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Synergetic Cities: Information, Steady State and Phase Transition

Implications to Urban Scaling, Smart Cities and Planning

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Implications to Urban Scaling, Smart Cities and Planning

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Hermann Haken
Center of Synergetics
University of Stuttgart
Stuttgart, Baden-Württemberg, Germany

Juval Portugali
Department of Geography and Human Environment
Tel Aviv University
Tel Aviv, Israel

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Preface

The last decades have witnessed the emergence of complexity theories of cities (CTC)—a domain of research that applies the various theories of complexity to the study of cities. As a consequence, there are now several theoretical perspectives on cities as complex systems; "synergetic cities" is one of them.

Synergetic cities (SC) is a theoretical perspective on cities that commences from the basic principles of synergetics. This is a field of research that deals with principles underlying the processes of self-organization in systems belonging to disciplines ranging from physics over biology and social sciences to the humanities including cognitive science.

The notion of SC that we present in this book has developed gradually out of the collaboration between the two of us. However, our aim in this book is not to summarize past studies but rather to extend the notion of SC and thus the domain of CTC. This, by adding to both three novel components: (1) the concepts of *Synergetic Inter-representation Networks* (SIRN), *Information Adaptation* (IA) and their conjunction SIRNIA—concepts that we developed in the past and elucidate the role of cognition in cities. (2) *Steady States* (StS) that are characteristic of the *longue durée* of cities, perhaps undergoing a smooth development. (3) *Phase Transitions* (PT) that are characterized by pronounced qualitative changes of important "indicators."

In particular, StS and PT are among the very basic aspects of complexity, which due to the specific development of the discourse on cities as complex systems, have not as yet received sufficient attention. The focus of interest in CTC was (still is) on the bottom-up emergence of new properties or structures in cities. But how/why does suddenly a new property emerges? What happens before and after its emergence? Such questions were largely overlooked in the CTC discourse. This is not the case with other domains (e.g., physics) in which one finds extensive discussions on StS and PT. And indeed, we start discussing PT in cities by means of analogies to case studies in physics, whereas we introduce new theoretical tools to study StS in cities. We then further elaborate the uniqueness of these processes in the dynamics of cities.

The book is conceived to reach a broad audience from a variety of fields starting with the young domain of CTC to more traditional disciplines such as human/urban geography, urban economy and sociology, city planning, architecture, urban design and more. Its backbone is a presentation of basic concepts without mathematics. But in line with the development of CTC, the concepts are complemented by mathematical approaches. Perhaps with one exception—a chapter on pattern recognition—all chapters are written in a pedagogical style to enable readers to familiarize themselves with the mathematical tools that are basic to synergetic systems theory, including stochastic processes (theory of chance events), information theory, Friston's Free Energy Principle, etc. All of them are useful tools for urbanism and are employed in our book. We hope that readers will enjoy reading it and find it useful for their own studies/research on the understanding of the marvelous phenomenon "city."

The book has greatly benefited from several of our studies in recent years. Thus, the second part of Chap. 3 is based on Sect. 4.2.2 of Portugali 2011. Chapter 13 largely follows our paper: Haken H, Portugali J (2019) "A synergetic perspective on urban scaling, urban regulatory focus and their interrelations." *Royal Society Open Science.* 6: 191087. http://dx.doi.org/10.1098/rsos. 191087. Chapter 14 is largely based on Haken H., Portugali J. (2017) "Smart cities: distributed intelligence or central planning?" In Pardalos P. M. and Rassia S. (Eds.) *Smart City Networks: Through the Internet of Things*, Springer, Heidelberg. Finally, Chap. 15 closely follows Portugali J. (2020) "Information adaptation as the link between cognitive planning and professional planning." In Gert de Roo, C. Yamu and C. Zuidema (Eds.) *Handbook on Planning and Complexity*. Edward Elgar Publishers.

We would like to close this preface with acknowledgments. In particular, Hermann Haken thanks his daughter Karin for her indefatigable help. Both authors thank Dr. Thomas Ditzinger and Mr. Gowrishankar Ayyasamy from Springer for their helpful cooperation. Special thanks also to Mrs. Shoshi Esronie from TAU for typing parts of the text.

Stuttgart, Germany — Hermann Haken
Tel Aviv, Israel — Juval Portugali
August 2020

Contents

Chapter 1
Introduction

1.1 Aim and Scope

Four concepts make the title of this book: *Synergetic cities* which is a view on cites as complex systems from the perspective of Haken's theory of synergetics; *information*, which is a view on cities as complex systems commencing from the perspective of information theory. Next come *steady state* and *phase transition* which are two central aspects of complex systems in general and of cities as complex systems. Our aim is to introduce and develop the above four notions and then to discuss their implication to three issues that stand at the core of current discourse on cities as complex systems: *urban allometery* (or *scaling*) and *smart cities*—both attract special attention in the discourse on cities of the last two decades, as part of the attempt to transform the study of cities into a science. The third issue, *city planning*, attempts to adapt the process of planning to the understanding, and reality, of cities as complex, adaptive self-organizing systems. Before we proceed, a few introductory words on the above four concepts and the rational of focusing on them is in place.

Synergetic cities. Complexity theory (or science) is an umbrella name for a set of theories that started to appear in the 1960s in order to deals with systems that are typified by the following properties: they are *open* in that they exchange matter, energy and information with their environment, they are in *far from equilibrium conditions* implying that they are never in rest, and yet they are more often than not highly ordered and tend to achieve their order spontaneously by means of *self-organization*; they exhibit long periods of *steady state* interrupted by short events of *chaos*, that often lead to *phase transition*, and much more. Synergetics is one of the founding theories in this new domain. All theories of complexity were applied to cities giving rise to *complexity theories of cities* (CTC)—a domain of research that studies cities as complex systems from the various perspectives of the "grand" complexity theories (Portugali 2011). And similarly to the core theories, each theory emphasizes a different aspect of the complexity of cities.

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Common to all CTC is that cities emerge from the bottom up. Synergetic cities too commences from this view but adds that once emerged, cities top—down determine ("enslave") the behavior of the urban agents and so on in circular causality. This view and property of synergetics makes it specifically attractive to study cities, as one of the central issues in the last 120 years of urban studies has always been the way cities affect their citizens: this issue attracted Simmel (1903) at the turn of the twentieth century with his classic *The Metropolisand Mental Life*, it is central to social theory oriented structuralist urban studies (e.g. Lefebvre 1970), and it is still discussed today in the context of urban allometry/scaling, regarding the relations between "Growth, innovation, scaling and the pace of life in cities" (Bettencourt et al. 2007).

Information. As shown below (Chap. 2), cities are *dual* and *hybrid* systems. Dual, in that each agent and the city as a whole is a complex system; hybrid, in that the city is composed of artifacts which are simple systems and urban agents which are complex systems. From these perspectives, central to the study of cities as complex systems is the interaction between the parts—the urban agents; as well as between the urban agents and the artifacts of which cities are composed (buildings, roads, … neighborhoods and whole cities). In these processes of interaction agents exchange information between themselves and between them and the information conveyed by the various urban artifacts and the city as a collective artifact. Our notions of *SIRN* (synergetic inter-representation networks), *IA* (information adaptation) and their conjunction—*SIRNIA*, were specifically designed to capture these processes.

Steady state and phase transition. Complex systems, cities included, are typified, firstly, by long periods of steady state during which, according to Synergetics, the system city is dominated by one or a few *order parameters* (OP). Secondly, by short events of strong fluctuations that interrupt the steady state and often entail a qualitative systemic change, that is, a *phase transition* (PT) that brings the system to a new steady state and so on. This is the "big picture", however; the more detailed one is that during steady state the system is interrupted by random fluctuations that the city (its OP) manages to "enslave"—only when such fluctuations happen in periods of instability, their effect might be dramatic and lead the system city to a PT and structural change. The fact is, that the general tendency in the domain of CTC is to focus on the bottom–up process of the emergence of a new systemic order and to ignore the dynamics of the long periods of steady state. As noted above, one of our aims is to correct this situation and elaborate on the dynamics of steady states and phase transition and the role of fluctuations in these processes.

As indicated by the title and as noted above, our aim is to discuss the implication of the above notions to three issues: *urban allometery* (or *scaling*), *smart cities* and *city planning*. While the three stand at the core of current CTC discourse, they differ considerably: Urban allometry studies are mathematically and ("big") data oriented representing the long history of attempts to develop a science of cities. Smart cities studies explore the implication of the so-called *4th industrial revolution* (Schwab 2016) with its smart devices—IoT, big data, AI, and the like—to various aspects of cities, ranging from transportation, through pollution and sustainability to governance and planning. Many studies in this domain are futuristic and somewhat utopic. Finally, similarly to, and in connection with, the study of cities, planning has a century long history of debates about the proper ways to plan cities. The appearance of CTC some three decades ago with notions such as self-organization and the like, gave rise to a study of the planning implications—theoretical and practical—of the finding that cities are complex adaptive systems, when the degree of adaptability may vary considerably between cities: While some cities flourish, others may have high debts, deteriorate, become obsolescent and lose their importance.

1.2 The Structure of the Book

The discussion in the book evolves in 15 chapters grouped into 3 parts. Part I lays the theoretical foundations. It starts by claiming that cities as complex systems differ from complex systems studied in the material and organic domains in that they are *hybrid complex systems* composed of artifacts which are simple systems and human urban agents which are complex systems; and, it is the urban agents that by means of their interaction, among themselves and with the urban artifacts, make the city a complex system (Chap. 2). Chapter 3 that follows is a short reminder of the theory of Synergetics, its basic concepts and language, and the early attempts to apply them to cities. Subsequent elaborations of the synergetic perspective on cities gave rise, firstly, to the notion of SIRN, then to the notion of IA that complements it and finally to their conjunction SIRNIA which is a theory that has a wider range of applications ranging from a solitary cognitive agent, through a sequence of agents to cities as hybrid complex systems. Chapter 4 thus introduces SIRNIA: first SIRN, next IA and finally their conjunction SIRNIA. The next two chapters introduce the two theoretical foundations of Synergetics: Chap. 5 the 1st Foundation which, as the title indicates, is a bottom–up approach, that is, from parts to order parameters, while Chap. 6 the 2nd Foundation which is a top–down approach—from sparse or big data to laws. Chapter 7 closes Part I by a novel discussion relating the Synergetics' 2nd Foundation and SIRNIA to Friston's *free energy principle* (FEP) regarding the tendency of complex biological systems (e.g. brain) to remain in *steady state* (StS).

Part II elaborates on two aspects/processes which are central to complex systems, yet for several reasons have not so far received sufficient attention in the domain of CTC: steady state and phase transition. In the context of synergetics, they are further associated with 'the slaving principle'—the process by which the system (the city) top–down effects the behavior of the parts (the urban agent), and the process of 'circular causality', that is, the continuous process of bottom–up/top–down mutual determination. Chapter 8 thus explores the process of steady state and the city, showing that a steady state entails, and is made possible by, a network of interdependencies of the actions of citizens.

Chapter 9 discusses several phenomena of phase transition in physics as a preparatory step toward Chap. 10 on phase transition and the city. Chapter 11 scrutinizes the slaving principle and circular causality in cities showing that in the urban realm it is often associated with a space-time diffusion process that in turn gives rise to variations in the nature of the urban order parameter(s).

Finally, Part III examines the implications to four issues that stand at the center of current CTC discourse: Urban allometery or scaling, the interplay between agents' motivation and the pace of life in cities, smart cities and urban planning. Thus, Chap. 12 shows that that the "classical" scaling law, that stands at the center of urban allometry, is typical of the steady-state periods of cities, while the strongly fluctuating phase transition periods, are typified by other scaling relationships. Chapter 13 further elaborates on the central claim of allometry that city size correlates positively with the pace of life in cities. Based on Ross and Portugali's (2018) finding that a city pace of life affects its citizens' motivational tendencies, Chap. 13 demonstrates how this finding further affects the dynamics of cities.

Chapter 14 turns attention to the implications of our findings to the smartification of cities due to the introduction of smart *Information communication technologies* (ICTs). In particular, Chap. 14 deals with information production by humans and smart devices and their interplay. It shows that the latter enhances the intellectual load of humans, a counterintuitive result. The challenge facing smart cities is thus, to identify a steady state that maximizes the relative advantage of the human sensorium and intelligence and that of the artificial ones. Last but not least, Chap. 15 focuses on the implications to urban planning. It, firstly, introduces *cognitive planning* as a basic cognitive capability of every urban agent, that is active in cities in addition to the regular *professional planning*. Then, looking at these two kind of planning from the perspective of the theoretical perspective of our book, it is shown how the two are interwoven with each other in a kind of circular causality.

The book concludes with a few preliminary comments on the COVID-19 pandemic which, as already can be seen, exhibits many of the ingredients of a complex system as well as strong links to cities, while its possible future effects on cities and their dynamics have yet to be seen.

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Part I
Theoretical Foundations

Chapter 2
Cities as Hybrid Complex Systems

2.1 Cities as Complex Systems

The last decades have witnessed two interrelated developments: Firstly, the emergence of *complexity theories* (CT) and secondly the emergence of *complexity theories of cities* (CTC). CT is a set of theories that started to appear in the 1960s, referring to open and complex systems that exhibit phenomena of selforganization, chaos etc. With the exception of Humberto Maturana's *Autopoiesis theory* (Maturana and Varela 1973), the founding complexity theories were first developed in the material sciences (physics, chemistry, etc.) closely linked to thermodynamics and with reference to phenomena such as fluid dynamics, laser a.s.o. At subsequent stages complexity theories were applied to other domains; in particular, their application to the organic domains entailed the inclusion in the vocabulary of complexity theories the notion of *adaptation* as a basic property of complex systems*:* Originally a life science property—'adaptation' was added to complexity theory by Nobel Laureate in physics Gell-Mann (1994, p. 17), who in his *The Quark and the Jaguar* coined the notion of CAS—*complex adaptive systems*; at a subsequent stage, computer scientist Holland (2006), further developed and popularized it.

All complexity theories were very successfully applied to cities, entailing the second development: the emergence of CTC (complexity theories of cities)—a domain of research that applies the various theories of complexity to the study of cities. And following the core theories, here too, the first wave of applications defined cities as complex systems in a physicalist sense, while the second wave treated cities as complex adaptive systems. CTC studies have shown that cities are open, complex, dynamical systems largely based on *selforganization,* associated with information processing, society and population dynamics and so on.

The above successful applications were a result of the fact that cities as complex systems share many similarities with natural material and organic complex systems. For example, similarly to material complex systems cities are open, complex, far from equilibrium, typified by self-organization, chaotic events, fractal structure and

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the like, and similarly to organic complex systems they are adaptive systems capable of adapting their structure to changing internal and external conditions, and more. On the other hand, however, cities also differ from natural complex systems in that they are *hybrid* and as a consequence *dual complex systems*.

2.2 Cities as Hybrid Complex Systems

Cities are composed of material components and organic/human components. As a set of material components alone (buildings, roads, bridges, … whole cities and metropoles), the city is an artifact; the artifacts of which a city is composed and the city as an artifact, lack some of the basic properties of complexity: they are incapable of interacting among themselves and with the environment and as such the city is a simple system. On the other hand, as a set of human components—the urban agents (individuals, families, households …)—the city is a complex system. The city is thus a *hybrid simple-complex system* and it is the urban agents that by means of their interaction—among themselves, with the city's material components and with the environment—transform the artifact city into the complex-artificial system 'city'.

As a complex artificial system, the city emerges out of the interactional activities of its agents that build the artifacts and thus the city, that once it emerges, it affects ("enslaves", in the language of synergetics) the behavior of its agents and so on in circular causality—a process that in the domain of social theory is termed *socio-spatial reproduction* (e.g. Lefebvre (1974); Giddens (1984)). In other words, the city is a large-scale collective and complex artifact that, on the one hand, due to its inhabitants and users (the urban agents), interacts with its environment, while on the other, due to its size, functions as an environment for the large number of people that live and act in cities. This latter effect and property of cities is becoming more and more prominent in society as the proportion of people living in cities is growing—as is well recorded (Wimberley et al. 2007), the last century has witnessed the fastest population growth in human history and the fastest urbanization processes with the result that, for the first time, more than 50% of the world population lives in cities. The city in this respect is a *complex artificial environment* (Portugali 2011, Chap. 11).

2.2.1 Cities as Dually Complex Systems

As discussed in some length in CCCity (*Complexity, Cognition and the City*, Portugali 2011), the city as a whole is a (hybrid) complex system and each of its parts (agents) is also a complex system. This is not the case with material complex systems in which complexity is a property of the global systems but not of the parts. Organic complex system are different as each of their parts is a complex system too. In an organic complex system, each of the parts and the system as a whole, are typified by the property of adaptation which as we've seen above, gave rise to the notion of

CAS. Cities too are CASs, but their hybridity differentiates them from natural CAS. To see how, we have to appreciate the links between artifacts, culture and evolution.

Artifacts such as ideas, habits, texts, buildings, roads and whole cities, are the stuff of *cultural evolution*—the process by which the various artificial objects that form culture are learned and transmitted between individuals and collectivities and in the process change over time. As we elaborate in Chap. 11, based on the neo-Darwinian synthesis of genetics and evolution, the theories of cultural evolution (Cavalli-Sforza and Feldman 1981; Creanza et al. 2017) suggest a process reminiscence of Darwinian evolution, but fundamentally differs from it with respect to time-scale: compared to Darwinian evolution, cultural evolution is extremely fast. One reason for that is implicit in Cavalli-Sforza and Feldman's (ibid.) theory: Biological evolution is based on genetic transmission, while cultural evolution and transmission on *learning*, which similarly to genetic transmission embodies the potential for a leaning mistake, that implies a *cultural mutation*. However, unlike biological transmission, which occurs between parent and child of successive generations only, cultural transmission occurs between parent and child of successive generations, between neighbors, and between neighbors of two successive generations. These are termed by Cavalli-Sforza and Feldman (ibid.), respectively, *vertical*, *horizontal* and *oblique* transmissions. Note that horizontal and oblique transmissions imply the space-time *diffusion* of the cultural mutations. But see further discussion in Chap. 11.

The aforementioned time-scale difference implies that since the parts of organic complex systems (e.g. plants or animals) are subject to the slow process of natural Darwinian evolution, the short-term feedback effect of the global system (e.g. a flock of birds or fish) on the parts (e.g. a single fish or bird) is negligible and thus the property of duality of such systems can be ignored. The situation is different with respect to the hybrid complex systems 'cities', as their agents are simultaneously subject to two evolutionary processes: The very slow natural evolution and the very fast cultural evolution whose effect on the urban agents is instantaneous—urban agents have thus to adapt to the fast changing urban environment. How do they adapt to fast cultural changes? By means of their cognitive capabilities! The implication is that we have to engage the cognitive capabilities of the urban agents in the study of the dynamics of cities.

2.2.2 Complexity, Cognition and the City

CCCity (ibid.) was a first attempt in this direction with emphasis on the capability of *cognitive mapping*. Namely, that similarly to other animals, the behavior of the complex parts of the city (the urban agents) is mediated, and thus strongly influenced, by their cognitive maps of the city. This is significant, because studies on "systematic distortions in cognitive maps" of humans (Tversky 1992; Portugali 2011, Chap. 6) have shown that "the map is not the territory", namely, that cognitive maps are not one-to-one representations of the environment; rather, they are often systematically distorted in several specific ways.

In a subsequent study Portugali (2016) directed attention to a second cognitive capability by means of which urban agents' adapt to fast cultural changes, namely, their relation to *time* and by implication to planning and design. The urban agents—the parts of the complex system city—are parts of a special kind: they are typified by *chronesthesia* that is, the ability to mentally travel in time; back to the past and forward to the future. Unlike cognitive mapping, the cognitive property of chronesthesia seems to be unique to humans (Suddendorf and Corballis 2007). One example of mental time travel (MTT) is *prospective memory* (Haken and Portugali 2005), referring to human ability to remember to perform an intended or planned action.

A third capability concerns planning as studied in the research domain of *cognitive planning* (Miller et al. 1960; Ormerod 2005). Humans are, in this respect, natural planners and designers. However, not only do humans have this ability to mentally travel in time, but they also cannot avoid mentally travel in time (Portugali 2016); studies show that "unlike other animals," human beings spend about half of their waking hours "thinking about what is not going on around them, contemplating events that happened in the past, might happen in the future, or will never happen at all" (Killingsworth and Gilbert 2010). So much so, that "stimulus-independent thought" or "mind wandering" has been shown to be the brain's default mode of operation (Raichle et al. 2001; Buckner et al. 2008). It means that much of urban agents' behavior is determined not by response to the present situation in the city, but in response to an urban reality that doesn't yet exist and might never exist.

To conclude, artifacts are the product of human interaction and as noted above, artifacts are simple systems and as such cannot interact—their interrelations in the context of urban dynamics is mediated by the urban humans agents.[1] Yet it must be emphasized that artifacts are not just the outcome of human interaction; rather they are also *the media of interaction* between the urban agents: Artifacts such as texts, cities, buildings or roads are *external representations* of ideas, intentions, memories and thoughts that originate and reside in the mind/brain of urban agents; that is to say, of *internal representations*. However, exactly as material artifacts (e.g. buildings, roads, …) cannot directly interact among themselves, so also ideas, thoughts, intentions, plans and other internal representations cannot. They interact by means of the externally represented artifacts; be they utterances, texts, clothes … buildings, neighborhoods and whole cities and metropoles. Urban dynamics thus involves an ongoing interaction between external and internal representations.

The notions of SIRN (Synergetic inter-representation networks), IA (information adaptation) and their conjunction—SIRNIA introduced in Chap. 4 below, are specifically designed to capture the dynamics of cities as hybrid complex systems and as dually complex systems.

[1]Having said this, and as elaborated in Chap. 14 below, with the introduction *of internet of things* (IoT), smartification, computer networks and the like, this situation is changing and soon we might have "artificial urban agents".

2.3 On Methodology: How to Study Cities as Hybrid Complex Systems?

2.3.1 The Two Cultures of Cities

Complexity theory is a relatively young research domain as just noted, while the modern study of cities has a long history that started in mid nineteenth century with von Thünen's (1826/1966)*Isolated State*. The implication: CTC did not arrive to a 'terra incognita', but rather to an evolving "urban terra" into which it had and still have to integrate. Looking at the study ("terra") of cities prior to the emergence of the CTC domain, one can identify a pendulum moving between *two cultures of cities*—two methodological approaches that echoes Snow's (1964) observation regarding the gap between *The Two Cultures* of science as a whole: A quantitative-analytic approach versus social-theoretic hermeneutic one, with a gap of miscommunication between the two. In the quantitative-analytic stream, one can further observe inductive versus deductive approaches. For example, with respect to systems of cities, between the inductive *rank-size* approach pioneered by Auerbach (1913), versus the deductive *Central Place Theory* of Christaller (1933). Somewhat similarly, in the social theoretic hermeneutic domain one can identify, e.g., structuralist studies that commence from "deep" social structure (similar to top–down), versus phenomenological studies that emphasize the subjectivity of individuals and places (similar to bottom up).

And what about complexity theory and CTCs? What position or side they take in face of the above dichotomies? To which culture of cities they are inclined? On the face of it, CT is a quantitative-analytic approach that originated in the sciences—whose basic concepts (e.g. PT, StS, emergence, entropy) are taken from physics. Accordingly, CT arrived with a new conceptual framework and most importantly with new quantitative, statistical and mathematical formalisms. In fact, many of CTCs early, as well as current, practitioners were and are physicists applying their conceptual and mathematical tool-kits to the domain of cities. It is therefore of no surprise that most CTC practitioners tend to perceive themselves as advancing a new and more sophisticated version of the "old" quantitative analytic approach to cities.

On the other hand, however, if you examine some of the basic concepts of the various complexity theories, you find that they have found in matter properties hitherto attributed, and similar, to properties and concepts typical of the hermeneutic domains (Portugali 1985). For example, in 'classical' physics' predictability and by implication certainty and causality, were traditionally seen as basic properties and capabilities of the quantitative-analytic-mechanistic approaches, while their negations—un-predictability, uncertainty and non-causality were seen as a consequence of insufficient data. Classical physics had (still has) a strong influence of the quantitative approach to cities, as well as on the social sciences in general [e.g. August Comte (1798–1857), one of the founders of sociology, has suggested calling this science *social physics*]. In the "soft" hermeneutic-humanistic domains, per contra (e.g. history), uncertainty and 'un-predictability' were always seen as basic properties of human (historical, political, …) processes. Scientific developments such as quantum physics (e.g. Heisenberg's uncertainty relation) and Chaos theory (e.g. the 'butterfly effect') have shown that this does no more apply to 20th century physics. The same applies to the various complexity theories—they refer to natural material and organic systems which are un-predictable, un-certain and not causal; not because of poor data, but ontologically so.

In particular, however, the above similarity between complexity and hermeneutic-humanistic views is prominent with respect to two basic properties of complex systems that form the focus of the present book—StS and PT: complex systems are typified by long periods of StS interrupted by short periods of strong fluctuations that often result with PT and the emergence of a new StS. To the latter, the theory of synergetics adds that following a phase transition and the emergence of new structure and order (parameter), the new order "enslaves" the parts of the system and so on in circular causality. Similar perceptions typify social theory views: social evolution is characterized by long periods—termed "*epochs*", "*age*" *periods*, … of relative stability when a given regime dominates, followed by periods of chaos and drastic change—*revolutions* in the parlance of social theory; and following a revolution, once again a relatively stable period prevails by means of a process of *socio-spatial reproduction*—identical to the slaving principle and circular causality of synergetics. (See further discussion on this in Chap. 11). From this perspective CTCs are akin to the hermeneutic approaches of cities, specifically so since cities, as noted above, are hybrid complex systems.

The fact is, however, that compared to the other CTCs' notions such as emergence, bottom–up or self-organization, StS and PT have received only marginal attention and when they are being referred to in CTC, they are presented in the most general way. The reason: there is an implicit link between methodology and content—between the methodology you favor and the research topics you choose: researchers in the "hard" quantitative-analytic "conviction" are specifically attracted by data rich research topics, while researchers in the "soft" hermeneutic camp by qualitative research issues—social, ethical, political, cultural and so on. Thus, in the context of urban studies, there has developed a kind of informal, implicit division of labor where most CTCs studies focus on data-rich, short-term, somewhat anachronistic more technical topics that afford quantification, leaving to students of the social theory oriented hermeneutic approaches, the qualitative long-term aspects of urban dynamics (to which StS and PT processes belong)—to our view, the really burning issues that stand at the core of twenty-first century problematics of cities. Currently, this division became even sharper due to the availability of big data, IoT and the like that according to Anderson (2008) indicates "The end of theory", since "The Data Deluge Makes the Scientific Method Obsolete". Whether CTC practitioners accept this view or not, the fact is that CTC studies on urban dynamics are strongly influenced by the "the data deluge".

Is the methodological gap between the two cultures of cities inevitable? Our view is that this is not the case. Firstly, as already suggested, due to the above noted similarity between CT and hermeneutic domains there is a potential that "Complexity theory [can function] as a link between space and place" (Portugali 2006, 2011), that is, between the two cultures of cities. The theory of synergetics and its extension "synergetic cities", with a focus on SIRNIA, StS and PT that we develop below, is part of an attempt to pave the way toward the realization of the above potential.

2.3.2 *Small Data is Beautiful*

How to study cities as complex systems? The fashionable answer these days, specifically in the context of smart cities, is *Big Data*: The new ICT with their data deluge, data mining and visual analytic techniques, make it possible for the first time to make use of the huge amount of data that is accumulating in the internet and other networks. Yet, the title of this section suggests an alternative view—it rephrases the title of Schumacher's (1973) book *Small is beautiful: A Study of Economics As If People Mattered.* This book was a critique of mid twentieth century's economic "gigantism" in the form of mass production, mass media, fast economic growth and urbanization that according to Schumacher entailed the de-humanization of people and their cultures. The subtitle of this section should thus implied: *A Study of cities as if people mattered.*

The common view in CTC is that cities emerge from the bottom–up out of the interactive behavior between their parts, the urban agents. It is also common to follow economics' "homo economicus" and to assume that urban agents behave and act in a consistently rational self-interested way. Our view, as implied from the aforementioned view of cities as dually complex systems, is that urban agents behave and act according to their subjective interpretation of the information conveyed by the city and the elements of which it is composed—in a way specified by our SIRNIA model (Chap. 4). The data about such behavior and action is generated by cognitive and brain sciences and is termed here *small data.* We use it here to understand and model the interactive behavior and action of the urban agents among themselves and with their urban environment.

According to our 'synergetic cities' view, and similarly to other CTC, cities as complex systems emerge from the bottom–up, that is, by means of the interaction between their parts—the urban agents (inhabitants, users, …). However, unlike other CTCs, synergetics suggests that once they come into being, cities top–down determine ("enslave") the action and behavior of their parts—the urban agents, and so on in circular causality. Accordingly, for the first, bottom–up, part of the urban process 'small data' is needed. Big data refers to the global structure and properties of a city as a whole and is thus needed to understand, study and model the top–down processes by which the city with it OP (e.g. urban scaling) effects the action and behavior of the urban agents (see discussion in Chap. 6). Big and small data thus do not negate each other, but rather co-exist in complementary relations. These complementary relations are at the core of the two foundations of the theory of synergetic: The 1st Foundation that commences from the bottom–up and continues top–down (Haken 1977), and The 2nd Foundation of synergetics (Haken 2006) that commences from the top–down taking into consideration the insight from the first foundation. The discussion in this book thus evolves as a back and forth movement and discourse between small and big data views: Chap. 5 develops a ‘bottom–up’ formalism—from parts to whole (OP), while Chap. 6 starts with big data from the top–down; this movement and discourse continues in the subsequent chapters of the book.

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