Preface

This book describes the struggle to introduce a mechanism that enables next-generation information systems to maintain themselves. Our generation observed the birth and growth of information systems, and the Internet in particular. To our surprise, information systems are quite different from conventional (energy, material-intensive) artificial systems, and rather resemble biological systems (information-intensive systems). Many artificial systems are designed based on (Newtonian) physics assuming that every element obeys simple and static rules; however, the experience of the Internet suggests a different way of designing where growth cannot be controlled but self-organized with autonomous and selfish agents. This book suggests using game theory, a mechanism design in particular, for designing next-generation information systems which will be self-organized by collective acts with autonomous components. Mechanism design has been studied for designing rules or protocols of economic systems based on autonomous, distributed, and selfish agents for performance. However, this design approach should be used for large-scale information systems where all the components are becoming autonomous and selfish (or in a dual perspective, in human systems where all individuals are connected and synchronized by the information systems). A mechanism in the "mechanism design" may be also defined as a "mathematical structure that models institutions through which economic activity is guided and coordinated" (Hurwicz and Reiter 2006). We are using the mechanism in this sense, although economic activity is done by exchanging resources among computers (nodes) in the information networks.

The global expansion of the Internet provides another reason for studying self-repair networks. The Internet may be analogously considered as the neural system of man–earth symbiotic systems to enhance and to synchronize global knowledge. In this analogy, information systems with sensors and actuators may be considered comparable to immune systems. This was the motivation of the previous book on immunity-based systems, which focused on mounting sensors and proposed self-recognition models. To cover the actuator part, repair actions are considered in self-repair networks.

The central theme of this book is: what happens if systems self-repair themselves? We have already explored a similar question: what happens if systems self-recognize themselves?

As an extension from reliability theory of systems involving active components of mutual (with distributed context) and self (with subject and object double-fold context of repairing and being repaired) repair, it is on a line extended from von Neumann's "Self-Reproducing Automata" (Von Neumann and Burks 1966):

"The ability of a natural organism to survive in spite of a high incidence of error (which our artificial automata are incapable of) probably requires a very high flexibility and ability of the automaton to watch itself and reorganize itself. And this probably requires a very considerable autonomy of parts."

It should be noted that von Neumann addressed also the problem of constructing reliable automata from unreliable components (involving some intrinsic error with a probability) in his lectures on "probabilistic logics and the synthesis of reliable organisms from unreliable components" (Von Neumann 1956). We have been addressing the problem: what happens if the system has such autonomy that each part can repair other parts with a certain probability?

Theoretically, self-repair networks struggle to devise a mechanism to avoid a defection-defection deadlock and all defectors ground state (from a game theoretical point of view); and to avoid locally stable attractors and to prevent the macro state of all abnormal states (absolute zero) from being globally stable (from a dynamical system point of view). In the engineering design, we focus on a new design method (model-based and simulation-based) for next-generation information systems, or artificial intelligence minding the self. This book examines the concept of applying biological closure and identity to information systems which are becoming closer year by year to biological systems, for biological systems are the ultimate reliable systems that have evolved for species, individuals, cellular, and genetic survival. We have presented several notes on applying biological closure and trials of the asymmetric approach to the modeling of biological systems:

- N1. A Critical Phenomenon in a Self-repair Network by Mutual Copying (LNCS 3682, 2005)
- N2. A Note on Space-Time Interplay through Generosity in a Membrane Formation with Spatial Prisoner's Dilemma (LNCS 5179, 2008)
- N3. A Note on Biological Closure and Openness: A System Reliability View (LNCS 5712, 2009)
- N4. A Note on Symmetry in Logic of Self-Repair: A Case of a Self-Repair Network (LNCS 6278, 2010)
- N5. A Note on the Collective Identity of Indistinguishable Entities: A View from the Stable Marriage Problem (LNCS 6884, 2011)

- A1 A Network Self-repair by Spatial Strategies in Spatial Prisoner's Dilemma (LNCS 3682, 2005)
- A2 Asymmetric Interactions between Cooperators and Defectors for Controlling Self-repairing (LNCS 5179, 2008)

A3 Asymmetric Phenomena of Segregation and Integration in Biological Systems: A Matching Automaton (LNCS 5712, 2009)
A4 Asymmetry in Repairing and Infection: A Case of the Self-Repair Network (LNCS 6278, 2010)
A5 Asymmetric Structure between Two Sets of Adaptive Agents: An Approach Using a Matching Automaton (LNCS 6884, 2011)

This book is based on [N1, N2, and N4] for biological closure and [A1, A2, and A4] for the asymmetric approach using a probabilistic cellular automaton and (cooperative/defective) selfish agents. Among others, [N1] introduces a probabilistic cellular automaton to derive critical points of the network cleaning problem (can a network be cleaned up by mutually repairing nodes?), and [A1] introduces the spatial prisoner's dilemma approach to design a mechanism for self-repair.

We use the "self-action model" as a method to approach biological closure. Self-involvement should be avoided as it causes infinite regress, and it is hard to handle in a closed logic. However, it cannot be avoided when dealing with biological closure, for self-involvement is so intrinsic in biological systems that it provides a distinction from artificial systems. Conventional system methods view the system from outside as a collection of interacting subsystems. However, the self-action model views the system from inside as a collection of entities capable of acting on other entities and being acted upon by the other entities as well. The other entities do not exclude the case of the system itself. Also, the term "action" is related to real systems involving monitoring, diagnosing, repairing, and rearranging.

To implement the self-action model, we use agents as primitives. Thus, we implement the self-action model as a collection of agents (autonomous, distributed, and even selfish entities). We may not be able to design the self-action system like designing conventional systems beforehand and from outside, but we need to design the system as a player viewing the system from inside (i.e., from the eyes of the constituent entities: agents).

This book contains interdisciplinary research encompassing game theory (prisoner's dilemma), complex systems (probabilistic cellular automaton), reliability theory (system reliability), and particle physics (critical phenomena). The particle physics approach is taken for information networks where nodes and operations among nodes correspond to particles and interactions, respectively. For a game theoretic approach on information networks, nodes and operations, respectively, correspond to players (agents) and actions; and a mechanism design for the reliability of the entire network has been studied assuming selfish and autonomous agents. Regarding the mechanism design, which is a subfield of economics (or subfield of game theory), Myerson (Myerson 2008) defined: "Mechanism design is the fundamental mathematical methodology for analyzing economic efficiency subject to incentive constraints." Thus, the design needs to assume not only autonomous distributed agents but also selfish ones.

As a game theoretical approach to networks, while Chaps. 3 and 7–11 present a naive model based on a probabilistic cellular automaton focusing on how uniform repair affects the networks, Chaps. 4–6 introduce cooperation (repairing other agents) and defection (not repairing other agents while accepting being repaired).

Regarding the economic theory of networks, Chap. 2 is a micro theory focusing on interactions between two agents (incentive for cooperation, in particular), while other chapters examine a macro theory of emergent properties of networked agents.

References

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