Preface

In May 2002 a number of about 20 scientists from various disciplines were invited by the Berlin-Brandenburg Academy of Sciences and Humanities to participate in an interdisciplinary workshop on structures and structure generating processes. The site was the beautiful little castle of Blankensee, south of Berlin. The disciplines represented ranged from mathematics and information theory, over various fields of engineering, biochemistry and biology, to the economic and social sciences. All participants presented talks explaining the nature of structures considered in their fields and the associated procedures of analysis.

It soon became evident that the study of structures is indeed a common concern of virtually all disciplines. The motivation as well as the methods of analysis, however, differ considerably. In engineering, the generation of artifacts, such as infrastructures or technological processes, are of primary interest. Frequently, the analysis aims there at defining a simplified mathematical model for the optimization of the structures and the structure generating processes. Mathematical or heuristic methods are applied, the latter preferably of the type of biology based evolutionary algorithms. On the other hand, setting up complex technical structures is not possible by such simplified model calculations but requires a different and less model but rather knowledge-based type of approach, using empirical rules rather than formal equations. In biochemistry, interest is frequently focussed on the structures of molecules, such as proteins or ribonucleic acids. Again, optimal structures can usually be defined. They are synthesized by elaborate experimental methods, but also by computer based evolutionary approaches, similar in general but different in detail from those used in engineering. Quite different is the study and explanation of existing structures and structure generating processes in biology and in the social sciences. Here a mathematical model can, as a rule, not be formulated, because the internal interactions are too complex and are strongly governed by large statistical uncertainties or even are of a non-causal nature. Analysis therefore requires, at least partially, approaches of analysis which are rather different from those of the physical, chemical or the technical sciences. Thought and experimental observation, rather than mathematical analysis, are the basis of analysing and documenting structures and structure generating processes in these fields. The economic sciences play a kind of intermediate role as both types of analysis are found. Finally, the question of optimality does not present itself in an unambiguous manner in these fields.

Generally, biological and social structures, although developing in an evolutionary way, cannot be considered as proceeding towards an a-priori definable goal of optimality.

In view of the many fundamental analogies of structures and structure generating processes in the various fields, and also of the equally fundamental differences, the workshop resulted in a broad conviction that a systematic interdisciplinary investigation of the topic would be of considerable scientific interest. On this basis an interdisciplinary study group was inaugurated with the beginning of 2003 by the Berlin-Brandenburg Academy of Sciences and Humanities. It was instituted for a period of three years, i.e. over the years 2003–2005, with the dedication of studying the emergence, analysis and evolution of structures in the various disciplines. This book documents the research results of this group, working out the transdisciplinary fundamentals and analysing their operation in a number of case studies. From the results it can be speculated that a new transdisciplinary research field of structure analysis may emerge, condensing the various strategies to a common approach towards a better understanding of structures and structure generating processes in all fields.

It first became necessary to define the characteristic features of structures and to find a useful classification for them. Here, the fundamental notions of static and dynamic structures, originally proposed in thermodynamics, turned out to provide a largely common basis for understanding and analysis. Static structures, isolated from their environments are determined by internal interactions of their constituting components only, and evolve, as time proceeds, towards a predetermined or at least implicitly definable goal. They remain unchanged over time when this goal has been reached. On the other side, dynamic structures, additionally influenced by interactions with the environment, develop in an essentially unpredictable way and without approaching a predetermined goal. They require steady exchange of material, energy and information with the environment for their persistence. Many structures, notably the artifacts in the technical and economic sciences, appear to be static at first sight. However, a closer look reveals that their design and operation depends to a large extent on the environment, which makes them assume typical features of dynamical structures. When looking at their evolution over a long time it can be seen that their interactions with the environment in terms of energy, material and information frequently change in a basically unpredictable way, sometimes abruptly, and with them the related structures, too. In this general view it appears that the common properties of structures in a general sense are those found in the dynamic structures, such as dependence on external interactions, abrupt changes and intrinsic unpredictability.

The basis of analysis of structures in all sciences are models. So, the modeling of reality as executed in the various fields had to be investigated. It turns out that the major approaches of modeling are rather different in the various disciplines. Still, there is also much in common. As an example, any model aiming at representing reality has to cope with various types of uncertainty. Methods to cope with uncertainty are available, ranging from error propagation and stochastic approaches in the technical model simulations to the approach of knowledge based decision making in complex applications of engineering and sociology. In cases in which a model maps the input parameters mathematically into a performance function, an algorithm has to be used to work out this relationship, either provided by strict mathematics or by some kind of heuristic. Models of real structures and structure generating processes in some fields are analysed in terms of optimality, at least partially, i.e. restricted in space and time. However, the assessment of optimality even if justified is not straightforward, since various conflicting goals contribute to its definition in most applications. While these goals may be objective or subjective in themselves, their relative weights for a global optimality assessment are in most cases subjective. Also sometimes these weights change over time due to subjective esteem. The complex aspects of qualitative and quantitative modeling, and the goal-oriented and statistical approaches to understanding the meliorisation efforts in the various fields are discussed, with the aim to help readers familiarize themselves with methods hitherto unusual in their own fields.

These transdisciplinary fundamentals can be seen at work in a large variety of case studies from various disciplines, which constitute the main body of the text. They are taken from the fields of natural and technical sciences such as engineering, biology, medicine and chemistry as well as from social sciences such as sociology, economics and psychology. On the basis of these case studies the general purpose of this book becomes evident: the exploration of the status of knowledge about structures and structure generating processes and of the tools available for analysing them in various disciplines. It is expected that information is provided that may help the reader to cross the border of the disciplines, with the result of being inspired by new ideas profitable in his or her own field. Also the fundamentals as well as the case studies considered may serve to point out a frequently perceived resemblance of rather different scientific fields.

The contributors to this book are listed at the end. While the authors of the case studies have been explicitly identified, the introduction, the chapter on the transdisciplinary foundations and the chapter on the transdisciplinary perspective have been written by the editors based on the discussions within group meetings unless stated otherwise. The final typing and layout of the manuscript was realized by I. Wallraven.

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