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How Many Cultures We Have?

10.1 Complexity as a Unifying Concept

10.1.1 Systems and Simulations

Complex systems theory, as we may understand it, preserves the best traditions of the general systems theory of von Bertalanffy, mentioned in Sect. 2.2.1. While he was a biologist, who worked on the basic principles of the life, he also explored the universal laws of organizations. It seems, however, that his main interest was improving the human condition by applying "systems thinking". Systems thinking is an important concept, and generally we feel that "complex problems" should be approached by different methods. Roughly speaking, a problem is "simple" when a single cause and a single effect can be identified. Probably the soft, and too abstract (better saying, empty) methods of systems thinking generated some revulsion, mostly among those who believe in the power of mathematical models of specific phenomena.

> Collective wisdom about specialists and generalists:
>
> The specialist knows everything about nothing, while the generalist knows nothing about everything.

Systems theory suggests that "the whole is more than the sum of its parts". This is a controversial statement, since we never know how it comes down in practice. Others may have similar feelings: " I usually hate this slogan but here it holds in a spectacular way", writes Karl Sigmund in his Customer Reviews,

(actually about [385]),
http://www.amazon.com/Evolutionary-Dynamics-Exploring-Equations-Life/dp/0674023382, 30 April 2007).

While most likely the quest for *universal laws* was not a feasible project, complex systems might have *universal features* [35]. The price to get universal features is to give up the details. Physicists are traditionally very good in neglecting the details to see the big picture. (As a humble chemist by formal training, who has been working mostly on computational neuroscience, I agree with those who believe that not the devil but the angels live in the details.)[1]

Tamás Vicsek is a particularly successful Hungarian physicist, who designed simulation experiments of very different crowd behaviors, from bacterial colonies via flocking of birds to collective phenomena of humans; the latter e.g., in theater (many hands clapping) and in soccer stadium (Mexican wave - La Ola - , and panic) [49, 485, 338, 150, 209]. His recurring method is to show with surprisingly simple models how collective phenomena emerge by self-organized mechanisms. There is no need to external instruction to form global order, interaction with local neighbors is sufficient. "Surprisingly simple" means that he has sufficient courage to use such models, e.g., of waves in excitable medium (mentioned in Sect. 4.2.3) to describe waves in human population. Actually the Mexican wave model was motivated by the Wiener-Rosenblueth model of the cardiac wave propagation [503] (and it is just a coincidence that Arturo Rosenblueth (1900–1970) was a Mexican physiologist). However complex a human is, her state is characterized by a scalar variable with three possible values. She may be in an active, inactive or refractory state. There is a somewhat more detailed model, but the approach is the same. "Many scientists implicitly assume that we understand a particular phenomenon if we have a (computer) model that provides results that are consistent with observations and that makes correct predictions..." [538]. Model making is a combination of art and science. The most important question to be answered is not what we should put into the model, but *what to neglect*. Vicsek's success indicates a possible direction.

10.1.2 The Topics of the Book in Retrospective: Natural and Human Socioeconomic Systems

A large part of the book illustrates through examples how causal dynamical systems work.

[1] "Mert az angyal a részletekben lakik. "Petri György: Mosoly" . . . "For the angel is in the detail." György Petri: Smile; Translated by Clive Wilmer and George Gömöri. (Thanks to Máté Lengyel.)

While *mechanical* systems are supposed to belong to the class of simple systems, even the mechanical clock, the symbol of a periodic machine Universe, (i) utilizes the concept of feedback and (ii) might benefit from a little chaos. Idealized (frictionless) mechanical systems show time reversibility, macroscopic processes have arrow of time. The first and second laws of *thermodynamics* reflects the constancy and change of nature.

Chemical kinetics uses both deterministic and stochastic models. Autocatalytic reactions are examples of positive feedback: the larger the concentration of a reagent, the larger the velocity of its own production. Such kinds of reactions are the ingredients of the generating mechanism of complex temporal and spatial patterns.

Reaction–diffusion systems, somewhat counter-intuitively, are the basis of biological pattern formation. While diffusion is a process which is driven by spatial gradients to eliminate inhomogeneities, the coupling of certain spatial processes (such as diffusion) and local processes (such as chemical reaction) may lead to the formation of spatial structures.

Systems biology adopts the perspective of a multilevel approach, and was developed recently as a reaction to the overwhelming success of molecular biology. It adopts different techniques from simulation of chemical reactions to analysis of biochemical and genetic networks. A challenge of the classical dynamic description is that cells are self-referential systems. It is far from being clear what is a really appropriate mathematical framework to describe the dynamics of such kinds of systems.

A higher level of *biocomplexity* is related to dynamics of *ecological networks*. A key question is whether how an ecological system preserves both its stability and diversity. Ecological communities seem to be connected together by weak relationships.

Epidemic models have also have large practical significance. Too much data have been accumulated to model the spread of such diseases, as HIV and SARS. The most important result of the classical epidemic model studies stated (in accordance to real data) that epidemics is a threshold phenomenon. The spread of an epidemic in human or computer networks is much more complicated, in certain situations the spread does not have any threshold.

One big family of *evolutionary dynamics* uses generalized versions of the replicator equation to describe selection and mutation. The units of replication may be very different, from molecules, via genes to behavioral strategies.

Neurodynamics has several different functional roles. First, it deals with the generation and control of normal and pathological brain rhythms. Epilepsy was mentioned, as an example, where unbalanced positive feedback leads to pathological behavior. It is also an example, where new methods of prediction may have important practical consequences. In relationship with another neurological disorder, anxiety, my own interest was reviewed: a new way of drug discovery can benefit from integrating the kinetic models of drug effects into the conventional network dynamics and to design drugs which are able to generate some “best” physiological temporal patterns.

Second, the emergence of complexity through self-organizing mechanisms has been studied on both the ontogenetic and the phylogenetic time scale. Self-organization phenomena are related to normal ontogenetic development and plastic behavior occurring at different hierarchical levels of the nervous system. An important question here is the balance between determinism and randomness in the nervous system. Mental development is seen not only as a simple “consequence” of neural development, since mind not only represents, but also creates reality.

Large sets of seismic data have been accumulated with the hope of being able to predict eruption of *earthquakes*. Unbalanced positive feedback was also mentioned, as a possible mechanism of amplifying smaller seismic activities.

The scope (and limits) of dynamical models of socioeconomic systems were illustrated by a number of examples.

Segregation dynamics is the popular, demonstrative example of the power of simulations in social sciences. By simulations the effects of different preference functions on the emerging spatial patterns can be analyzed. The core models of social epidemics and opinion dynamics were reviewed. Simple assumptions, such as interactions among three basic populations (infected, susceptibles and removed) reflect the characteristic features of behavioral patterns for the propagation of ideas.

The *war* and *love dynamics* were examined by toy models. There are different qualitative outcomes. Occasionally there are pure winners and losers. Under other conditions, everybody survives at a certain fixed level, or there is a periodic transition among different states (say, love and hate...).

Economic activities, such as *business cycles* often show oscillations, and fluctuations. Technically oscillations are deterministic phenomena generated by the interaction of variables, such as investment and saving. Probably the real patterns are not truly oscillatory, and chaotic processes (including their control) may be more relevant. Fluctuations are random phenomena. One of the key discoveries of the new discipline, econophysics, is that financial time series have much larger fluctuations, than a Gaussian distribution would predict. Stock market data, among others, should be subject of statistical analysis of extreme events.

Dynamics of illicit *drug market* seems to be chaotic, due to the interaction of positive and negative feedback loops among the addicts and sellers populations. Model-based control strategies may offer methods to shift the system to a predictable periodic state, or even a low level fixed equilibrium.

The availability of the on-line database of the US *patent citations* opened the possibility to explain the temporal development of the network of citations by a dynamical model. We assumed that the attractiveness of the patents (combined by their age and popularity) characterizes sufficiently well the state of the system. The development of the network was given by a simple probabilistic rule, and worked well.

Models of *evolution of cooperation* are now extended. Originally it was assumed that altruistic mechanisms work for gene-sharing communities, but it seems to be reasonable that different levels of reciprocal interactions are the driving force behind constructive evolution.

I am fully aware of not mentioning in this book many important issues, which are often related to complex systems. Global warming and terrorist networks have been hot topics, and complex systems research has already offered methods to analyze them. Also, I mention here that Yaneer Bar-Yam's Dynamics of Complex Systems [42] thematically obviously overlaps with the present book, but of course you may notice the ten years difference (and the different interest of the authors).

While complex systems approach has the power to unify different levels, methods, problems from physical via biological to social systems, there is no magic bullet. Complexity systems have a number of ingredients.

10.2 The Ingredients of Complex Systems

Paradoxes. We have seen two types of *paradoxes*, one in linguistic situation, as it was discussed in Sect. 1.2.3 and another related to multistable perception of figures mentioned in Sect. 2.2.3. Paradoxes are characterized by some deviation between the expected and the actual behaviors of a system, and it is generally a consequence of false assumptions. In a logical situation the observer's opinion oscillates between a "true' and a "false" value.

Circular and network causality. As opposed to simple systems, where causes and effects (actually most often a single cause and a single effect) can be separated, a system is certainly complex, if an effect feeds back into its cause. Biological cells, ecological networks, business relationships and other social structures are full with such kinds of feedback loops.

Organizational closures. As Robert Rosen suggested, a cell is internally controlled, and it main feature is its organizationally closure. Of course, it does not mean that it is not thermodynamically open. But the connection of these two types of open/closed properties, I think, was never addressed appropriately.

Finite-time singularity. Unbalanced positive feedback may lead to finite-time singularities if the self-amplification is larger than the threshold necessary to exponential increase. In such systems the characteristic variable tends to have infinite value during finite time. In chemical systems this phenomenon is identified with explosion. In other systems, such in case of stock prices, the superexponential increase cannot be continued for "ever" due to the unstable nature of this process, and is followed by a compensatory process (i.e., stock market crash).

Chaos and fractals. Chaos it is often, erroneously, identified with complexity. As we know, systems with low structural complexity (as the logistic map) also may lead to chaos. Chaos is certainly dynamically complex, and different measures of complexity, such as fractal dimension, have been defined. The extreme sensitivity to initial conditions are very important property of chaos, and lead to fractal attractors. It generated a big excitement when it turned out that chaos generated fractal structures that are rather extensively found in nature and society.

Emergence. Complex systems (understood now as population of homogeneous or heterogeneous units) may show collective phenomena, which cannot be predicted from the behavior of the constituents. Self-sustained oscillation (a technically not very complex phenomena) and chaos may emerge in consequence of interactions of specific variables in certain regions of parameters. Levels of hierarchical organizations, from subatomic to cosmic, are emergent products. Organization principles, which regulate the emergence, were suggested to exist from quantum physics, via chemical kinetic and life itself to, say, the evolution of social behavior, as cooperation, and the formation of urban segregation, panic, stock market crash, etc.

Self-organized complexity. Many events/phenomena are characterized by probability distributions with long tails, which follow the power law relationship. Phenomena with large fluctuations, as stock market crashes, or natural disasters are extremely rare events. Seemingly different phenomena might be generated by similar mechanisms. Power law distribution is a specific case of the property of power law scale-invariance, which assumes a relationship between two variables in the form of

$$y = ax^k, \tag{10.1}$$

where a and k are constants, the latter is called the scaling exponent. Statistical physics has a formalism to treat phase transitions. The characteristic variable of the transition behaves as (10.1), where $x := |T - T_c|$, T is the temperature, T_c is its critical value, and k is the critical exponent. One of the big successes of statistical physics is the demonstration of common critical exponents for various phenomena. So a large family of phenomena belong to the same universality class, independently from the details. Maybe angels live in the universal, too. *Self-organized criticality* and *intermittent criticality* are general mechanism suggested to explain the emergence of self-organized complexity in physics, the brain, finance, and in many other situations. While both approaches is based on the integration of different space- and timescales, mechanisms based on intermittent criticality may be predicted. Many specific examples are being studied now by these methods.

10.3 Complexity Explained: In Defense of (Bounded) Rationality

Complexity, Explanation, Rationality: What We Wanted to Achieve?

Complex systems theory has a double soul and double strategy. First, it suggests that there is an already existing methodology, the theory and practice of dynamic modeling, and we believe that many social phenomena, traditionally studied by descriptive-normative methods, can be attacked by them. Second, we clearly see the limits of our own methods, mostly for situations, when different space- and timescales are integrated, when networks of positive and negative loops are interconnected, when the observer is not independent from the observed phenomena, etc. Whatever is the situation, physical, biological and social complexity could and should be understood as an emergent product of the interplay among constituents, and it is difficult to imagine other possibilities, at least within the scientific framework. This view does not exclude the possibilities of having a feedback from the "whole" to the "parts".

From Natural Science to Humanities and Back

Whether we like it or not (actually *not*, we can't do too much just to see the reduction of the prestige of science, the somewhat increasing influence of pseudoscientific ideas. "Intelligent design" pretends to be science. Many of us feels that it is a strange and inadequate situation that science must defend itself. Of course, critics of science appeared in novels of giant writers, such as in Flaubert' Bouvard and Pecuchet, in Canetti's Auto-da-fé and Hesse's The Glass Bead Game [175, 90, 235]. (To the memory of Péter Balassa.)

Complex systems approach comes predominantly from natural sciences, but we are fully aware of the existence of limits of model-based scientific thinking. Still, scientists have the ambition to tell something about the possibility of understanding and controlling our uncertain world. Also we know, that only very few scientists are celebrities, and only a very very few of us has any influence on media and popular culture.

Science War or the Crisis of Modernity

While the science war was initiated by accusing social scientists to use "fashionable nonsense", and already Popper (a rare philosopher whom scientists like) claimed that the criteria of rationality in social sciences are much less solid, than in natural sciences. Well, fellows from social sciences/humanities pass judgments on scientists - these uneducated hicks - because of their lacking consideration of the crisis of modernity.

Among my coeval and elder colleagues there is a common understanding that, after all, the real stuff is Science: we measure and calculate, and the caravan keeps moving on, however slowly, accompanied simply by the unharmful barking of some philosophers.

The rationale of classical Science is : experiment-measure-calculate. The engineering version is plan-construct-control/command, while humanities rely on understanding, interpretation, participation.

However beautiful are constructions based on definitions, axioms, statements and proofs, they rarely reflect faithfully what is called reality. Mathematicians, the most respected rational fantasy players already left a big battle behind, and the rigorous, formalist program of mathematics could not be completed. Imre Lakatos (1922–1974)'s work on the philosophy of mathematics analyzed the way of progress in mathematics. After his early death it was written [570]:

"The thesis of 'Proofs and Refutations' is that the development of mathematics does not consist (as conventional philosophy of mathematics tells us it does) in the steady accumulation of eternal truths. Mathematics develops, according to Lakatos, in a much more dramatic and exciting way - by a process of conjecture, followed by attempts to 'prove' the conjecture (i.e., to reduce it to other conjectures) followed by criticism via attempts to produce counter-examples both to the conjectured theorem and to the various steps in the proof."

The alternative of classical rationality is not at all irrationality. As Herbert Simone suggested, the concept of "bounded rationality" is more appropriate to describe our behavior (fortunately) than perfect rationality. A new type of rationality, what we might call "resigning rationality", asks what we can do in situations, when we have difficulties with concepts of objective external observer and of objective reality. Can we accept the existence of "tacit knowledge" of Michael Polanyi [410], or the possibility of self-reflection?

Model and Truth

By thinking in and with models we consciously give up a language, which implies that we might be the only ones, who are able to know the only truth. We don't say that "these and these are the facts, and only the facts matter". A more appropriate language says: "By assuming this and that, and adopting the set of these rules, we may imply this and that". This is not a shame. We may admit that we are not the owners of the final and infallible truth.

The Age of Fallibility

What can we do after accepting the limits if classical rationality? George Soros, known as Popper's student and admirer, argues that *reflexivity* and *fallibility* are the most important features of the new age we live. Reflexivity is related to our decision making mechanisms (say, buying/selling in the stock market). The decision depends on both knowledge and expectation, and they influence reality [475].

George Soros

Could the recognition of our imperfect understanding serve to establish the open society as a desirable form of social organization? I believe it could, although there are formidable difficulties in the way. We must promote a belief in our own fallibility to the status that we normally confer on a belief in ultimate truth. But if ultimate truth is not attainable, how can we accept our fallibility as ultimate truth?

This is an apparent paradox, but it can be resolved. The first proposition, that our understanding is imperfect, is consistent with a second proposition: that we must accept the first proposition as an article of faith. The need for articles of faith arises exactly because our understanding is imperfect. If we enjoyed perfect knowledge, there would be no need for beliefs. But to accept this line of reasoning requires a profound change in the role that we accord our beliefs....

To derive a political and social agenda from a philosophical, epistemological argument seems like a hopeless undertaking. Yet it can be done. There is historical precedent. The Enlightenment was a celebration of the power of reason, and it provided the inspiration for the Declaration of Independence and the Bill of Rights. The belief in reason was carried to excess in the French Revolution, with unpleasant side effects; nevertheless, it was the beginning of modernity. We have now had 200 years of experience with the Age of Reason, and as reasonable people we ought to recognize that reason has its limitations. The time is ripe for developing a conceptual framework based on our fallibility. Where reason has failed, fallibility may yet succeed.

From the ”The Capitalist Threat” [474].

Interestingly, while Soros benefited literally very much from his deep understanding of the heterogeneous nature of the world (economy), as the Reader knows, Thomas Friedman, an influential journalist of the New York Times, wrote a best-seller about the globalization (I found strange that Soros was not mentioned) with the title “The World Is Flat” [185], stating that there is a tendency to reduce this heterogeneity, mostly due to the development of Internet technologies. This makes possible to include China and India in the complex supply chain.

Towards a New Synthesis? From the ”two cultures” to the third

C. Snow pointed out the gap between the cultures of literary intellectuals and of scientists [470]. Actually he blamed mostly non-scientists.

Snow's critique:

"A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: Have you read a work of Shakespeare's?

I now believe that if I had asked an even simpler question – such as, What do you mean by mass, or acceleration, which is the scientific equivalent of saying, Can you read? – not more than one in ten of the highly educated would have felt that I was speaking the same language. So the great edifice of modern physics goes up, and the majority of the cleverest people in the western world have about as much insight into it as their neolithic ancestors would have had."

I used to annoy my social scientist friends by asking about the laws of thermodynamics, but abandoned this endeavor, since I realized that it is counterproductive, and does not help to narrow the gap between our way of thinking. Probably I am not right. Steven Pinker, Harvard psychologist, working on cognition and languages, and who writes also excellent popular books, just wrote (27 May 2007) in the New York Times Book Review:

Steven Pinker about scientific illiteracy:

People who would sneer at the vulgarian who has never read Virginia Woolf will insouciantly boast of their ignorance of basic physics. Most of our intellectual magazines discuss science only when it bears on their political concerns or when they can portray science as just another political arena.

From [408].

Pinker is a member of the informal group coordinated by John Brockman. Thanks to Brockman, the works and thoughts of a set of scientific intellectuals seem to be integrated in a "third culture" [75, 76], see also the website http://www.edge.org.

The third culture movement is optimistic with the hope to understand and explain the real world of humans, machines, societies and the Universe. Science, technology and business is now interconnected and forms a global culture.

> The new humanists
>
> “...something radically new is in the air: new ways of understanding physical systems, new ways of thinking about thinking that call into question many of our basic assumptions. A realistic biology of the mind, advances in physics, information technology, genetics, neurobiology, engineering, the chemistry of materials -all are challenging basic assumptions of who and what we are, of what it means to be human. The arts and the sciences are again joining together as one culture, the third culture...”
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> From John Brockman: Introduction: The New Humanists, in [76].

Instead of Summary

I think, the perspective what a pluralistic theory of complex systems offers, is the key to understand, explain and control the world which seemed to be derailed. We may have the chance to get a better insight into our own cognitive-emotional structures. Analysis based on the combination of biological and social approaches will help to explain and control our choices and decision makings at individual level, and the evolution of norms and values in societies. Increasing knowledge about our (and others) genes, brains and minds, our willingness to cooperate and compete both individually and in groups should help to understand the world and our role in it.

But of course, flat or not, that will be a different world.