Preface

When we want to achieve high effectiveness of intelligent decision support systems, the solution of problems pertaining to the identification, optimization, filtration, classification, etc., of the existing models of complex dynamic systems plays an important role. In dealing with complex objects, along with the classical methods of constructing their stochastic or deterministic models, it becomes necessary to introduce into consideration the factor of fuzziness. Fuzziness arises both from expert evaluations and from expert observations in fuzzy time intervals. With the growth of the complexity of systems, our ability to arrive at correct decisions comes to a level below which such characteristics of information as precision and certainty come into conflict with each other. It frequently happens that the exact quantitative analysis of real complex dynamic systems (weakly structurable dynamic systems in our case) fails to suit our purposes, and hence we have to turn to the fundamental analytical or heuristic fuzzy methods of solution. In that case, adequate automated systems are created by taking the systems approach to the construction of models of complex systems with statistical-fuzzy uncertainty. These automated systems form the instrumental analytical basis of constructing solution technologies for expert analytical problems.

This book presents a new approach to the investigation of weakly structurable dynamic systems (WSDS). The core of the approach is the six papers by Gia Sirbiladze published in the *International Journal of General Systems* (Modelling of Extremal Fuzzy Dynamic Systems (EFDS), Parts I–VI: 34, 2, 2005, pp. 107–138; 139–167; 169–198; 35, 4, 2006, pp. 435–459; 35, 5, 2006, pp. 529–554; 36, 1, 2007, pp. 19–58). In contrast to other approaches in which it is assumed that the source of fuzziness in dynamic systems is expert knowledge, in our approach both time and expert knowledge are considered to be factors that account for fuzzy uncertainty. Prediction or evaluation of the time of a complex event occurrence is fuzzy in itself; it is such, for example, in anomalous and monotone processes, catastrophes, extreme situations, natural disasters, and so on. The introduction of such a dualized (fuzzy time + expert knowledge) factor of uncertainty in dynamic systems not only enables experts to use their intellectual ability to the best advantage

in the process of knowledge formalization, but also essentially widens the range of problems that are amenable to investigation.

Problems arise because processes occurring in society and the environment are imperfect, fuzzy, or extreme; relations between the objects of an investigated complex system are of subjective (expert) nature because of the scarcity of objective information on the evolution of the system in its respective area. There is a great diversity of areas, such as, for example, the economy of developing countries, business, conflictology, sociology, medical diagnostics, the management of evacuation processes in disaster-stricken regions, the evaluation of disease incidence in regions with an outbreak of an epidemic disease, the study of complex systems in applied physics, and so on. One of the accomplishments of this book is the creation of scenarios describing a possible WSDS evolution by the methods constructed in the framework of expert-possibilistic theory. Moreover, we propose a few new algorithms for the intelligent-possibilistic simulation of anomalous and extreme (monotone) processes.

Our main method of investigation of dualized uncertainty is fundamental quantitative analysis and its use in the modeling of complex dynamic systems. In this connection, we actively use the rapidly developing theory of monotone measures and integrals. Using this theory, in 2005–2007, the author developed a new mathematical approach to the construction of decision-making systems. He actually used that part of the theory that deals with extremal monotone measures, which at the time was little investigated. His proposed new method of extended extremal monotone measures was based on Sugeno's upper and lower integrals, which was applied to construct new fuzzy extremal models of a weakly structurable dynamic system (which in this book is also called an extremal fuzzy dynamic system), where the expert knowledge is reflected in fuzzy time intervals. The structure of time is represented by classes of monotone extremal measurable sets. On such structures of time, uncertainty is described by means of extremal monotone measures, which makes it possible to solve problems of the fuzzy statistics of extremal fuzzy processes such as fuzzy identification, fuzzy filtration, fuzzy optimal control, and so on. The problems formulated and solved in this book illustrate the application of the new approach to the fuzzy modeling of dynamic processes from the standpoint of systems research.

Part I of the book is devoted to theoretical studies of the following topics:

1. Probability representations of a monotone measure and problems of its restoration.
2. Fuzzy weighted statistics in the fuzzy environment
3. Sugeno-type extended extremal monotone measures.
4. Extended extremal monotone measures on composition products of measurable spaces.
5. Modeling of extremal and controllable extremal fuzzy processes.
6. Identification problems for fuzzy-integral models of extremal fuzzy processes; problems of restoring the input/output operator describing the EFDS state transformation structure.

7. Problems of an optimal extremal fuzzy process control. Sufficient and necessary conditions for the existence of an optimal EFDS control in the case of a gain–loss extremal fuzzy process using Bellman's optimality principle.
8. Problems of evaluation (filtration) of EFP states; construction of a fuzzy observer for the discrete case.

Part II deals with the application of the obtained results. Its topics are:

1. A discrete possibilistic model of an EFDS.
2. Transformation of the discrete possibilistic EFDS to the finite model.
3. Construction of a genetic algorithm for the identification of a finite possibilistic EFDS model.
4. Application of the finite possibilistic EFDS model in the technology of expert knowledge stream evaluation.
5. Forecasting of financial risks for the Georgia-based Industria Kiri, Ltd. company by the discrete possibilistic EFDS finite model.

Furthermore, Part II also presents a software library that is a collection of decision-making and discrete EFDS identification and other methods developed as a result of the fundamental studies carried out in this book. The library will enable users to construct intelligent decision-support systems in various areas of human activities—economics, business, politics, medicine, engineering, and so on, i.e., in areas where decision-making is the prerogative of an expert, information is uncertain and imprecise, and the time factor plays a decisive role. In the modern world, users of "intelligent technologies" like our software library are various governmental bodies, state departments, rescue services, medical centers, business enterprises, and many others. They reduce the cost and time of experts' effort and therefore have a commercial value. Our software library is based on strict mathematical analysis, so that a system constructed by its methods will certainly possess great credibility.

Though many expert systems have appeared in recent years, the methods realized in them are mostly of a statistical nature, which restricts their applicability. Such systems cannot be used in many practical situations where time is the fuzzy factor. As mentioned above, unlike other approaches in which the expert knowledge is the source of uncertainty in dynamic systems, the novelty of the approach presented in this book is that it considers time and expert knowledge, as well as the scarcity of information, as sources of uncertainty. Our software library is able to support the construction of a combined time-dependent expert-analytical decision support system for a particular user and a particular sphere of application. An intelligent decision support system constructed by means of our library in combination with a particular user's interface and knowledge base is able to make possibilistic prediction and adopt an optimal decision.

Examples of the applications presented in this book clearly illustrate the usefulness of the library for the construction of a temporalization process of expert knowledge streams in nonprobabilistic utility theory, A. Kaufmann's theory of expertons, and forecasting of financial risks of an enterprise.

The book is intended for a wide circle of readers, including theoretical researchers who are concerned with fuzzy process modeling, identification, optimization, and filtration, and also with construction of monotone measures on algebraic structures; theoretical researchers and practical engineers in various disciplines who are interested in anomalous, extreme, and monotone processes in nature and society; commercial organizations who may show interest in our software library; postgraduate students studying fuzzy analysis, intelligent system modeling, decision-making systems, and their applications. This book will be of interest to readers who use methods of fuzzy statistics in their research and in the solution of applied problems.

Chapter 1 of Part I of the book is introductory. Here we describe the general scope of our research, formulate problems, and discuss the methods of their solution.

Part I deals with fundamental issues. In particular, Chapter 2 studies problems of two probabilistic representations of monotone measures, fuzzy statistical estimators and their restoration. Furthermore, new variants of weighted fuzzy averages are proposed. Chapter 3 contains an account of the theory of extended extremal monotone measures and structures of extremal fuzzy time intervals. In Chapter 4, the results of Chapter 3 are used in constructing compositional extended extremal monotone measures. In Chapter 5, fuzzy dynamic models of weakly structurable and/or controllable systems are constructed using the results from Chapters 3 and 4. Chapter 6 is devoted to the investigation of identification problems of the systems from Chapter 5. In Chapter 7, we discuss the problems of optimal control of weakly structurable controllable systems based on Bellman's optimality principle. In Chapter 8, we consider problems of filtration of weakly structurable systems. Part I ends by summarizing the obtained theoretical results and stating final conclusions.

Part II of the book deals with applications. In particular, Chapter 10 describes the application of finite extremal models in problems of synthesis and analysis of expert knowledge streams. Examples from nonprobabilistic utility theory and the theory of expertons are given. Chapter 11 is a discussion of the application of the models constructed in the theoretical part for the forecasting of financial risks of a concrete enterprise. Chapter 12 presents a genetic algorithm and software for modeling discrete weakly structurable dynamic systems.

The book is provided with a vast bibliography. Two glossaries are included for the convenience of the reader—a glossary of acronyms (Appendix A) and a glossary of symbols (Appendix B).

Organization of the Book

For the convenience of the reader, the book is intentionally organized so that its three parts can be read independently of one another. For instance, if the reader is interested only in applications, then he may proceed directly to Part II, and what is more, each of the three chapters of this part can also be read independently.

However, in order that the reader obtain a good understanding of the applications in Part II, it is advisable that first to read Chapter 2 of Part I; this will be enough even for readers who are not familiar with functional theory and analysis.

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