Modelling of High Complexity Systems with Applications

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High complexity systems are a serious challenge for both academic and industry people. These systems usually raise problems not to be solved through classical, traditional methods. The book is a research monograph, of an interdisciplinary scope, that brings together complexity system analysis, hybrid modelling and simulation, knowledge-based and fuzzy control engineering. It attempts to demonstrate the effectiveness and usefulness of hybrid methods and techniques, based on mathematical-heuristic modelling, herein discussed, for a correct approach to any high complexity system. The author takes PC-based numerical insights into solving natural systems problems, and man-developed systems problems, and exemplifies all his assertions. As uncertainty is the keyword in the definition of high complexity systems, considerable attention has been paid to working out the *Principle of Uncertainty,* that governs the behaviour of high complexity systems. The book sets out to provide new methods and techniques for computer modelling of high complexity systems. Development of simulation and control techniques, and of problem-solving applications, is the aim. The discussed methods/techniques are called mathematical-heuristic methods, to enter the category of hybrid methods. The *mathematical-heuristic model* for simulation and control is composed of several models, of different kinds, i.e. a continuous and/or a discrete-time model, a discrete-event model, and a heuristic knowledge-based model and/or a fuzzy knowledge-based control model. The compatibility of models is ensured by two theorems of compatibility between mathematical, heuristic or fuzzy models. The author has developed an *algorithm for simulation and control of high complexity systems* based on a mathematical-heuristic model. The algorithm underlies the designing of a new type of controller, called *the fuzzy knowledge-based controller.* Stability criteria for complex control systems, including fuzzy control and risk analysis of high complexity systems, have been set out. An important aspect has been that of numerical analysis of the computation algorithm, based on the mathematical-heuristic model. This may bring about a series of numerical analysis problems, such as the problem of numerical convergence. Numerical approach has been inspired by both mathematical-heuristic models, which exploit not only expert-acquired qualitative knowledge, but also quantitative knowledge (expressed by numbers, intervals, etc.) and numerical simulation of processes, described by mathematical-heuristic models.

The book covers numerous PC-run applications for simulation and control of high complexity man-made and natural systems, ecological systems and environment protection systems. One example is the simulation and control of industrial systems, for discrete-time manufacturing processes, as shown by the application in the book. The fuzzy control model has been produced to compute new control variables, able to reset, provided its having an exit from within the intervals, the product inventory within the sub-optimality intervals. The mathematical-heuristic model has proven efficiency in simulation and control of power systems. More specifically it proved so in the simulation and control of an electrical energy distribution system, composed of several interconnected distribution stations, which supply electrical energy to a large number of consumers. The mathematical-heuristic model could assist modification of control variables so that the state variables, i.e. active and reactive powers, the total electric power and the power factor of each distribution station, be reset within the sub-optimality intervals, provided these have an exit from within the intervals. The mathematical-heuristic model can also largely contribute, based on a simulation experiment, to the analysis of a country's economic development and management. At the same time the mathematical-heuristic model enables an analysis of macroeconomic stability. The computer-run experiment consists in the computation of the control variables able to reset some state variables, i.e. *Gross Internal Product* and *Gross National Product*, within expert desired sub-optimality intervals. A series of applications is being devoted to natural systems. One such application is the solving, via simulation, of the complex hydrological and biochemical control problems of a river delta ecosystem (e.g. control of water circulation and water refreshment in lakes, prediction of the chemical and biological state variables: nutrients, submerged plants biomass, plankton biomass, fish biomass, populations of

ichtiophagous birds and mammals, bio-diversity). Another application is solving, via simulation, of the control problems related with biological state variables of plants and soil, as for example: dynamics of living vegetal biomass and wooden biomass, in a forest ecosystem as well as in an agro-ecosystem. One last application will be solving, via simulation, of the problem of air pollution monitoring, i.e. simulation of the industrial chemical pollutants diffusion in the urban atmosphere, considering multiple emission sources, such as gases, i.e. sulphur dioxide, nitrogen dioxide, ethyl acetate, toluene, or heavy metals powders. All the applications are beneficial for both experts and managers. Comparison of simulation results with those obtained by experts, following direct measurements, has certified computer simulation results. Each chapter includes a dedicated bibliography. The book addresses a large readership: computer scientists, system analysts, modellers, simulationists, control engineers, naturalists, ecologists, environment experts and managers, teachers, students/masters of science, doctoral students and others. The book attaches a CD with the application software for modelling, simulation and control of high complexity man-made and natural systems, e.g. ecological systems (big lakes, rivers, river deltas, soil systems, forests, agro-ecosystems) and for environmental protection (diffusion of industrial chemical pollutants in urban atmosphere, air quality control).

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