Preface

Optimization problems in practice depend mostly on several model parameters, noise factors, uncontrollable parameters, etc., which are not given fixed quantities at the planning stage. Typical examples from engineering and economics/operations research are: material parameters (e.g., elasticity moduli, yield stresses, allowable stresses, moment capacities, specific gravity), external loadings, friction coefficients, moments of inertia, length of links, mass of links, location of center of gravity of links, manufacturing errors, tolerances, noise terms, demand parameters, technological coefficients in input–output functions, cost factors, interest rates, exchange rates, etc. Due to the several types of stochastic uncertainties (physical uncertainty, economic uncertainty, statistical uncertainty, model uncertainty), these parameters must be modeled by random variables having a certain probability distribution. In most cases, at least certain moments of this distribution are known.

In order to cope with these uncertainties, a basic procedure in the engineering/economic practice is to replace first the unknown parameters by some chosen nominal values, e.g., estimates, guesses, of the parameters. Then, the resulting and mostly increasing deviation of the performance (output, behavior) of the structure/system from the prescribed performance (output, behavior), i.e., the "tracking error", is compensated by (online) input corrections. However, the online correction of a system/structure is often time-consuming and causes mostly increasing expenses (correction or recourse costs). Very large recourse costs may arise in case of damages or failures of the plant. This can be omitted to a large extent by taking into account already at the planning stage the possible consequences of the tracking errors and the known prior and sample information about the random data of the problem. Hence, instead of relying on ordinary deterministic parameter optimization methods—based on some nominal parameter values—and applying then just some correction actions, stochastic optimization methods should be applied: Incorporating stochastic parameter variations into the optimization process, expensive and increasing online correction expenses can be omitted or at least reduced to a large extent.

Consequently, for the computation of robust optimal decisions/designs, i.e., optimal decisions which are insensitive with respect to random parameter variations, appropriate deterministic substitute problems must be formulated first. Based on the decision theoretical principles, these substitute problems depend on probabilities of failure/success and/or on more general expected cost/loss terms. Since probabilities and expectations are defined by multiple integrals in general, the resulting often nonlinear and also nonconvex deterministic substitute problems can be solved by approximative methods only. Two basic types of deterministic substitute problems occur mostly in practice:

- Expected primary cost minimization subject to expected recourse (correction) cost constraints

  Minimization of the expected primary costs subject to expected recourse cost constraints (reliability constraints) and remaining deterministic constraints, e.g., box constraints. In case of piecewise constant cost functions, probabilistic objective functions and/or probabilistic constraints occur;
- Expected Total Cost Minimization Problems:

  Minimization of the expected total costs (costs of construction, design, recourse costs, etc.) subject to the remaining deterministic constraints.

The main analytical properties of the substitute problems have been examined in the first two editions of the book, where also appropriate deterministic and stochastic solution procedures can be found.

After an overview on basic methods for handling optimization problems with random data, in this present third edition transformation methods for optimization problems with random parameters into appropriate deterministic substitute problems are described for basic technical and economic problems. Hence, the aim of this present third edition is to provide now analytical and numerical tools—including their mathematical foundations—for the approximate computation of robust optimal decisions/designs/control as needed in concrete engineering/economic applications: stochastic Hamiltonian method for optimal control problems with random data, the H-minimal control and the Hamiltonian two-point boundary value problem, Stochastic optimal open-loop feedback control as an efficient method for the construction of optimal feedback controls in case of random parameters, adaptive optimal stochastic trajectory planning and control for dynamic control systems under stochastic uncertainty, optimal design of regulators in case of random parameters, optimal design of structures under random external load and with random model parameters.

Finally, a new tool is presented for the evaluation of the entropy of a probability distribution and the divergence of two probability distributions with respect to the use in an optimal decision problem with random parameters. Applications to statistics are given.

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Munich, Germany Kurt Marti
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