Complexity and Emergence. key concepts in non-linear dynamic systems

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Chapter 3

Complexity and Emergence – key concepts in non-linear dynamic systems

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Abstract. Complexity and Emergence are key concepts in non-linear dynamic systems. Both nature and society are dynamic and non-linear and both realms can be defined as systems. They are both composed of single elements (agents), both are constituted by relations between their composing elements and structured in a hierarchy of subsystems. The paper discusses the potential application of the findings of the theories of complexity to the analysis of human-nature interactions and addresses the required change in research perspective from linear development to non-linear behaviour. It also highlights the task of translation that will be necessary in order to use the findings of complexity research fruitfully for applied research in other fields.

The theories of complexity can contribute to a *Gestaltwechsel* which facilitates the consideration and analysis of coupled natural and social systems. In these systems it is the iterate activity of interacting entities which influence the system's trajectory. Agents are decisive for the history of a system. Emergence and self-organisation are strong paradigms which draw attention to the new perspective of systems analysis. The question is no longer *how* to reduce complicated issues to simple processes but *how* can something complex arise from the simple? The explanatory paradigm changes towards an exploratory paradigm. The new research objective is the translation of mechanisms of individual activity into divergent systems' trajectories and the search for the reasons behind divergent planning cultures in different societies. At this point, we move from theoretical discussion to an application mode. Linear thinking can be dangerous in a non-linear world. Emergent behaviour and surprises have to be accepted as inherent to complex systems.

Key Words. Theory of complexity, structural complexity, behavioural complexity, non-linear dynamic, agents, emergence, surprise

Introduction

Complexity and emergence are buzz words in our modern world. But what do they mean? And how can they help us to see and to understand the world in a different manner? Complexity and emergence are key concepts in the study of non-linear dynamic systems. Theories about these "complex systems" attempt to explain how relationships between components of the system give rise to patterns of collective behaviour that define the properties of the "whole system", which interacts and forms relationships with its environment. A complex system contains many autonomous components which interact with each other, for example: human society and the economy, insect colonies, cellular automata on computers, some chemical systems, and other systems in various domains. Nature and society are two examples of dynamic, non-linear systems. Both realms can be defined in terms of the individual elements they are composed of and by the relations between these elements. Many of these elements will themselves be complex systems; the large scale systems are composed of a hierarchy of subsystems.

In all these systems, global behaviour emerges from the local interactions between the participants. This behaviour can be studied with reference to structural and functional properties of whole system, based on the hypothesis that these are more relevant than specific details about the behaviour of individual system components. By contrast, the study of complexity tries to explain the emergence of macro-scale phenomena as the product of non-linear and dynamic interactions between micro-scale elements (Mainzer 2003, 2007). "Emergence is the reason why there are hurricanes, and ecosystems, and complex organisms like humankind, not to mention traffic congestion and rock concerts. Indeed, the term is positively awe-inspiring." (Corning 2002: 2) But what is emergence? What does it really explain? And why is it so readily welcomed, in spite of its opacity, by many different scientists, whether system thinkers or not?

Scientific use of the terms complexity and emergence needs to be based on formal definitions and a consideration of their limitations in specific research contexts. It is important to distinguish between a situation where complexity itself is the research object, that is, we are engaged in the “study of systems”, and one where the aim is to use the concept of complexity in the study of traditional scientific disciplines, such as biology or sociology, to gain insights and new perspectives on our objects of study in these fields (comp. Egner, Ratter and Dikau 2008). In the latter case, the findings of complexity research need to be translated to facilitate their application in these new contexts. This paper is a contribution to this ongoing work.

A promising field for the application of the findings of complexity theories is the analysis of human-nature interactions. Natural and social systems are dynamic and non-linear. In considering the interaction of both systems we are dealing with coupled socio-ecological systems. In order to analyse such systems we have to acknowledge the interdependency that exists between subsystems and elements on different scales with different spatial and temporal characteristics (Berkes et al. 2003, Egner and Ratter 2008) and the fact that interaction between the elements on one scale can lead to emergent phenomena on another scale. The theory of complexity, which is rooted in chaos theory, provides a new perspective on the behaviour of such systems as well as the interaction between different systems. This concept encourages a *Gestaltwechsel*[16] – a change in perception – which helps to see things differently and fosters the search for new answers to emerging questions about the interaction of human-nature interface.

What is complexity?

The term “complex” is used in many different ways and encompasses a great variety of phenomena. In daily life the word “complex” is mainly used when we mean “complicated”. But complex is not the same as complicated. Complex is not “*even more complicated than complicated*” (comp. Ratter 2006). The terms complexity, complex and complex systems are currently used widely in the scientific community. The multifarious use and the lack of a distinct and unambiguous definition pose a risk that these terms will become empty phrases. Drawing on the mathematical definition of Kolmo-gorov complexity, Okubo adopts a quantitative approach to complexity and states: “The more complex a

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[16] The concept is based on the fundamental principle of *gestalt perception* according the Berlin School of Gestalt Psychology (comp. Bruce, Green and Georgeson 1996).

model becomes, the more parameters are involved." (Okubo 1980: 6) In contrast to this understanding of complexity, there are definitions which focus on the kinds of relations between system elements. Manson (2001) considers what kinds of interaction between elements of a system can give rise to complex behaviour. This behaviour is shaped by the relations between the entities which make up the system, the processes occurring within the system, its internal structure and self-organisation of the system to adapt to conditions in the external environment. Berkhoff, Karstens and Newig (2004) describe complexity as a state between order and chaos with a high degree of structural diversity. They explain that characteristic properties of complex systems are the result of the co-existence of many heterogeneous entities, the dynamics of the system, the process of spontaneous self-organisation and emergent behaviour (comp. also Mainzer 2003).

The different examples make clear that there are at least two fundamentally different ways to define complexity. On the one hand, emphasis is placed on the number of elements of a system, and on the other the focus is on the relationships and the processes occurring between the elements of the system. In other words, one approach focused on the constitution of the system and the other on its behaviour.

Structural complexity versus behavioural complexity

The computer scientist Schamanek (1998) makes the distinction between structural and behavioural complexity. When a system consists of a lot of different elements and interactions, this is structural complexity. Behavioural complexity arises from processes and relations between the system elements. However, behaviourally complex systems are not necessarily composed of large numbers elements and relations between them. That is, the complex behaviour of a system does not automatically imply a complicated structure. A system that exhibits behavioural complexity can consist of simple OR complicated structures (comp. Ratter 2001). This point can be illustrated by considering the example of the behavioural complexity of a double pendulum. A double pendulum is a very simple physical system. It consists of a pendulum A attached to another pendulum B. Each pendulum is a simple mechanical system. However, joined together, the double pendulum AB exhibits complex behaviour (comp. Selinger 2000 and see Figure 1).

This is an example of the application of a theory of complexity which refers to the *behaviour*, not only to the structure of a system.

Simple systems can show a complex behaviour; complicated systems with many elements are structurally complex *and* can show a complex behaviour – then they are structurally *and* behaviourally complex. The fundamental question is: how can something complex arise from the simple? It is assumed that behaviour cannot be understood solely with reference to the properties of single elements but that it can be explained from the interactions of the system elements. Even simple systems can have a complicated behaviour, e.g. the double pendulum. But structurally complex systems such as the weather or the stock exchange can show complex behaviour too, which is determined by the interaction of many single elements and/or agents as parts of the system. In such dynamic systems the elements (e.g. agents) interact in a non-linear way. Complicated counterintuitive behaviour can emerge through non-linear interactions. A complex system can display surprising properties when elementary sub-processes are coupled together to form a larger system (Casti 1994: 40).

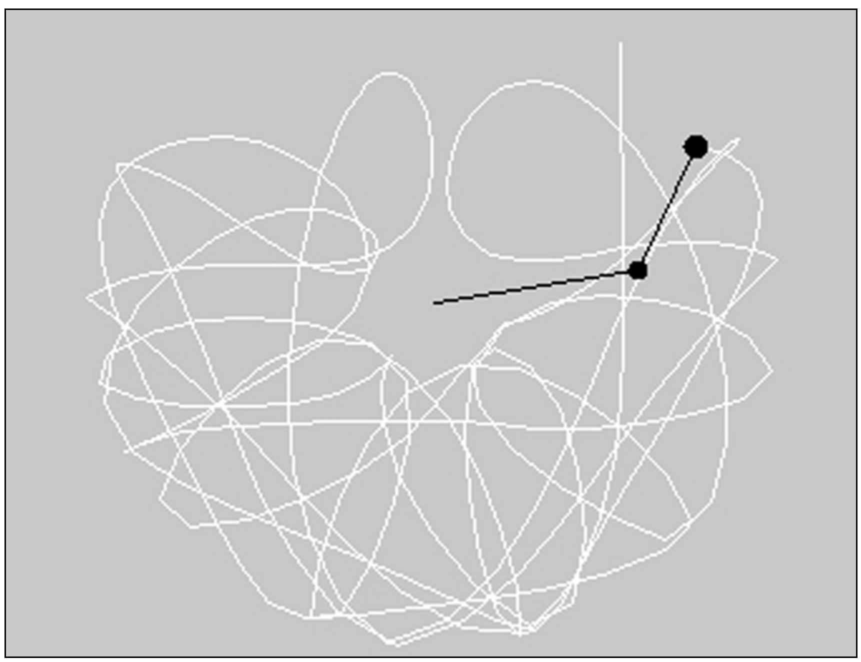

Figure 1: Double pendulum with canvas traces (Selinger 2000)

Behavioural complexity considers the qualities and properties of a system as well as the relations and processes between the elements. Fundamental in this is the recognition that non-linear behaviour of a complex system is irreducible. The behaviour of the system is to a high degree dependent on its history. It is unpredictable because of its non-linear and dynamic character. The behaviour of complex systems can be random (comp. Mainzer 1997, 2003; Waldrop 1992). The attributes of self-organisation ensure the self-preservation of the system; however, the structure of the system can change over time through internal feedback processes and adaptation to changes in the system environment. In effect, the identity of the system can change over time. Therefore, knowledge about the history of the system is fundamental in order to understand its present character. A system is behaviourally complex if it possesses *key characteristics* and not only *key variables*. The ongoing processes of structure building in a complex system are unpredictable. Structural reorganisation has no single cause, but arises from micro-scale interdependencies that act together to cause major changes: the spontaneous appearance and disappearance of order and system structures. The emphasis is on the "*becoming*". Complex means becoming, development, emergence – which can lead to profound qualitative transformations (Ratter 2006). This is the point where the theory of complexity becomes practical relevance in the analysis and planning of human-nature interactions. I shall come back to this issue later.

In order to recognise patterns in systems with emergent characteristics, it is necessary to shift to non-linear thinking; linear thinking will not help to understand the interactions between system elements and even less the resulting patterns of system behaviour because of the irreducible character and unpredictability of emergent systems. Complexity theory incorporates a set of principles that can be applied in the study of different types of complex system. It provides the basis for understanding *how* patterns are formed due to the local and repeated interaction between system components and *how* these patterns change. In this context, interactions and the consequences of these interactions are significant. It is not assumed that systems exist in equilibrium and therefore the changing relationships between system elements are of importance.

Surprise as part of the system

Dynamic systems are systems in which a stable state can occur and disappear abruptly. Stability is represents a transitory period of equilibrium within the longer term alternation of the system between pattern and non-pattern phases. In order to understand systems undergoing constant changes surprise should be accepted as an inherent feature of system dynamics (Ratter 2006: 116). Qualitative transformations can occur as a result of internal system processes and changing relations between the elements of the system, without external stimulus. Therefore, emergent characteristics can not be understood without reference to relations between the components of the system (Manson 2001: 406).

"Complex systems involve the collective behaviour of a large group of relatively simple elements or agents, in which the interactions among these elements typically are local and non-linear." (Bedau and Humphreys 2008: 209) Based on the theory of complexity, complex systems show emergent macro-scale structures, which evolve from the interaction of the constituent parts and subsystems (Janssen 2002). Or as Mainzer (1997) puts it – referring to Aristotle: "the whole is more than the sum of its parts" or "the whole is not only the sum of its parts". This basic theorem of system thinking emphasizes the fact that identifying system elements is not sufficient in order to understand a complex system. The deconstruction of a system can provide insights but suppresses the interactions between the system elements (comp. Ratter and Treiling 2008). In the analysis of coupled socio-ecological systems this suppression could have serious consequences.

What is emergence?

Emergence is something which we do not expect but which we experience in different ways and situations. An illustrative example of the phenomenon "emergence" in social systems is the phenomenon of traffic congestion. We all get hooked up in traffic jams once in a while – but do we ask ourselves why this happens? Traffic congestion can emerge without a specific cause such as a car accident, a broken bridge or road works. Even without these blocking events we get trapped in traffic jams, merely as a result of car drivers following simple rules. For example: drive a at certain speed and do not crash into the car in front; slow down if there is a car close ahead, speed up if not. "Traffic jams can start from small *seeds*. These cars start with random positions and random speeds. If some cars are clustered together, they will move slowly, causing cars behind them to slow down, and a traffic jam forms. Even though all of the cars are moving forward, the traffic jams tend to move backwards. The behaviour of the group is often very different from the behaviour of the individuals that make up the group." (Wilensky 1997)

The concept of emergence can be traced back to an argument of Aristotle in his *Metaphysics*: "The whole is something over and above its parts, and not just the sum of them all." (comp. Aristotle reprint 1974). This implies an ontological distinction between parts and wholes. For Goldstein (1999: 51) emergence can be defined as: "…the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems." (comp. also Corning 2002). Emergence has been used by physicists to explain Bénard (convection) cells, by psychologists to explain consciousness, by economists to explain stock market behaviour, and by organisation theorists to explain informal „networks" in large companies.

However, emergence can also be understood as the appearance of something unexpected. According to Corning (2002) the overwhelming majority of people understand the term emergence as a synonym for "appearance" or "growth", rather than as a referring to the relation between parts and wholes. Example of emergence in this sense are democracy in Russia, soccer as a school sport in the U.S., the Internet, mad cow disease, etc. (Corning 2002: 24).

The two different concepts of emergence can lead to confusion in the definition and use of the term. Emergence can be understood as *appearance of something*, and also in the Aristotlean sense as *a phenomenon of synergy* – "a parts-whole relationship." (Corning 2002: 24) In complexity theory emergence is associated with dynamic systems whose behaviour arises from the interaction among its parts and cannot be predicted from knowledge about the parts in isolation (Casti 1997). In the context of a paradigm shift from stability to change, from equilibrium to non-equilibrium, and from continuity to discontinuity, processes in nature and social systems are perceived differently. Corning (2002) calls this phenomenon the "*re-emergence of emergence*". Hundreds of years after Aristotle, the perception of stability and equilibrium is finally being questioned again and the classical perception of continuity in natural development is being overcome. In consequence, the Darwinian dictum ought to be rephrased as: *natura facit saltum*!

Corning himself considers that it is difficult to pinpoint the exact date of the re-emergence of emergence as a mainstream concept, "…but it roughly coincided with the growth of scientific interest in the phenomenon of complexity and the development of new, non-linear mathematical tools – particularly chaos theory and dynamical systems theory – which allowed scientists to model the interactions within complex, dynamic systems in new and insightful ways (Corning 2002: 23). Nowadays, emergence is considered in theories about various natural and social sciences.

Emergent structures are patterns not created by a single event or rule. Nothing commands the system to form a pattern. Instead, the interaction of each part with its immediate surroundings causes a complex chain of processes leading to some sort of order. One might conclude that emergent structures are more than the sum of their parts because the emergent order will not arise if the various parts are simply coexisting; the interaction between these parts is central. Emergent structures can be found in many natural phenomena, from the physical to the biological domain, e.g. weather phenomena such as hurricanes are emergent structures (comp. Bedau and Humphreys 2008).

Fenzl (2003) considers emergence as the appearance of a new property of a system which can not be deduced or previously observed as a functional characteristic of the system. "For example, water has emergent properties different from its interconnected parts (molecules of H and O). These properties disappear if the molecules are separated again." (Fenzl 2003: 252) Self-organisation is the appearance of new system structures without explicit pressure from outside the system, that is, from the system environment.

Strong versus weak emergence

Emergence can be divided into two perspectives: "weak emergence" and "strong emergence". Weak emergence describes new properties arising in systems as a result of the interactions at an elemental level. Emergence, in this case, is merely part of the model that is needed to describe a system's behaviour. According to Stephan (1999) "weak emergentism" is characterised by three postulates: physical monism, systemic properties, and synchronous determinism. These postulates mean that there are no supernatural powers or entities which decide on how the system should behave; that systems may have properties that none of their parts have; and that these properties are coupled to its micro-structure. This means that the properties of a system only change as a result of a change in its structure or in the properties of its parts. Brunner and Klauninger (2003: 28) argue that weak emergentism is practically indistinguishable from reductionism.

On the other hand, systems can have qualities not directly traceable to the system's components, but rather to how those components interact. These new qualities are irreducible to the system's constituent parts and their properties (Laughlin 2005). This view of emergence is called strong emergence. Regarding strong emergence, Bedau (1997) observes: „Although strong emergence is logically possible, it is uncomfortably like magic. How does an irreducible but supervenient downward causal power arise, since by definition it can not be due to the aggregation of the micro-level potentialities? Such causal powers would be quite unlike anything within our scientific ken. This not only indicates how they will discomfort reasonable forms of materialism. Their mysteriousness will only heighten the traditional worry that emergence entails illegitimately getting something from nothing."[17]

From this point of view emergence is a phenomenon which evolves from the interaction of constituent elements of a system, but which can not be explained only from the single elements and its properties. One calls emergence counterintuitive because emergent structures are generated by processes of self-organisation inside a system without external influences.

The non-linear interactions between the composing parts of the system give rise to a high-level, global emergent structure or organisation that is not straightforward to explain from the local components (see Figure 2).

[17] For further explanations and distinction of strong and weak emergence see Bedau 2008, see also Arshinov and Fuchs 2003.

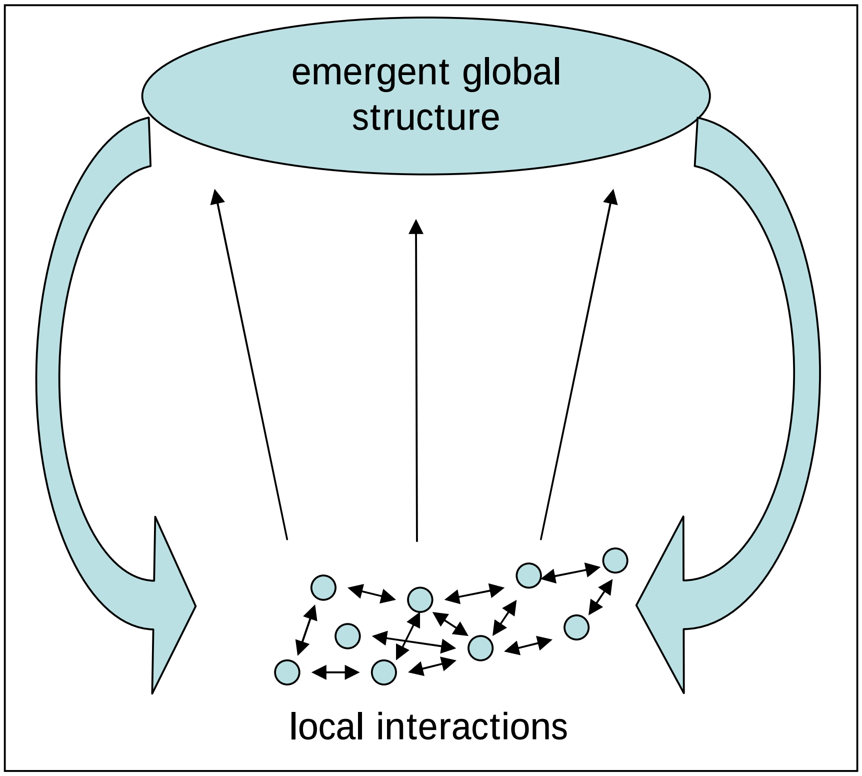

Figure 2: Abstract illustration of emergence in complex systems (accord. Lewin 1993: 25)

The occurring emergent behaviour impacts those components which evolved the emergent behaviour due to a mechanism of feedback in the system. A number of systems share this kind of architecture. They contain many individuals/elements/agents, each one of which interacting with its neighbours. From the network of these local interactions, global features emerge (up-going arrows): market forces, cultural and social trends, features of insect colonies etc. The global features define an environment which influences the rules of interaction of the single participant with its neighbours (down-going fat arrows). To understand a complex system one has to analyse the higher level of emergent collective behaviour as well (Lewin 1993).
The problem when dealing with these kinds of systems is the impossibility of predicting how changes in the rules governing individual interactions will affect global system behaviour. For example, a new law that aims to change the conduct of individual participants in a social

system may give rise to global side-effects, which will finally yield a collective behaviour that is just the opposite of what was originally intended. Thus, to act effectively in such domains, it is important to understand the ways in which a global behaviour emerges from the collection of many local interactions. There are many open questions here, and one of the most important is: which exactly are the systems that exhibit this kind of behaviour?

Complex systems with emergent qualities have some coherent behaviour for a certain period of time (Goldstein 1999). This coherence correlates the level of the producing entities into a unity on the level of emergence. Emergent qualities are not pre-given, but the result of the dynamical development of complex systems. The notion of emergence means that a system is more than the sum of its parts and that a developing system has new qualities that can not be reduced to old states or prior existing systems. A key cause of emergent phenomenon is therefore the interaction of elements or agents of a system.

Not agents, but actors

Single locally acting persons can be pioneers or initiators of macro-level developments – they act as *agents* in the sense of the theory of complexity. An agent is a unit or element of the system which acts locally and which can not directly influence the system globally. Agents are restricted in their actions, which however, have system changing character through iteration and repetition. They create spatial clusters of quasi symbiotic unities or combating complexes (Casti 1994, Ratter 2001). An agent is not the same as an actor. *Actor* is the superordinate concept. *Agent* is a special type of actor without or with incomplete knowledge about the system as a whole. Its activities can only affect areas beyond his local level indirectly, that is, via some form of mediation. It is not chance that the term *agent* is also sued to describe spies, in the sense of "secret agent". Agents or spies engaged in the cloak-and-dagger games of the former superpowers had similarly restricted knowledge, about only their own operational areas. Their local activities on the micro-level, however, could have global significance and influence the macro-level behaviour of the system (Ratter 2001: 57ff).

This type of system, composed by interacting agents, can be analysed formally under certain conditions (Casti 1995/1996: 7ff). One approach is by way of simulation. Simulation is possible (1) if the agents possess only limited local information; (2) if agents possess restricted information processing capacity and (3) if the system itself is composed of a limited number of interacting agents – enough to give rise to interesting structures; but few enough for simulation to be possible. The analysis of these types of systems can be approached by multi-agent simulation (MAS) (comp. Mandl 2003 and see Glaser/Krause in this volume). Simulation can be used to understand how a system has behaved in the past – for backcasting – and to evaluate proposed policies by forecasting their impact on system behaviour. A simulation is nothing more and nothing less than a model of systems.

These systems are significant because local interactions between system elements have a determining effect on the history of the system (comp. Epstein and Axtell 1996, Kochugovindan and Vriend 1998). Nature and society can be conceived as the product of interactions between agents: as non-linear dynamic systems or the emergence from the non-linear interaction of agents. The focus on interactions fosters a Gestaltwechsel – a new perception of systems as coupled micro and macro behaviour that can help explain the emergent properties of systems.

Why complexity?

"Complex systems exhibit emergent properties in order to adapt to changing circumstances in an effective and efficient manner, they adaptively self-organise." (Bullock and Cliff 2004: 4) Complex systems show key attributes such as dynamics, non-linearity and emergence. These attributes should be part of the research objective since they are fundamental to an understanding of dynamic systems. System development is history dependent and contingent: the identification of bifurcation points, behavioural jumps and surprises is a key challenge in order to understand the behaviour of a dynamic system. In research into human-nature interactions we deal with non-linear systems and try to understand how they work. The trajectories of non-linear systems display discontinuities and cannot be predicted with any degree of confidence, as they are the result of strong emergence from the interaction of the constituent agents and elements. Bifurcation points are fundamental turning points where the system state is poised between two alternative future paths of development. Uncertainties and surprises are part of the system's history and not exceptions. And system's behaviour is heavily path-dependent. Each system has its own history.

An analysis aimed at only the structural complexity of a system can not encompass the dynamic character of non-linear systems. The interaction of society and nature is therefore not sufficiently described and understood if one restricts it to direct causality. Behaviourally complex systems are characterized by intensive processuality. This means that "reality" of such systems is constantly changing and they can not satisfactorily be described with reference to their invariant elements (Eisenhardt et al. 1995). The key characteristics of complex systems (dynamic processes, non-linearity, emergence) have to be considered as part of the system and accepted as part of the system's history and behaviour. The identification of the bifurcation points can help us to understand current system behaviour and contribute to the determination of policy measures that facilitate adaptation by the system to environmental changes (comp. Ratter 2001, Treiling 2009).

Why emergence?

Emergence and self-organisation are strong paradigms in the theory of complexity which draw attention to the new perspective of systems analysis. The increasing use of these concepts in natural as well as in social sciences and in manifold disciplines, ranging from brain research to economics, indicates that the classical reductionist approach in science is being replaced by a new paradigm. The question is no longer *how* to reduce complicated issues to simple processes but *how* can become something complex arise from the simple? The explanatory paradigm (A is just the same as B) changes towards the exploratory paradigm (can A create B?). These ideas have even found their way into politics which there is more an and interest in the possibility that certain services can be provided without hierarchy and central state influence by using the self-organising forces of the civil society. The new research objective is the translation of mechanisms of individual activity in divergent systems' trajectories and searching for the reasons of divergent planning cultures in different societies. At this point the theory of complexity acquires practical relevance (Ratter 2001: 55, 237).

The behaviour of agent-based non-linear systems results in uncertainty, which we experience in daily life and which we have to take into account especially in strategic planning. The system trajectory can not be controlled. Lau (2006) declares: "Systems can not be controlled but tickled." One can try to set frames or give impulses in order to encourage the system to change. But one can not presage what the system is going to do next, but trust that it will do something. The idea of preordaining the system's development should be abolished as well as the hope of understanding system behaviour completely. Nevertheless, if change is an inevitable result of the agents' interaction, one could at least attempt to learn from these processes (Lau 2006).

Planning in spite of uncertainty

Planning is the intention to construct certainty in an uncertain environment. In a complex and non-linear system planning security does not exist. The system behaves dynamically and its development is continuously non-linear. Planning takes places in the context of unpredictable system dynamics. It has to be adaptive and can only make short-term predictions about how the system will develop from its current state (Mainzer 1997, 2003). In this context, the most appropriate planning approach is an adaptive management, which accepts non-linear dynamics and emergence as a fact of life and adopts an iterative adaptation process based on monitoring and feed-back. One step beyond adaptive management is *complex management,* which in addition takes account of the social and cultural background of a society, different perceptions and the political framework (Ratter 2001). Planning takes place in a socio-cultural environment with interacting agents tickling the system's trajectory in innumerable ways. Under these circumstances planning becomes the management of uncertainty – dealing with non-linear coupled human-nature systems and making preparations for changes and surprises.

Summary

Theories of complexity can contribute to a *Gestaltwechsel* – they can help us to look at systems differently, to search for new questions and new answers. A new perspective in systems analysis facilitates the consideration and analysis of coupled natural and social systems, which are both dynamic and non-linear. In these systems it is the iterative activity of agents which has the greatest influence on the system's trajectory. Agents and bifurcation points are decisive for the history of a system. Process simulation on the basis of MAS can lead to a deeper understanding of system dynamics – but can not change the unpredictable development of reality. Surprises have to be accepted as inherent to the system. Linear thinking can be dangerous in a non-linear world.

An aspect of non-linear dynamic systems are that big changes which occur are not the result of single big causes but more emerge out of micro-scale-interdependencies. There is spontaneous emergence and dis-appearance of order and structures. Theories of complexity provide a set of principles that can be applied to a range of complex systems. They enable us to describe *how* patterns are formed out of repeated local interactions between components and *how* these patterns change. The focus is on the description of behaviour, regardless of whether the make up of the system is simple or complicated. It is assumed that the behaviour of systems can be explained from the interactions taking place between the system elements. But the emphasis is on "becoming" and on qualitative discontinuities.

In order to examine emergence, complexity research focuses on non-linear relationships instead of focusing on linear relationships (e.g. of energy and information). "This stocks-and-flows perspective emphasizes quantities of flow and not necessarily its quality. Complexity research employs techniques … to examine qualitative characteristics such as the symbolic content of communication." (Manson 2001: 406)

System behaviour is contingent. An emergent phenomenon can be defined as a „subset" of the vast universe of cooperative interactions that produce synergistic effects of various kinds, both in nature and in human societies. "In this definition, emergence would be confined to those synergistic wholes that are composed of things of "unlike kind". It would also be limited to qualitative novelties – i.e., unique synergistic effects that are generated by functional complementarities, or a combination of labour." (Corning 2002: 28) In order to understand such systems where the system state is constantly changing, surprise must be accepted as part of the system dynamics (Ratter 2006: 116).

However, it should not be understood from the forgoing that theories of complexity are a justification for doing nothing or for not interfering. Rather they should be seen as underlining the importance of including a wide range of agents in the planning process. "The problem is that doing nothing does not necessarily stabilize the equilibrium of a complex system and can drive it to another metastable state." (Mainzer 1997: 324) The most important thing to know about complexity is simple: "There is still something to come." (Lotter 2006: 46) Emergence has to be included in our line of thoughts.

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