UNDERSTANDING COMPLEX SYSTEMS

Springer: COMPLEXITY

Octavian Iordache

Modeling Multi-Level Systems

Springer

Springer Complexity

Springer Complexity is an interdisciplinary program publishing the best research and academic-level teaching on both fundamental and applied aspects of complex systems - cutting across all traditional disciplines of the natural and life sciences, engineering, economics, medicine, neuroscience, social and computer science.

Complex Systems are systems that comprise many interacting parts with the ability to generate a new quality of macroscopic collective behavior the manifestations of which are the spontaneous formation of distinctive temporal, spatial or functional structures. Models of such systems can be successfully mapped onto quite diverse "real-life" situations like the climate, the coherent emission of light from lasers, chemical reaction-diffusion systems, biological cellular networks, the dynamics of stock markets and of the internet, earthquake statistics and prediction, freeway traffic, the human brain, or the formation of opinions in social systems, to name just some of the popular applications.

Although their scope and methodologies overlap somewhat, one can distinguish the following main concepts and tools: self-organization, nonlinear dynamics, synergetics, turbulence, dynamical systems, catastrophes, instabilities, stochastic processes, chaos, graphs and networks, cellular automata, adaptive systems, genetic algorithms and computational intelligence.

The two major book publication platforms of the Springer Complexity program are the monograph series "Understanding Complex Systems" focusing on the various applications of complexity, and the "Springer Series in Synergetics", which is devoted to the quantitative theoretical and methodological foundations. In addition to the books in these two core series, the program also incorporates individual titles ranging from textbooks to major reference works.

Understanding Complex Systems

Founding Editor: J.A. Scott Kelso

Future scientific and technological developments in many fields will necessarily depend upon coming to grips with complex systems. Such systems are complex in both their composition - typically many different kinds of components interacting simultaneously and nonlinearly with each other and their environments on multiple levels - and in the rich diversity of behavior of which they are capable.

The Springer Series in Understanding Complex Systems series (UCS) promotes new strategies and paradigms for understanding and realizing applications of complex systems research in a wide variety of fields and endeavors. UCS is explicitly transdisciplinary. It has three main goals: First, to elaborate the concepts, methods and tools of complex systems at all levels of description and in all scientific fields, especially newly emerging areas within the life, social, behavioral, economic, neuroand cognitive sciences (and derivatives thereof); second, to encourage novel applications of these ideas in various fields of engineering and computation such as robotics, nano-technology and informatics; third, to provide a single forum within which commonalities and differences in the workings of complex systems may be discerned, hence leading to deeper insight and understanding.

UCS will publish monographs, lecture notes and selected edited contributions aimed at communicating new findings to a large multidisciplinary audience.

Octavian Iordache

Modeling Multi-Level Systems

Springer

Author

Dr. Octavian Iordache
Polystochastic
Pitfield blvd. St. Laurent 3205
H4S 1H3 Montreal
Canada
E-mail: polystochastic@bellnet.ca

ISBN 978-3-642-17945-7 e-ISBN 978-3-642-17946-4

DOI 10.1007/978-3-642-17946-4

Understanding Complex Systems ISSN 1860-0832

Library of Congress Control Number: 2011921006

Typeset & Cover Design: Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

…his way was to carry his mind into his laboratory, and literally to make of his alembics and cucurbits instruments of thought…

C. S. Peirce

The Fixation of Belief, 1877

Preface

Modeling multi-level complex systems is the object of this book.

Complex systems are assemblies of several subsystems and are characterized by emergent behavior resulting by nonlinear interactions among subsystems for multiple levels of organization.

The complexity of numerous systems is rooted in the existence of many levels of self-organization corresponding to different time and space scales.

There is a need to provide general frameworks able to combine several scales and reality levels of the complex systems in one coherent and transdisciplinary discourse. A challenge for complex systems science and technology is to develop mathematical formalisms and modeling methods able to capture complete systems dynamics by integration of contribution at several hierarchically organized levels. Existing models involve a large number of nonlinear equations, difficult to handle analytically or numerically, and to correlate with real systems behavior. Among the open questions, we mention the definition of relevant parameters and variables to be measured at each scale or level, the study of coupling between different levels, the insufficiency of the algorithmic schema for evolvable or autonomous systems modeling.

The proposed modeling tools for multi-scale and multi-level systems are the polystochastic models, PSM. These characterize systems coming out when several stochastic processes, running at different conditioning levels, are capable to interact with each other, resulting in qualitatively new processes and systems.

Polystochastic models aim to discover and describe new structures and behaviors, which cannot be detected by one level approaches and cannot be reduced to the summation of several levels contributions.

The book is divided in 12 chapters. The chapters 1 to 4 delineate the problems and the methods. The role of multiple levels of reality for different concepts and theories of complexity is highlighted in the first chapter of the book. The relation between levels of reality and categories is emphasized.

Several mathematical methods that have been used in PSM development are briefly presented in chapter 2. This refers to “random systems”, “non-Archimedean analysis”, and “category theory”. Specific concepts as categorification and integrative closure are introduced. Categorical formulation of integrative closure offers the general PSM framework which serves as a flexible guideline for the large variety of research and multi-level modeling problems presented in the book.

Chapter 3 introduces the conventional real-field frame for PSM and some illustrative examples. Chapter 4 leads into the new PSM methodologies. The model categorification method is illustrated. The need of appropriate notions of time and probabilities and of new theoretical concepts is emphasized.

The chapters 5 to 8 are dedicated to case studies relevant to the sciences of nature.

For this part the levels are usually associated to time scales. Chapters 5 and 6 elaborate PSM for mixing and transport in single or multi-compartmental systems while chapter 7 contains a multi-scale study of dispersion and turbulence. Major applications for these chapters range from chemical engineering to pharmacology and environment.

Chapter 8 highlights entropy and entropy production roles for integrative closure conceptual framework. Application concerns entropy production for multi-scale biosystems. Based on different types of causation, new informationl entropy criteria are proposed.

The next four chapters, 9 to 12, outline the potential of the proposed multi-level modeling methods for the domain of system sciences. For this part the levels are conceptual knowledge levels or reality levels associated to categories. Chapter 9 establishes the contact of PSM with formal concept analysis. Applications include enumeration of separation flow-sheets, pharmacology, security management for information technology, and failure analysis. Diagrammatic reasoning using existential graphs is presented in chapter 10. The correlations with pragmatism and studies of continuity are emphasized.

Chapter 11 applied evolvable designs of experiments to pharmaceutical pipeline for drug discovery and development, to reliability management systems and failure analysis for printed circuits.

The connection of the presented PSM methodology with some forward-looking research directions for autonomous systems has been outlined by Chapter 12. Delineated case studies refer to autonomous experimentation, case based reasoning, beliefs desires intentions agents, organic and autonomic computing, autonomous animats, viable systems modeling, and multi-level modeling for informational systems.

Necessary elements of non-Archimedean functional analysis and category theory are presented in appendices.

The case studies analyzed in the book, represent a source of inspiration for emerging technologies in their current transition from adaptive toward evolvable and autonomous systems. They joint also recent trends advocating the convergence of disciplines and the need for transdisciplinary research for complexity. The multi-level modeling is in place at the intersection of sciences of matter as chemistry, life sciences, cognitive sciences, engineering and mathematics.

The PSM methodology presented and developed in this book is successfully confronted with an exciting field of major practical interest and a key area for future investigations, the multi-level complexity.

Contents

1 Introduction 1
1.1 Multi-level Systems 1
1.1.1 Levels and Complexity 1
1.1.2 Related Concepts and Theories 3
1.2 Levels of Reality and Categories 6
References 9

2 Methodological Resources 11
2.1 Random Systems 11
2.2 Non-Archimedean Analysis 13
2.3 Categorical Frames 14
2.3.1 Introducing Category Theory 14
2.3.2 Higher Dimensional Categories 16
2.3.3 Models Categorification 18
2.3.4 Synthetic Differential Geometry 19
2.4 Closure 21
2.4.1 Semantic Closure 21
2.4.2 Two Levels Modeling 22
2.4.3 Integrative Closure 24
References 31

3 Conventional PSM Frames 35
3.1 One Conditioning Level Frame 35
3.2 Multiple Conditioning Levels 38
3.3 Illustrative Case Studies 41
3.3.1 Mixing in Turbulent Flow 41
3.3.2 Diffusion on a Hierarchical Space 44
3.3.3 Different Views for the Same Phenomenon 48
References 51

4 New PSM Frames 53
4.1 General Frameworks for PSM 53
4.1.1 Basic Categorical Frameworks 53
4.1.2 Multiple Levels 55
4.2 Time Frames 61
4.2.1 The Problem of Time Frame 61
4.2.2 Frame of Infinitesimals 62
4.3 Probabilities and Possibilities 63

4.3.1 Frame of Infinitesimals for Probabilities and Possibilities 63
4.3.2 Non Well Founded Sets and Probabilities 65
4.4 Models Categorification Methodology 66
4.4.1 Frame of Infinitesimals for PSM 66
4.4.2 NA Difference Equation 68
References 69

5 Mixing in Chemical Reactors 71
5.1 Discrete Model of Imperfect Mixing 71
5.1.1 Residence Time Distribution, RTD 71
5.1.2 Discrete Model for Residence Time Distributions 75
5.1.3 Local Anesthetic Effects 80
5.1.4 Stochastic Features. Real Field Probabilities 81
5.1.5 PSM Frame for Discrete Model 83
5.1.6 Comparison with Theory 84
5.2 Continuous Model of Imperfect Mixing 85
5.2.1 The Continuous Model 85
5.2.2 PSM Frame for Continuous Model 89
5.2.3 Comparison with Theory 90
5.2.4 SDG Solution for Imperfect Mixing 93
References 94

6 Compartmental Systems 95
6.1 Compartmental Models 95
6.2 Discrete Models for a Series of Imperfectly Mixed Vessels 97
6.3 Continuous Time Model 99
6.3.1 Residence Time Distributions 99
6.3.2 Interaction of Chemical Compound with Membranes 103
References 105

7 Turbulent Mixing 107
7.1 Dispersion 107
7.1.1 The Dispersion Equation 107
7.1.2 The Frame of Infinitesimals 109
7.1.3 Hydrological Experiments 113
7.1.4 SDG Solution for Dispersion 115
7.1.5 Convection Model 117
7.2 Intermittency by Vortex Line Stretching 118
7.2.1 Conventional Frame 118
7.2.2 Multi-level Frame 120
References 123

8 Entropy 125
8.1 Background 125
8.2 Informational Entropy 127
8.3 Entropy Production for Biosystems 129

8.4 Entropy and Integrative Closure 135
8.5 Cooperative Model for Nerve Excitation 138
References 141

9 Formal Concept Analysis 143
9.1 Galois Lattices 143
9.2 Separation Lattice 144
9.3 Drugs Mixture 148
9.4 Failure Analysis 149
9.5 Triadic Context Analysis 151
9.6 Rough Set Approximations 153
9.7 Hierarchical Class Analysis 156
9.8 Tetradic Context Analysis 158
9.9 Security Management Architectures 160
References 162

10 Existential Graphs 165
10.1 Systems of Existential Graphs 165
10.2 Continuum and Existential Graphs 170
10.3 Separation Flow Sheets 173
References 176

11 Evolvable Designs of Experiments 179
11.1 Pharmaceutical Pipeline 179
11.2 Designs of Experiments for Drug Discovery 182
11.3 Drugs Development 184
11.3.1 General PSM Framework for Discovery and Development 184
11.3.2 Informational Tools 185
11.3.3 Anesthetics Mixtures 187
11.3.4 Acylthiocarbamates Library Design 190
11.4 Reliability Management System 193
References 196

12 Autonomous Systems Perspective 199
12.1 Autonomous Experimentation 199
12.2 Case Based Reasoning Systems 200
12.3 Belief Desire Intention Agents 203
12.4 Autonomic and Organic Computing 205
12.5 Autonomous Animats 207
12.6 Viable Systems Models 208
12.7 Meta-modeling Architectures 209
References 211

Appendices 213
Appendix 1: Non-Archimedean Analysis 213
A1.1 Valued Fields 213
A1.2 Normed Linear Spaces and Orthogonality 214
References 217

Appendix 2 Category Theory 218
A2.1 Category Theory 218
A2.2 The n-Categories..219
A2.3 Periodic Table..220
A2.4 Categorification and Coherence..222
A2.5 Toposes Modeling SDG...225
References 226

Index 229

List of Figures

2.1 Multiple scales networks and n-graphs 17
2.2 Semantic closure 22
2.3 Two-level models 23
2.4 Integrative closure network 24
2.5 Integrative closure network with sub-levels 25
2.6 Integrative closure for categories 26
2.7 Integrative closure for categories and sub-categories 26
2.8 Integrative closure for centered categories 29
2.9 Cybersemiotic star and integrative closure 30
2.10 Tetradic sign 30

3.1 RSCC model 36
3.2 Continuous time RSCC model 38
3.3 Example of PSM frame 41
3.4 Mixing process 42
3.5 One level of states 44
3.6 Energy barriers 45
3.7 PSM frame for one level of states 46
3.8 Multi-levels of states 46
3.9 PSM frame for multiple levels of states 47
3.10 States at different levels 48
3.11 RSCC associated to one level conditional stochastic chain 49
3.12 PSM frame associated to multiple levels conditional stochastic chain 50

4.1 Two levels framework 54
4.2 Three levels hierarchical framework 55
4.3 Three realms network 56
4.4 Four levels hierarchical framework 57
4.5 Four realms network 57
4.6 Fully integrated four realms network 59
4.7 Centered four realms network 60
4.8 Cycle of cognition 60

5.1 Imperfect mixing 75
5.2 Discrete time scales and integrative closure for one cell 79
5.3 Continuous time scales and integrative closure for one cell 91

6.1 Cellular model ... 97
6.2 Cellular models with imperfect mixing ... 98
6.3 Time scales and integrative closure for multiple cells ... 103

7.1 Scales and integrative closure ... 115
7.2 Intermittency by vortex line stretching ... 120
7.3 Two time scales intermittency ... 121

8.1 Entropy production for multi-scale systems ... 134
8.2 Integrative closure for multi-scale entropy production ... 136
8.3 Integrative closure and entropy principles ... 137

9.1 Galois lattice for separation-four properties ... 147
9.2 Galois lattice for separation-reduced labeling ... 147
9.3 Procaine ... 148
9.4 Galois lattice for composed drugs ... 149
9.5 Galois lattice for failure analysis ... 151
9.6 Trillatice for triadic power set context ... 153
9.7 Galois lattice for separation-five properties ... 154
9.8 Oriented formal contexts ... 155
9.9 Hierarchical structure of classes for dyadic context ... 157
9.10 Triadic classes hierarchy study ... 158
9.11 Tetralattice for tetradic power set context ... 159
9.12 Integrative closure for tetradic lattice ... 160
9.13 Four realms network for security of information systems ... 161
9.14 Four realms network for failure diagnosis ... 161
9.15 Four realms network for security management ... 162

10.1 Sep: A is false or separated ... 166
10.2 Subgraphs ... 166
10.3 Double seps ... 167
10.4 Nested levels of subgraphs ... 167
10.5 Double seps rule of equivalence ... 168
10.6 Insertion and erasure ... 168
10.7 Iteration/Deiteration ... 169
10.8 Broken seps ... 170
10.9 Integrative closure for existential graphs ... 172
10.10 Monoidal flow-sheets ... 174
10.11 Monoidal flow-sheets: tree like form ... 174
10.12 Braided flow-sheets ... 175
10.13 Parity cube flow-sheets ... 176

11.1 Pharmaceutical pipeline ... 180
11.2 Pharmaceutical pipecycles ... 181
11.3 EDOE basic framework ... 183
11.4 Framework for drug discovery and development ... 185

11.5 Acylthiocarbamates structure 191
11.6 Framework for reliability management system 194
11.7 Integrative closure for EDOE 196

12.1 Architecture for autonomous experimentation 200
12.2 CBR basic framework.. 201
12.3 Centered frameworks for evolvable CBR 203
12.4 Structure of BDI agents 204
12.5 Centered frameworks for evolvable BDI architecture 205
12.6 Automatic computing architecture.. 206
12.7 Organic computing architecture.. 207
12.8 Architecture for autonomous animats... 208
12.9 Architecture for viable systems 209
12.10 Centered meta-meta-modeling frameworks.. 210

A2.1 Pentagon relations... 223
A2.2 Hexagon relations 224
A2.3 Parity cube relations.. 224

List of Tables

5.1 Action potential amplitude for the anesthetic effect 80
5.2 Objective function for single compartment model 80
5.3 RTD functions predicted by different models.. 92

6.1 Compartmental models 96
6.2 Relative height of the compound action potential 104
6.3 Objective function for multi-compartments model.................................... 104

9.1 Input information-isomers properties 145
9.2 Formal context: components and properties 145
9.3 Formal context for separations-four properties.. 146
9.4 Properties of drugs 148
9.5 Plating voids type for different processing steps 150
9.6 Triadic power set context.. 152
9.7 Formal context for separations-five properties 154
9.8 Dyadic formal context 156
9.9 Triadic context 157
9.10 Tetradic power set context (partial data) 159

11.1 Greco-Latin square design 184
11.2 Topical anesthetics.. 188
11.3 Informational entropies for mixtures 189
11.4 Reference set for acylthiocarbamates-radicals... 191
11.5 Reference set for acylthiocarbamates-matrix... 191
11.6 Informational entropies for Acylthiocarbamates 192
11.7 Latin square design 194
11.8 Resistance patterns. Classification table 195

A2.1 Periodic table of categories.. 221
A2.2 Correspondence between sets and categories 222

Abbreviations

CT-category theory

EDOE-evolvable design of experiment

EG-existential graphs

FCA-formal concept analysis

GL-Galois lattice

NA-non-Archimedean

NBIC-nano-bio-info-cogno

PSM-polystochastic model

RS-random systems

RSCC-random systems with complete connections

RTD-residence time distribution

SDG-synthetic differential geometry

SKUP-states, conditions, operators, possibilities

Chapter 1
Introduction

Abstract. A major property of complex systems is their self-structuring in multiple conditioning levels with different spatial and temporal scales.

Multi-scale and multi-level aspects for modern theories and concepts as: dissipative structures, auto-catalytic systems, catastrophes, synergetics, fractals, artificial life, complex adaptive systems, cybernetics, and biomimetic computation are revealed here.

The topic of multi-level structure of reality and its relation to the study of categories is discussed with emphasize on ontology and pragmatism.

1.1 Multi-level Systems

1.1.1 Levels and Complexity

A complex system is described as a structure or a process involving non-linear interactions among many parts and levels, which displays emergent properties. This means that the aggregate system activity is not derivable from the linear summation of the activity of individual components and that novel structure, patterns or properties arise, from interactions among parts.

A survey of the literature indicates that there is no standard definition of a complex or emergent system. However features such as hierarchy of levels, timescales, emergence, unpredictability, interconnectivity, self-organization, self-similarity, collective behavior, evolvability are focused in complexity studies (Adami 2002, Bar-Yam 1999, Kauffman S. 1995, Mainzer 1996).

Complexity is supposed to come from non-linearity and from a large number of elements with many degrees of freedom and many relationships.

A key property of complex systems is their self-structuring in conditioning levels, each of more or less homogeneous characterization.

Spatial and temporal scales may be associated to conditioning levels.

Self-organization will occur when individual independent parts in a complex system interact in a jointly cooperative manner that is also individually appropriate, such as to generate a new level organization.

Complex systems can be studied at different levels of investigation. For example we can study an industrial installation at the level of molecules or at the level of devices interactions. The number of observation levels is finite. The understanding of complexity changes with the domains of application. Some surveys consider that the complexity level has not an absolute meaning, and it is only a relative notion depending on the level of observation or abstraction. These surveys emphasize a facet of complexity as a relative concept which depends both on the task at hand and on the tools available to achieve this task.

For environmental, industrial or pharmacological systems, despite the fact that numerous physical or chemical processes are identified as complex, more of the conventional ones may be operated in regimes were multi-level complexity properties are neglected. For several centuries, physical and chemical sciences made great steps by experimenting and constructing simplified single level models of complex phenomena, deriving properties from the models, and verifying those properties by new experiments. This approach worked because the multi-level complexities ignored in that models were not the essential properties of the phenomena. It does not work when the multi-level complexity becomes the essential characteristic. In an increasing number of cases the multi-level complexity is not transient or atypical, but it is an intrinsic property of that systems.

Several examples will clarify these aspects of complexity.

Consider the moisture dispersion in soil, a first example inspired from environmental studies. Taking into account only particle movements in the inter-particle space of macro pores, simple stochastic process of moisture dispersion will result. This model corresponds to the one level approach. More detailed studies should be concerned about different levels of the real moisture transport process, after macro pores, successive scales of micro pores, restrictions for flow, and so on. In more developed environmental studies a two-state conditional process valued on the set {“wet”, “dry”}, should be taken into account on daily and on seasonal scale. The basic physical phenomenon, the moisture migration in soil, arrive to be perceived now as a multi-level complex phenomenon in which many interacting processes, at different levels of organization, evolve in a randomly changing environment. The evolvable multi-scale fluid dispersion ecosystem, self-adapting, self-creating the internal and external restrictions, is the object of the PSM studies.

The next example we will consider is the problem of modeling in industrial multi-scale systems (Fraga et al. 2006). Modeling frameworks should incorporate evolvability in order to selectively manipulate the models and to incorporate details and complexity only in those areas of the models which are critical to provide an adequate solution and remove such details and complexity were it is not. Thus we can imagine a multi-level modeling and simulation capability within which the following hold:

- A model consists of a hierarchy of layers or scales of increasing detail, complexity and sophistication, spanning the entire set of length and time scales from molecules to business chains

- Each layer or scale contains a model definition and a number of parameters
- Each layer accepts parameters from below and calculates the parameters required by the layer above
- Evolvability capabilities such as ontology, languages and agents, may be incorporated at any point to define and modify the models, parameters and solutions

Such multi-level architecture should have a number of capabilities as for instance:

- Should be flexible and extensible
- Should provide a rational and consistent basis for multi-scale models
- Should incorporate external modules, models, codes and be integrated with laboratory and plant systems
- Should allow to the user to indicate fitness for purpose
- Should ensure systems evolvability and autonomy in an environment changing at an ever-increasing rate

As another example we will consider the drug action in pharmacological systems.

The pharmacology seeks to develop a global understanding of the interactions between individual physiology and drug action. To develop such an understanding it is necessary to analyze interactions across and between various scales of organization.

The organisms should be analyzed at the levels of organs, tissues, cells or molecules. Drugs are prescribed at the organism level but exert their effect by interacting with their target at the molecular level.

As observed from these illustrative examples, the complexity of systems arises not only from the number of its components or levels but rather from the way these components are interconnected.

Non-linear interactions between different levels and scales represent a characteristic of complexity. Complex systems differ basically from complicated ones. Systems may outline complexity on both structural and on functional level. Structural complexity increases with the number of interacting subunits, the mutual connectedness among them and the degree of interactions of individual subunits. On a functional level, complexity increases with the minimum length of the algorithm from which one can retrieve the full behavior of the system. Complexity in computing science accommodates a hierarchy of conditioning levels depending on the computational time for computer programs or algorithms. The conditioning levels are determined by the structure as well as the degree of coherent cooperativeness among similar modules of the complex system.

1.1.2 Related Concepts and Theories

Since a universally accepted theory of multi-level complexity does not exists, a brief comparison with related theories sharing similar objectives with PSM, and allowing the study of multi-level systems would be of interest.

Prigogine (1980, 1989) and his group ("Brussels School") have shown that systems far from equilibrium are able to self-organize in a hierarchical way, in several levels. The equations of dynamics or of thermodynamics are nonlinear and drive to bifurcations. Non-linearity proves to be necessary but not sufficient for complexity. The emergence of hierarchical levels appears to be one of the possibilities. The complex system organizes itself by jumping from an equilibrium state with few hierarchical levels to another equilibrium state with more levels. By this process the system gets more complex. The resulting structures stable in space and time are called “dissipative structures” (Nicolis and Prigogine 1989). Bénard’s cells and oscillating chemical reactions have been studied as examples of self-organizing processes.

In relation with the above theory, Eigen and Schuster (1979) focused on the origin of life, the domain where chemical self-organization in levels and biological evolution met. The developed concepts were that of “hypercycle”, an auto-catalytic cycle of chemical reactions containing other cycles, and of “quasispecies”, the fuzzy distribution of genotypes characterizing a population of quickly mutating organisms or molecules.

In the theory of so-called “catastrophes”, Thom studied the mathematics of abrupt jumps from a stable steady state to another stable steady state when a control parameter is varying (Thom 1975). For a critical value of the control parameter, the complex system spontaneously jumps from one equilibrium state to another. The process of self-organization by emergence of new levels can be seen as a hierarchical catastrophe by which a system jumps into more and more hierarchical states. For critical values of control parameters, when a new configuration with new levels appears, the system will select it by stochastic mechanisms Catastrophe theory proposes classifications of the critical behavior of continuous mappings.

Haken (1983) has studied the processes of self-organization by “synergy”, that is by cooperative actions of parts of a system. Results concerning the stability of systems with a large number of degrees of freedom corresponding to different levels associated to timescales and concerning the replacing of fast varying variable by time averages have been pointed in “synergetics” theory. Old structures become unstable and break down by changing control parameters. On the microscopic level the stable modes of the old states are dominated by unstable modes. The main principle in synergetics is the “enslavement principle”. Due to small differences in initial conditions caused by natural fluctuations, one mode will become the master and enslaves all other modes. As a consequence, just a few order parameters are sufficient to describe the complex system. This seems to be the case in the presented here approach were one basic level induce the convergent behavior of the first, second and third levels.

In the last decades the term “fractal” coined by Mandelbrot (1982) was extensively used to describe the class of objects and phenomena, which display scale-invariance and self-similarity for different levels. Fractal identifies structures in which increasing magnification reveals increasing detail and the newly revealed structure looks the same as what one can observe at lower magnification. It was supposed that many structures and features in nature appear as fragmented and manifest properties of scaling and self-similarity. Notable examples are trees and dendrites, humidity pictures, clouds in a solution, amorphous and porous materials, branched polymers, diffusion-limited aggregates, percolation clusters, and glasses.

General features of the multi-level organized complex stochastic systems with memory have been revealed for “self-organizing systems” theory (Kauffman S. 1995), “stochastic automata” theory ,“cellular automata” (Wolfram 1994), in “genetic algorithms” theory (Holland 1996), in “artificial neural network” theory (Carpenter and Grossberg 1987) for adaptive resonance theory, in “artificial life” theory (Langton 1989, 1990), in “complex adaptive systems”, “second order cybernetics” (von Foerster 1981) , “autopoiesis” theories (Maturana and Varela 1992), and so on. Multi-level aspects of some of the above enumerated concepts and theories will be briefly presented in what follows.

Kauffman S., (1995) has studied how networks of mutually activating or inhibiting genes can give rise to the differentiation of organs and tissues during embryological development. This led to investigate the properties of multi-level Boolean networks of different sizes and degrees of connectedness. The genetic algorithms introduced by Holland (1996) are parallel, computational representations of the processes of variation, recombination and selection on the basis of fitness that underlay most processes of evolution and adaptation. They have been applied to general problem solving, control and optimization tasks, inductive learning and the modeling of ecological systems.

The “artificial life” approach, tries to develop technological systems such as computer programs and autonomous robots that exhibit life-like properties as for instance, reproduction, swarming, and co-evolution. Based on cellular automata studies, and investigations of self-organized criticality, Langton (1989, 1990) has proposed the general thesis that complex systems emerge and maintain on the edge of chaos, the narrow domain between frozen constancy and chaotic turbulence. The "edge of chaos" idea is a step towards a general definition of multi-level complexity.

Though it shares its subject, the general properties of complex systems across traditional disciplinary boundaries, with cybernetics and systems theory, the theory of “complex adaptive systems” is distinguished by the extensive use of computer simulations as a research tool, and an emphasis on less organized systems, such as ecologies or markets. The "second-order cybernetics” is a theory developed to describe the observed and observing systems (von Foerster 1981). The emphasis on circular, self-referential processes has been continued in Maturana and Varela work on autopoietic systems. The “autopoiesis” that is the self-production denotes the fact that complex systems produce their own components. In that sense they are autonomous or "organizationally closed". For them the environment is merely a source of perturbations that need to be compensated in order to maintain the system's organization (Maturana and Varela 1992).

The “general systems theory” and the study of complex systems in various fields of human sciences testify the wide variety of hierarchical organizations (Klir 1985, Salthe 1985, Ahl and Allen 1996). It is generally accepted that there is a hierarchy of complexity in nature with more or less highly developed levels of organization. A self-organization realizing the most effects with a restricted