.

A complex network is a graph consisting of numerous nodes and links, with unique structures that differentiate it from its simple counterparts such as regular and random networks [6]. Simple networks have a simple structure. In a regular network, all nodes have a uniform degree of connectivity. In a random network, the degrees of connectivity only vary slightly from one node to another. As a consequence, a random network hardly contains any clusters, not to say overlapping or nested clusters. On the contrary, complex networks, such as small-world and scale-free networks [7,8], tend to contain many overlapping and nested clusters that constitute a scaling hierarchy ([9]; see a working example in Section 2). The scaling hierarchy is a distinguishing feature of complex networks or complex systems in general. For example, a city is a complex system, and a set of cities is a complex system [10–13], both having scaling hierarchy seen in many other biological, social, informational, and technological systems. This paper demonstrates that the wholeness bears the same scaling hierarchy as complex networks or complex systems in general.

Relying on the complex network perspective, this paper aims to demonstrate that wholeness is not just in cognition and psychology, but something that exists in space and matter. It also aims to show that the concept of wholeness is important not just for understanding the phenomenon of order, but also for creating order with a high degree of wholeness through two major structure-preserving transformations: differentiation and adaptation. I argue that there are major differences between the whole as a vague term and wholeness as a recursive structure. The wholeness comprises recursively defined centers induced by itself, whereas the whole, as we commonly perceive, comprises pre-existing parts. The mantra that *the whole is more than the sum of its parts* should be more truly rephrased as *the wholeness is more than the sum of its centers*. This paper examines the notions of wholeness and centers from the perspective of complexity science. It also discusses two types of coherence respectively created by differentiation and adaptation processes, which are consistent with the spatial properties of heterogeneity and dependence for understanding the nature of geographic space.

The remainder of this paper is structured as follows. Section 2 briefly introduces complex networks and scaling hierarchy using head/tail breaks—a classification scheme and a visualization tool for data with a heavy-tailed distribution [14,15]. Section 3 compares related concepts, such as whole and parts versus wholeness and centers, and discusses the theory of centers using two examples of a cow and an IKEA desk. Section 4 presents three case studies to show how wholeness emerges from space and how it can be generated through the two major structure-preserving transformations of differentiation and adaptation. Section 5 further discusses implications of the complex-network perspective and wholeness. Finally, Section 6 draws a conclusion and points to future work.

2. Complex networks and the underlying scaling hierarchy

Small-world and scale-free networks are two typical examples of complex networks, which fundamentally differ from their regular and random counterparts. A small-world network is a middle status between the regular and random networks, so it has some nice properties of its regular and random counterparts. These properties are local efficiency of regular networks characterized by high clustering coefficient, and global efficiency of the random networks measured by short average path length [7]. Scale-free networks are a special type of complex networks, and their degree of connectivity demonstrates a power-law distribution, indicating far more less-connected nodes than well-connected ones [8]. In other words, very few nodes, or hubs, have the highest degree of connectivity, many nodes have the lowest degree, and some in between the highest and the lowest. Complex networks are so called precisely because of their complex structure that involves a large number of nodes and components. The nodes are the basic units, while the components are those built from the basic units.

Complex networks tend to contain many components, termed communities or clusters [16]. A cluster has many inside links and a few outside links, so constitutes a coherent sub-whole or sub-structure that adapts to its context. Clusters within a complex network nest each other, forming a scaling hierarchy of far more small communities than large ones [9]. To illustrate, we adopt the Karate Club network [17], widely studied in the literature of social and complex networks. This network, consisting of 34 nodes and 78 links, can be broken down into 14 communities of different sizes: 28, 15, 10, 6, 5, 5,