Risk-adjusted stochastic dual dynamic solution to a disaster preparedness and relief distribution problem

Ebru Angün

We consider a multi-stage disaster management problem with risk adjustments. The first-stage determines the quantities of emergency supplies to be pre-positioned at the known suppliers and the locations of transfer centers. These first-stage decisions are made before observing the random demands of the disaster victims for these supplies and the random road capacities. We assume that both demands and road capacities have joint and continuous distributions with known distribution functions. After the occurrence of a disaster and observing the realizations of the random data, the second-stage determines the quantities of supplies to be transported from the suppliers to the disaster victims through the transfer centers located at the first-stage.

We formulate this problem as a multi-stage stochastic programming problem, with Conditional Value-at-Risk (CV@R) constraints. We solve the reformulated multi-stage problem through the so-called *Stochastic Dual Dynamic Programming* (SDDP) algorithm combined with the *Sample Average Approximation* (SAA) method. Finally, we present the numerical results of a large-scale example, which considers an earthquake scenario in Istanbul.

Uncertainty Management Using Sequential Parameter Optimization

Thomas Bartz-Beielstein

I will discuss methods which are implemented in the Sequential Parameter Optimization (SPO) framework. SPO implements a sequential approach for constructing a meta-model based on noisy data. Simple strategies such as resampling will be compared with enhanced techniques such as Optimal Computational Budget Allocation.

Optimal stock allocation in the airport maintenance supply chain

Annalisa Cesaro and Dario Pacciarelli

We study a single echelon inventory system with complete pooling characterized by expensive spares, long repairing time and a strict service constraint. Specifically we face the problem of spare part allocation for protecting operations in airports against disruptions. The latter happen randomly, therefore explicitly represent uncertainty in inventory models is a safe way for modeling realistically such system dynamics. We model uncertainty through a stochastic inventory model and specifically we formulate the spares allocation problem as a non convex integer program. The objective is the minimization of the total costs for inventory holding, lateral transshipments and emergency shipments. The special structure of the problem allows to design an efficient branch and bound procedure. Computational experiments, carried on practical data, show that this method solves at optimality many practical instances.

Variability of metamodels in simulation-optimization

Gabriella Dellino and Carlo Meloni

Metamodels are often used in simulation-optimization for the design and management of complex systems enabling the integration of discipline-dependent analysis into the overall decision process. These metamodels yield insight into the relationship between responses and decision variables, providing fast analysis tools in place of the more expensive computer simulations. The combined use of stochastic simulation experiments and metamodels introduces a source of uncertainty in the decision process that we refer to as metamodel variability. To quantify this variability, we combine validation and bootstrapping techniques. The rationale behind the method relies on the fact that, after the validation process, the relative validation errors are small indicating that the metamodels give an adequate approximation, and bootstrapping these errors allows to quantify the metamodels' variability in an acceptable way. The method has the advantage to be general and can be used with different kind of metamodels and validation techniques. The resulting methodology is illustrated through some examples using regression and Kriging metamodels.

Accounting for Statistical Uncertainty using Regression Metamodels with Bootstrapping

Russell Cheng

This talk is based on several workshops conducted by the author on 'understanding statistical uncertainty' for Defence Science and Technology Laboratories. We consider how statistical metamodels provide a flexible framework for understanding the structure and behaviour of complex stochastic systems. The talk will focus on model building and show how bootstrapping enables effective models to be fitted and validated even in cases that are considered difficult using classical statistical methods. Examples drawn from actual studies, with demonstrations of their solution, will be presented.

Optimization of computationally expensive black-box systems

Dirk Deschrijver, Ivo Couckuyt, Tom Dhaene

For many problems in science and engineering it is impractical to perform experiments on the physical world directly. Instead, complex, physics-based simulation codes are used to run experiments on computer hardware. While allowing scientists more flexibility to study phenomena under controlled conditions, such experiments require a substantial investment of computation time. This places a serious computational burden on associated optimization problems. Surrogate-based optimization becomes standard practice in analyzing such expensive black-box problems. This talk discusses some approaches that make use of surrogate models for optimization and its application to several examples.

Simulation modeling and optimization for operations management

Jan Fransoo

Simulation modeling has been used for several decades now to model and study operational processes, such as in warehousing, logistics, manufacturing, and services. Over the past decades, the orientation of these studies have become more and more applied, and consequently, the research contributions to the operations management field have decreased. Recently, new advances in the field of simulation, generally captured under the concept of simulation optimization, are finding their way through in application in operations. The current research paradigm is however not yet receptive to these new methodologies. In this talk, I will outline the opportunities for simulation optimization techniques to contribute to research in operations.

Applications of simulation and optimization methods in logistics: municipal waste collection by means of assignment problems

Kostanca Katragjini, Federico Perea, Rubén Ruiz

In this talk we will show the results obtained when working on a problem proposed by a municipality regarding their waste management. More specifically, the municipality wants a support system able to decide when and how to collect their waste containers so that the associated costs are minimized. In problem settings, there are two types of waste that are collected simultaneously, typically cardboard and general waste, as these two types of waste are the most frequent and abundant. In order to do so, a special truck with two compartments is employed. Balance in the amount of collected waste per day is also a concern of the company. We propose a mixed integer linear programming (MILP) model that decides which locations should be collected on each service day, so that no container overflows, the amount of waste collected per service day is relatively constant, and the locations visited on each service day are as close to each other as possible, over a weekly planning horizon. A computational experience over a number of instances shows the applicability of our methods. However, uncertain components inherent within waste management systems may render many deterministic optimization techniques unsuitable. The major sources of uncertainty in waste management are due to the considerable dynamic and seasonal fluctuations in the quantities, types, and composition of the collected wastes. Evolutionary simulation and optimization techniques can be adapted to incorporate data uncertainty directly into optimal solution creation.

Uncertainty problems in simulation-based energy management: dealing with stochastic computer models

Bertrand Iooss and Fanny Douard

In this talk, we will present some recent works about the uncertainty management using cpu-expensive stochastic computer codes. Sensitivity analysis and kriging metamodeling tools from deterministic computer codes have been extended to stochastic code cases. Connections will be done with optimization problems and design issues will be discussed. Moreover, a few industrial examples will illustrate our purpose.

A first example deals with oil production forecasts based on numerical simulation models. In this case, the stochastic characterization of the geological layer induces the randomness of the computer code. A second example concerns the optimization of the whole life cost of EDF nuclear fleet using exceptional maintenance tasks strategies. Such tasks may be preventive or corrective toward a wearing mechanism that may lead to a failure with a low probability and high potential consequences. To help the decision maker to choose the best strategy, EDF has developed a dedicated tool based on Monte-Carlo simulation to compute many technical economic indicators among which the density function of the Net Present Value (NPV) is the most relevant.

Partition based global optimization methods

Gianpaolo Liuzzi, Stefano Lucidi, Veronica Piccialli

This talk considers partition-based deterministic algorithms for global optimization of Lipschitz-continuous functions without requiring knowledge of the Lipschitz constant. After describing a general partition-based algorithm scheme, we focus on DIRECT (DIviding RECTangles), a successful and efficient algorithm belonging to this class. It is well known however, that this algorithm may have some problems when the dimension of the considered problem increases and it has difficulties to exploit information on the problem. Starting from the DIRECT algorithm we introduce some modifications that made possible to tackle difficult real world problems. In particular, we focus on three problems with different difficulties:

(i) the minimization of Morse potential of molecular clusters,

(ii) the box-constrained global optimization problem arising in the detection of gravitational waves emitted by coalescing binary systems of compact objects,

(iii) an optimal design problem arising from multidisciplinary design optimization : three coupled disciplines (structure, aerodynamics, and propulsion) are used to represent a simplified aircraft model, with 10 variables.

The first class problems are difficult due to the large dimension, while the second problem has an objective function involving a small number of variables, but highly nonlinear and expensive to evaluate, and presents a huge number of local extrema and unavailable derivatives. As for the third one, it is a pure black-box function and highly constrained.

For all these test problems, we were able to get competitive results by using our algorithms.

On the use of several environmental conditions in an evolutionary simulation optimization search

Henri Pierreval, Ahlem Baccouche

The use of metaheuristic in simulation optimization has been widely reported in the literature. On the one hand, one major benefit of these optimization approaches is that they are generally less sensitive to local optima than other types of approaches. Unfortunately, on the other hand, metaheuristics are known to be computationally expensive methods. This is an important shortcoming since running the simulation model can also be time consuming (especially if long runs or replications are needed). When the analyst is also concerned with the robustness of the simulation optimization results, then several environments may also be contemplated to evaluate a given solution (e.g., using Taguchian principles). Unfortunately, evaluating using simulation every solution under several environmental conditions can be extremely long and therefore not suited for many concrete applications. To cope with such a difficulty, we will propose the use of multimodal evolutionary simulation optimization. We will explain how the results can be studied using several environments, so as to build a table of results from which we can derive non dominating solutions. We also show how these results can be exploited to get a better insight than a single robustness measure.

Stochastic Nonlinear Programming by Monte-Carlo estimators

Leonidas Sakalauskas

Optimal decisions in business and finance are provided often by solving a nonlinear stochastic programming problems with linear constraints:

$$F(x) \equiv Ef(x,\xi) \to \max_{x \in X}, \qquad (1)$$

where the objective function is an expectation of certain random function $f:\Re^n \times \Omega \to \Re$ and where the feasible set $x \in X \subset \Re^n$ is a bounded and convex linear set in general: $X = \{x | Ax = b,\, x \geq 0\}$, $b \in R^m$, A is the $n \times m$-matrix, $X \neq \varnothing$.

The methods of stochastic approximation are proposed first to solve stochastic programming problems, ensuring the convergence by varying certain step-length multipliers in a scheme of stochastic gradient search (see, (Robins-Monro, 1951, Kiefer-Wolfowitz, 1952, Ermoliev, 1976, Michalevitch et al, 1987, Kushner, 1997, etc.). However, the rate of convergence of stochastic approximation slow down up for constrained problems (Vazan, 1969, Ermoliev, 1976, Uriasyev 1990), besides, the gradient type projection method, usually applied here, can no converge when constraints are linear due to "zigzagging" or "jamming" (Bertsekas, 1982, Polyak, 1987).

The Monte-Carlo method is a flexible tool applied in solving problems of stochastic optimization appearing here, particularly, in that of stochastic linear programming (Prekopa (2005), Ermoliev et al, 2003). Application of this method to stochastic optimization rely on replacing of the objective function, being an mathematical expectation, by averaged means, provided during Monte-Carlo simulation (see, e.g. Shapiro (1989), L.Sakalauskas (2002), EJOR). Note, sampled Monte-Carlo estimators usually have the Gaussian distribution in asymptotics (see V.Bentkus and F.Gotze (1999)) that offers a way of applying the standard theory of normal statistics to a simple computation of confidence intervals of estimators and testing of optimality hypotheses, etc.

The properties mentioned have been used in the development of the approach for unconstrained and constrained stochastic optimization by Monte-Carlo estimators (Sakalauskas, 2004, 2006), where the optimality is tested in a statistical manner and the rule for Monte-Carlo sample size adjustment has been introduced in order to decrease the total amount of Monte-Carlo trials and, at the same time, to guarantee the solution of an optimization task with an admissible accuracy. We extend this approach to stochastic problems with linear constraints using the method ε-flexible estimators. Financial applications with counterexamples are considered, too.

Kriging and bootstrapping: two examples

Wim van Beers

Kriging (or Gaussian process) metamodels approximate the input/output (I/O) functions implied by the underlying simulation models. These metamodels may serve both sensitivity analysis and optimization, because Kriging models can adequately approximate complicated I/O functions over large (global) experimental areas. Simulation optimization requires an adequate metamodel. In expensive random simulation, distribution-free bootstrapping may improve these metamodels. Assuming that each simulated input combination is replicated several times through non-overlapping pseudo-random number streams, the bootstrap simply resamples—with replacement—these replicated simulation outputs. This enables the estimation of the variances of predictions for inputs not yet simulated. Whereas simulation may take much computer time, bootstrapping takes virtually no computer time. In this talk we discuss two applications of bootstrapping in expensive simulation: 1) a sequential design that accounts for the specific I/O behavior and 2) monotonicity-preserving Kriging metamodels. Empirical results show that bootstrapping in expensive simulation improves the Kriging metamodels.

Expected improvement in efficient global optimization through bootstrapped kriging

Inneke van Nieuwenhuyse

In this talk, we adapt the classic expected improvement (EI) in efficient global optimization (EGO) through the introduction of an improved estimator of the Kriging predictor variance, based on parametric bootstrapping. Classic EI and bootstrapped EI are compared through various test functions, including the six-hump camel-back and several Hartmann functions. The empirical results demonstrate that in some applications bootstrapped EI finds the global optimum faster than classic EI does; in general, however, the classic EI may be considered to be a robust global optimizer.