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Abstracts

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Contents

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Hybrid simulation with qualitative and quantitative integrated model under uncertain business environment

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Keywords: hybrid simulation, qualitative modeling, quantitative modeling, scenario evaluation

In a rapidly-changing business environment, a flexible decision-making for the environmental changes is required in companies. To realize such decision-making, "Scenario Planning" is proposed, which is a framework of support for decision-makings based on clarifying cause-effect factors in a target business, mostly achieved by using a causal structural graph model. In the causal structural graph model, a scenario designer sets a state to controllable nodes(operational nodes) and evaluates a state of attended nodes.

In case that the model is quantitative, factors of causes in the model are numerical and causal relations between factors can be described in some equations. "System Dynamics"has been used for this situation, however, it is sometimes difficult to grasp causal relations quantitatively.

On the other hand, "Qualitative Simulation" has been used for simulation of the model including some qualitative factors that can't be described in numerical data or equations. Qualitative simulation has been applied to business scenario evaluation, in which all quantitative factors and causal relations are converted to qualitative ones. However, the value of originally quantitative factors can't be decided because the qualitative causal relations are intrinsically ambiguous.

A simulation method for the hybrid model including qualitative information and quantitative information is strongly demanded to handle such a real situation. In order to simulate the hybrid model, it is necessary to decide values of factors having a qualitative causal relation that is too ambiguous to decide values of factors. Therefore, we propose a simulation method using Monte Carlo Simulation on the hybrid model. In the proposed method, qualitative values are set to probability variables and values of nodes are decided statistically by propagation of effects using random numbers. The value of a destination node is decided by input values of operational nodes. Finally, values of attended nodes are output by deciding the values of the nodes repeatedly. The value of a destination node is decided by a causal relation given in each arc. Values of quantitative nodes connecting to a quantitative arc can be decided by an equation of a quantitative arc. On the other hand, values of quantitative nodes and qualitative nodes connecting to qualitative arcs can't be decided simply by interpreting cause-effect relations. Through applied results to practical models, it was confirmed that the characteristics of scenarios can be investigated.

Uncertainty in the future nitrogen load to the Baltic Sea due to unknown meteorological conditions

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Keywords: nitrogen deposition, Baltic Sea, HELCOM

Monitoring of nitrogen load to the Baltic Sea is an important tasks of the HELCOM Commission. Rivers, direct discharges and atmospheric deposition are the major sources of nitrogen in the Baltic Sea and atmospheric part accounts for approximately 20-30% of the load varyig from one year to another. The Norwegian Meteorological Institute has a long term project with HELCOM for regular calculation of annual atmospheric deposition of nitrogen to the Baltic Sea.

In 2005, the institute got an additional a project from HELCOM with the aim of estimating atmospheric nitrogen deposition to six sub-basins and catchments of the Baltic Sea in the year 2010, using nitrogen emission projections according to agreed emission ceilings under the EU NEC Directive and the Gothenburg Protocol. In addition, the CLE scenario developed at IIASA within the CAFE Program was also taken into account in the computations.

The results of the project have been used to assess the impact of different agricultural policy scenarios in HELCOM Contracting Parties on nutrient inputs in the Baltic Sea catchment area and on the eutrophication status of the Baltic Sea. The final aim is to enable the identification of cost-effective measures in the different parts of the Baltic Sea catchment area required to achieve good ecological status throughout the Baltic Sea area.

Nitrogen emission inventories resulting from the secenarios described above have been used in the EMEP model runs to estimate resulting depositions in 2010. Since, the meteorology for the year 2010 is not known, model calculations were performed for four selected years with different meteorology: 1996, 1997, 1998 and 2000, which are available in the EMEP database. Final deposition values for the year 2010 were calculated as average over selected four years. In this way we were able to estimate the uncertainty related to meteorological variability.

The ranges between minimum and maximum of calculated depositions to sub-basins and catchments are large indicating significant variation of the deposition depending on meteorological conditions. The standard deviation computed depositions due to varying meteorological conditions is relatively large, up to 20-30% of computed depositions. The maxima of standard deviation are located close to the maxima of computed depositions. Computed standard deviation in relation to computed deposition is largest for wet deposition ($\sim$30%) and lowest for dry deposition ($\sim$10%). It is larger for oxidized nitrogen deposition ($\sim$25%) than for reduced nitrogen deposition ($\sim$20%). Standard deviation for the total deposition is in the middle of the range.

The relative range of the depositions due to variable meteorology is rather large, both for sub-basins and catchments of the Baltic Sea. For the deposition of oxidized and reduced nitrogen to sub-basins and the entire basin of the Baltic Sea there is more variability in wet than in dry deposition. Relative range of nitrogen deposition to the catchments is in general lower that the relative range of nitrogen deposition to sub-basins of the Baltic Sea. The largest uncertainty due to meteorological variability, can be noticed for GUB (Gulf of Bothnia) sub-basin and catchment with relatively low nitrogen deposition.

Optimal ellipsoidal estimates of uncertain systems: an overview and new results

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Keywords: uncertain systems, bounded perturbations, set-membership estimation, ellipsoidal estimates, control of dynamical systems

Dynamical systems subjected to unknown but bounded perturbations appear in numerous applications. The set-membership approach which is a natural counterpart to the well-known stochastic, or probabilistic, one makes it possible to obtain guaranteed estimates on reachable sets and thus to evaluate the family of all possible trajectories of the perturbed system.

In the framework of the set-membership approach, the ellipsoidal estimation seems to be the most efficient technique. Among its advantages are the explicit form of approximations, invariance with respect to linear transformations, possibility of optimization, etc. The earlier results on the ellipsoidal estimation were summarized in [1, 2]. The concept of optimality for two-sided (inner and outer) approximating ellipsoids was first introduced in [3] and generalized, extended, and summarized in books [4, 5].

In this paper, basic concepts and results of the method of optimal ellipsoids are outlined, and certain recent results are presented.

Dynamical systems subjected to bounded controls and/or perturbations are considered. For these systems, nonlinear differential equations are obtained that describe the evolution of the optimal ellipsoids representing two-sided (inner and outer) estimates for reachable sets. The approximating ellipsoids depend on the choice of the optimality criterion (e.g., volume of ellipsoids, sum of their squared axes, etc.), and on the notion of local/global optimality.

Various useful properties of the optimal approximating ellipsoids have been established. Asymptotic behavior of the ellipsoids near the initial point and at infinity have been studied. As a rule, the nonlinear equations for these ellipsoids are to be integrated numerically. However, certain explicit analytical solutions have been obtained [6].

Outer and inner ellipsoidal approximations can be used for various applications in control and estimation, including two-sided approximations for optimal control and differential games, analysis of practical stability and parameter excitation, state estimation in the presence of observation errors, control in the presence of uncertain perturbations, etc.

Examples are presented.

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Computer implementation of a volume algorithm

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Keywords: volume algorithm, Monte Carlo integration

An $O*(n^4)$ volume algorithm has been presented for convex bodies by Lovasz and Vempala. Essentially the algorithm is a series of Monte Carlo integrations. In this lecture we describe a computer implementation of the volume algorithm, and present some computational results in dimension $n = 2-9$.

Robust decision making under uncertainty

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Keywords: decision analysis, uncertainty, visualization

We consider a standard multicriteria decision making problem with a finite number of decisions and a finite number of criteria. For simplicity, we assume that all criteria are utilities, i.e., they are all to be maximized. For this scenario, many tools have been developed. They range from outranking methods to multicriteria value functions, reference point methods, and others. Most of them, at least in their basic forms, are deterministic. This is, of course, not realistic, and it impedes their use specifically in scenarios of a strategic nature, which is what the models are designed for. Our contribution allows the payoffs to be random variables, and it develops tools that make the benefits and costs clearly visible to the decision maker in two- dimensional graphs, regardless of the size of the problem.

Suppose that the outcome of decision i evaluated on criterion j is a random variable. For each criterion, the decision maker has specified an aspiration level (or an ideal point) as well as a lower cutoff point below which the decision is considered to perform less than satisfactorily. The ideal point can be any point that is deemed acceptable by the decision maker. Typically, it is the maximal achievement regarding the criterion under consideration. The probability distribution of the outcome is arbitrary, and it is expected to be modified in a sequence of sensitivity analyses.

For each decision, it is then possible to compute the expected outcome as well as the probability that a decision falls short of the prespecified lower cutoff point. Straightforward rules are developed to identify dominated strategies. We then employ the usual agglomeration of criteria to a single overall value. In particular, we use the weighted sum approach. Each combinations of weights results in a point in an outcome - risk graph for each decision. Plotting such points for all decisions in the graph allows us to identify the nondominated set. The proportion of a decision being included in the nondominated set given a number of reasonable scenarios will then allow the decision maker to define a ranking of decisions that may be a useful aid in the decision-making process.

A new algorithm of fuzzy clustering for data with uncertainties

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Keywords: clustering, uncertainty, tolerance, hyper-rectangles, optimization

Data clustering or more simply, clustering is known to be the method of unsupervised classification and fuzzy c-means (FCM) is one of the typical technique of fuzzy clustering.

In general, information on a real space is transformed to data in a pattern space to be analyzed by clustering. Therefore, there are some problems that should be considered when transforming, for example, measurement error margin, data that cannot be regarded as one point, and missing values in data. In the past, these uncertainties of data have been represented as interval range and many clustering algorithms for these interval ranges of data have been constructed and one of the authors have also proposed one of such algorithms. In these algorithms, nearest neighbor distance, furthest neighbor distance and Hausdorff distance have been used to calculate the dissimilarity between the target data in clustering. However, the guideline to select the available distance in each case has not been shown so that this problem is difficult. When we consider such a situation, it is more desirable to calculate the dissimilarity between such interval ranges of data without introducing a particular distance, e.g., nearest neighbor one and so on.

One of the authors introduced the new concept of tolerance which includes the above-mentioned uncertainties of data and is different from the interval from the viewpoint of introduction of tolerance vectors, and proposed two clustering algorithms, one is based on Euclidean norm and the other is L_1-norm. The tolerance is defined as hyper-sphere in these algorithms.

In this paper, we consider new optimization problems in which the tolerance is defined as hyper-rectangles. Here, let n and c be the number of data and clusters and let $x_k \in \boldsymbol{R}^p$, $\varepsilon_k \in \boldsymbol{R}^p$ $(k = 1, \ldots, n)$, $v_i \in \boldsymbol{R}^p$ $(i = 1, \ldots, c)$ and $\mu_{ki} \in [0, 1]$ be data, tolerance vector, clucster center and membership grade of x_k to to the i-th cluster, respectively.

The problems on L_1-norm are as follows:

$$J_{\text{sFCM-}L_1} = \sum_{i=1}^{c} \sum_{k=1}^{n} \mu_{ki}^m |x_k + \varepsilon_k - v_i|_1,$$

and

$$J_{\text{eFCM-}L_1} = \sum_{i=1}^{c} \sum_{k=1}^{n} \mu_{ki} |x_k + \varepsilon_k - v_i|_1 + \lambda^{-1} \mu_{ki} \log \mu_{ki}$$

under the constraints

$$\sum_{i=1}^{c} \mu_{ki} = 1, \quad (\mu_{ki} \geq 0)$$

$$|\varepsilon_{kj}| \leq \kappa_{kj}, \quad (\kappa_{kj} > 0)$$

where, $|\bullet|_1$ means L_1-norm.

The problems on Euclidean (L_2-) norm are as follows:

$$J_{\text{sFCM-}L_2} = \sum_{i=1}^{c}\sum_{k=1}^{n} \mu_{ki}^m \|x_k + \varepsilon_k - v_i\|_2^2,$$

and

$$J_{\text{eFCM-}L_2} = \sum_{i=1}^{c}\sum_{k=1}^{n} \mu_{ki} \|x_k + \varepsilon_k - v_i\|_2^2 + \lambda^{-1}\mu_{ki}\log\mu_{ki}$$

under the same constraints as the problems on L_1-norm. $\|\bullet\|_2$ means L_2-norm.

Moreover, we construct new clustering algorithms based on sFCM (Standard Fuzzy c-means) and eFCM (Entropy regularized Fuzzy c-means) on L_1-norm and L_2-norm for data with tolerance through solving the optimization problems. The proposed algorithms for hyper-rectangle are expected to be more available to classify the uncertain data than the conventional ones for hyper-sphere from the viewpoint that we can deal with each attribute of data independently.

Stochastic optimization methods for catastrophic risks management under endogenous discounting

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Keywords: stochastic optimization, risk management, catastrophes, discounting

Traditional discounting dramatically underestimates outcomes of catastrophic risks. The misperception of discount rates produces inadequate evaluations of the risk management strategies, what may provoke further catastrophes and significantly contribute to increasing vulnerability of our society.

We show that arbitrary discount factors can be linked to irreversible stopping time catastrophic (*killing*) events, which define the discount-related random horizon (*the end of the world*) of evaluations. On the other hand, any stopping time event induces discounting. In particular, we show that a typical set of such events induces declining discount rates that are asymptotically dominated by least probable events. These induced discount rates are conditional on the degree of social commitment to mitigate risk. In general, catastrophic events affect discount rates, which alter the optimal mitigation efforts that, in turn, change events. The endogeneity of discounting calls for using equivalent undiscounted random stopping time criteria and stochastic optimisation methods. Combined with explicit spatio-temporal catastrophes modelling, these criteria induce the discounting which allows to properly match random horizons of potential catastrophic scenarios. In contrast to standard discounting, the resulting induced discounting can also be viewed as spatio-temporal discounting. We illustrate application of the endogenous discounting methodology for a case study of catastrophic flood risks.

Robust decisions under endogenous uncertainty and risks

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Keywords: risk management, inherent uncertainty

This talk is based on collaborative work with IIASA projects and results of various case studies in Italy, Russia, Hungary, Ukraine, Poland, China. A good sample of relevant publications can be found in K. Marti, Y. Ermoliev, M. Makowski, G. Pflug (Eds.) Coping with Uncertainty, Springer Verlag, Berlin, New York, 2006.

Traditional statistical decision theory deals with situations in which the model of uncertainty, the optimal solution (*true parameters*) and its performance are defined by the sampling model. The robustness in this case is characterized by a continuity of estimates w.r.t. low probability *outlyers*. In general problems of decision making, feasible solutions, concepts of optimality and robustness have to be characterized from the context of decision making situations (e.g., socio-economic, technological, environmental, risk perspectives).

Unlike statistical robustness, general decision problems may have rather different facets of robustness. In particular, a key issue is, in a sense, discontinuity with respect to low-probability catastrophic events. That is, robust decisions in the presence of catastrophic events are fundamentally different from decisions ignoring them. Specifically, proper treatment of catastrophic events requires new sets of feasible decisions, adjusted to risk performance indicators, and new spatial, social and temporal dimensions, in particular, explicit representation of various agents.

The inertia of the global process and the possibility of abrupt catastrophic changes restrict purely adaptive *wait-and-see* approaches. Moreover, rare extreme events of high consequences, which have to play a decisive role in the evaluations of global changes, are considered on average as improbable events during a human lifetime and, hence, they are simply ignored.

A 500-year disaster (say, an extreme flood that occurs on average once in 500 years) may, in fact, occur next year. However, it is impossible to research all the details connected with such an occurrence in order to achieve evaluations required by the traditional models in economics, insurance, risk-management, and extreme value theory. For example, standard insurance theory essentially relies on the assumption of independent, frequent, low-consequence (conventional) risks, such as car accidents, for which decisions on premiums, claims estimates and the likelihood of insolvency can be calculated via rich historical data. Existing extremal value theory also deals primarily with independent variables quantifiable by a single number (e.g., money). Catastrophes are definitely not quantifiable events in this sense.

Under inherent uncertainty and heterogeneity of global processes the role of models rests on the ability to guide comparative analysis of the feasible decisions. Although exact evaluations are impossible, the preference structure among decisions can be a stable basis for a relative ranking of alternatives in order to design robust optimal strategies.

The notion of robustness critically depends on the nature of decision problems. This talk is primarily focused on some issues relevant to on-going modelling activities at IIASA. In particular, we discuss stochastic optimization methods enabling to deal with singularities of robust decisions. We illustrate them by fragments of various case studies.

Spatial planning of agricultural production under environmental risk and uncertainty

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Keywords: risk, uncertainty, spatial planning, agriculture planning

Growing needs for agricultural products boost the development of industrial input-intensive agriculture, which in many countries of the world is running into environmental limits impacting water, land, air, or causing livestock related disease outbreaks. Such negative impacts indicate that preserving natural resource quality requires sustainable approaches to intensification as well as diversification of production systems.

Approaches to planning agricultural production traditionally have been classified along two separate lines. One approach deals with estimation of physical production potential of land, usually without too much concern of socio-economic driving forces and constraints. A second approach concentrates on aggregate socio-economic and behavioral aspects of producers and consumers. Resources like land or water are only very generally described. However, within the limits of natural resources, effective land performance is largely determined by anthropogenic factors, i.e. the availability of infrastructure, market access and the interaction of behavioral, socio-economic, cultural and technological factors.

In this paper we propose a framework that integrates these two lines. The proposed approach incorporates environmental indicators such as, for example, abundance of excess nutrients form chemical fertilizers and livestock manure, density of confined livestock, availability of land for excess nutrient uptake, health risk proxies. We show that explicit representation of uncertainties and risk indicators is an essential component of sustainable agricultural production planning in order to ensure robust welfare generating solution.

Specifically, we focus on a case study of spatial crop and livestock production planning in China under environmental and health risks.

Stochastic optimization and modelling of uncertainty in the multiagent environment: the case of telecommunication services

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Keywords: multiagent environment, telecommunications, stochastic programming, data services

We consider the optimization problems under uncertainty when a substantial part of uncertainty has endogenous nature and results from actions of independent decision makers which constitute the modeled environment. Often such actors are united by complex relations of competition and collaboration which result from participation in the common value network. Examples of such value networks are common in supply chain management and in the telecommunication service provision among other fields. Game theory provides a natural modeling framework for such problems. However, the game theoretical models rely heavily on equilibrium concepts and such equilibrium is very often lacking in reality.

Stochastic programming provides a natural alternative in such cases. We provide examples of stochastic programming models of such risk/performance networks and provide numerical techniques for solution of resulting optimization problems.

Modeling robust technological developments under increasing returns and uncertainties

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Keywords: increasing returns, technology, uncertainty

The proper modeling of technological changes (TC) is decisive for the evaluation of the true socio-economic and environmental impacts of innovations and development policies. Traditional neo-classical models assume that technological innovations are key factors of long-term productivity, continuous economic growth and the prosperity of nations. However, on-going global changes, in particular, the pollution with potential catastrophic global climate changes, the increasing gap between the rich and poor, uncontrolled growth of settlements and their vulnerability, inspire great concerns about sustainable developments, equity and the welfare. Searching only for economic efficiency and growth may produce adverse impacts of innovations which are often impossible to properly represent in traditional models. This can lead to wrong conclusions about the necessity to deal with emerging alarming global change tendencies. Although technology is considered as the central issue of global changes, modeling of technological changes is typically the least satisfactory aspect of global change modeling. In many models technological change is represented by exogenous variables which improve efficiency and costs of technologies through time independently of policies and other economic variables. As a consequence, such models strongly advocate to postpone investments in new technologies until they became cheap enough, i.e., adaptive *wait-and-see* In reality technological changes are endogenous. They are induced by various pressures and needs, i.e., they can be affected by deliberate policies related to urgent socio-economic, environmental and safety issues.

Models with exogenous TC ignore the necessity to invest in new technology in order to make this technology cheaper. In contrast, models with endogenous TC emphasize this necessity. IIASA studies demonstrate that endogenous TC with proper treatment of uncertainties, risks and increasing returns of new technologies, call for earlier (immediate) investments in new technologies. In other words, in contrast to the *wait-and-see* policy, these results indicate that earlier investments have dramatic effects on the total cost of global climate stabilization policy. Specifically, the stabilization of global emissions can be achieved at zero or even negative costs.

The aim of this paper is to discuss new methodological challenges involved in modeling of endogenous TC with increasing returns and uncertainties. In particular, we emphasize the need for new modeling approaches because the increasing return phenomenon restricts the applicability of standard models, e.g., general equilibrium models.

On joint modelling random uncertainty and fuzzy imprecision

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Keywords: probability, Dempster-Shafer possibility, fuzzy random variables

Probability has been used for many years as the only mathematical model of uncertainty. However, close examination of different types of uncertainty has revealed that in certain instances probability models are insufficient. Thus, some extensions of the classical probability theory, namely the Dempster-Shafer theory or Peter Walley's theory of lower (upper) previsions, have been proposed. Independently, Zadeh's theory of fuzzy sets has been extensively used for modeling of linguistic imprecision.

Starting from late 1970s many papers have been published on mutual relationship between probability and fuzzy sets. For example, it was shown that possibility distributions that are described by fuzzy sets are special cases in the Dempster-Shafer theory. Later on, several models of fuzzy probability have been proposed. The two most frequently used models, one proposed by Kwakernaak and second proposed by Puri and Ralescu are under certain conditions equivalent, are frequently used for statistical modeling of imprecise random data.

In the paper we present a brief description of different models of uncertainty. We stress the differences between these models from a point of view of a practitioner. Then we show an example how the fuzzy-probabilistic models may be used for the analysis of both imprecise and precise statistical data. In the first example we present the problem of statistical testing of a hypothesis about the equivalence of two exponential distributions in presence of imprecise data. In the second example we show how a fuzzy-probabilistic model may be used for modeling precise statistical data coming from different sources.

Uncertainty in greenhouse gas inventories: how to go about it

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Keywords: Kyoto Protocol, greenhouse gas emissions, uncertainty, robust decision making

The assessment of greenhouse gases (GHGs) emitted to and removed from the atmosphere is high on both political and scientific agendas internationally. As increasing international concern and cooperation aim at policy-oriented solutions to the climate change problem, several issues have begun to arise regarding verification and compliance under both proposed and legislated schemes meant to reduce the human-induced global climate impact. The issues of concern are rooted in the level of confidence with which national emission assessments can be performed, as well as the management of uncertainty and its role in developing informed policy.

The approaches to addressing uncertainty that was discussed at the 2nd International Workshop on Uncertainty in Greenhouse Gas Inventories[1] attempt to improve national inventories or to provide a basis for the standardization of inventory estimates to enable comparison of emissions and emission changes across countries. Some authors use detailed uncertainty analyses to enforce the current structure of the emissions trading system while others attempt to internalize high levels of uncertainty by tailoring the emissions trading market rules. In all approaches, uncertainty analysis is regarded as a key component of national GHG inventory analyses.

This presentation will provide an overview of the topics that are discussed among scientists at the aforementioned workshop to support robust decision making. These range from achieving and reporting GHG emission inventories at global, national and sub-national scales; to accounting for uncertainty of emissions and emission changes across these scales; to bottom-up versus top-down emission analyses; to detecting and analyzing emission changes vis-a-vis their underlying uncertainties; to reconciling short-term emission commitments and long-term concentration targets; to dealing with verification, compliance and emissions trading; to communicating, negotiating and effectively using uncertainty.

[1] September 27-28, 2007, at IIASA, `http://www.ibspan.waw.pl/ghg2007/`.

Uncertainty analysis of weather controlled systems

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Keywords: modeling, error propagation, optimal control, storage

Indoor climates, as in buildings, greenhouses and storage facilities and controlled by outdoor weather conditions, are typical examples of weather controlled systems. For indoor climate predictions in, for instance, optimal control strategies weather forecasts are needed. As weather forecasts are uncertain, predicted model states and related costs become uncertain.

Usually, the medium-range weather forecast consists of an ensemble of forecasts. Hence, the uncertainty of the weather forecast is known a priori.

In this contribution, we focus on a specific application, i.e. a nonlinear model of a storage facility with forced ventilation with the ambient.

At first, we evaluate the effect of the weather uncertainty, in particular temperature, on the calculated and realized costs. Since we had both temperature predictions and realizations of the weather available a comparison between calculated (predicted) and realized costs is straightforward. Furthermore, in addition to the open loop evaluation a closed-loop evaluation has been considered as well.

In addition to this, model reduction, linearization and discretization techniques, well-known in systems theory to simplify nonlinear models, are used. Based on a linearized version of the storage model standard error propagation rules are used to predict the system uncertainty analytically. It is well-known that optimal control calculates control inputs such that a prespecified cost criterion is minimized. In our approach the model prediction uncertainty is integrated into the cost criterion to allow a trade off between an optimal nominal solution and a minimum variance control solution.

The objective of our contribution is now to evaluate weather uncertainties on the costs of a dynamical system under open/closed loop conditions. This evaluation is in particular further worked out for a specific application i.e. storage of agricultural produce.

In the simulation case-study with real weather forecasts and observed weather it appeared that there are only slight cost increases due to uncertainty in weather forecasts if the optimal control problem is calculated every 6 hours in a Receding Horizon Optimal Control (RHOC) context. Furthermore, even the a priori known worst-case scenario from the weather forecast ensemble leads to a satisfactory result with a 6 hour RHOC interval. Hence, the interval between two subsequent optimal control runs can be increased given a user defined uncertainty limit. In our specific application, an increase of the interval to 24 hours leads to a maximum increase of less then 5

Furthermore, when the operating point of a process is kept within bounds the model can be linearized on this interval by using an optimality criterium instead of using standard linearization techniques around a point. If the controls are known or have been calculated in advance, the storage model becomes linear and the error propagation calculation can be done analytically. Finally, the model prediction uncertainty is incorporated in an optimal control framework such that the predicted 95confidence limits are kept as close as possible to the reference trajectory. If implemented as state constraints the confidence limits can also be used for risk avoidance.

An approach to the SN ratios based on the proportional models and its applications

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Keywords: error factor, inverse Gaussian distribution, Taguchi method, variance stabilizing transformation

In the Taguchi method, SN ratios are used to quantitatively evaluate the quality of products and the performance of processes. However, since SN ratios are dependent on the unit systems of inputs and outputs, we cannot use them as a universal measure of good performance. In this paper, we propose the population SN ratio that is independent of the unit systems for the zero point proportional (multiplicative) model, where signal factors and characteristic values are positive real numbers, and we discuss the properties of the estimators. Furthermore, under the assumption that the errors follow inverse Gaussian distributions, we derive the distribution of the sample SN ratio and we test the statistical hypothesis of the population SN ratio. We also discuss data analysis based on real data. Next, we discuss how the performance of signal-response systems can be compared by testing SN ratios for homogeneity based on experimental data. We describe a test based on a certain hypothesis using the SN ratio proposed as a dimensionless performance measure for positive-valued data, and then construct an approximation test. First, we consider the case where the error distribution has inverse Gaussian distributions. We then propose SN ratios for the error factor in the Taguchi method and show how it is possible to test the homogeneity of SN ratios in each case.

Coupled modeling, in-field, and Earth observations data analysis for emergency response optimization

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Keywords: technological accidents, data analysis, Earth observations, socio-ecological threats

The study presented is dedicated to assessment of the consequences of technological accidents using varied approaches to data analysis. The case study is derailment of transport with crude phosphorus in Western Ukraine on July 16, 2007. The character, available measured parameters, and general description of the accident are presented.

The data measured by authorized national agencies have been processed. On this base the pollution scenarios were calculated and analyzed. Used methodology of data measurements and processing are discussed and evaluated from the viewpoint of its relevance to assessment of long term socio-ecological threats. The existing data and methods uncertainty as well as the methodological gaps have been defined.

As it was shown the additional data is required for more adequate analysis. Using Earth observation data as the information with higher spatial Integration the alternative pollution scenarios have been calculated. Also the partial models of the pollutants atmospheric transfer were developed and utilized for EO data analysis.

On the base of scenarios obtained the socio-ecological unidentified Threats and deferred risks have been specified taking into account local natural and anthropogenic features.

Thus the role of EO in the technological accidents consequences analysis was determined as well as the ways of optimal satellite observations data utilization. Calculated set of pollution scenarios allows to elaborate recommendations to fulfill the methodological gaps in existing national emergency response services. The necessity of optimization of relevant decision making system is highlighted.

On the approximation of a multivariate probability distribution using certain clustering approach

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Keywords: approximation of multivariate probability distributions, cherry tree, graph clustering, Kullback–Leibler divergence, Chow–Liu tree

Most everyday reasoning and decision making is based on uncertain premises. The premises or attributes, which we must take into consideration, are random variables, so that we often have to deal with a high dimensional multivariate random vector.

We are going to construct an approximation of a high dimensional multivariate probability distribution that is based on the dependence structure between the random variables and on a certain clustering of the graph describing this structure. Our method uses just one, two and three dimensional probability distributions.

We give a formula that expresses how well the constructed approximation fits to the real probability distribution. We then prove that every time there exists a probability distribution, constructed in this way, that fits to reality at least as well as the approximation constructed from the Chow – Liu tree.

In the last part we give some examples that show how efficient is our approximation in applications like pattern recognition.

Optimal topologies in case of probabilistic loading

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Keywords: topology optimization

In engineering practice the uncertainties play a very important role, but due to the complex nature of the stochastic calculation the designers usually apply deterministic data during the design process.

The aim of this paper is to introduce a new type of probabilistic topology calculation method where the elaborated algorithm is suitable to use thousands of design variables. The elements of the loading are given randomly and they can have linear relationship. This pre-design condition can be considered as a load combination. In the proposed probabilistic topology optimization method the design is described by the minimum penalized weight design of the structure what is subjected to compliance constraint with uncertainties and side constraints. The calculation of compliance value is based on the assumption that external loads have uncertainties where their joint normal distribution function, mean values and covariances are known. If the probability of this compliance value is given by the use of recommendation of Prekopa [3] this probabilistic expression can be substituted with an equivalent deterministic one and used as a deterministic constraint in the original problem. The object of the design (ground structure) is a rectangular disk in plane stress with given support conditions. The material is linearly elastic. The design variables are the thickness of the finite elements. To obtain the correct optimal topology some filtering method (the ground elements are subdivided into further elements) has to be applied to avoid the so-called "checker-board pattern" [1]. By the use of the first order optimality conditions a redesign formula of the stochastically constrained topology optimization problem can be derived which is an improved one of the previously [2] presented iterative expression. The new class of optimal topologies with their numerical confirmation are presented. The standard FEM computer program with quadrilateral membrane elements is applied in the numerical calculation. Through the numerical examples the paper investigates the optimal topologies obtained in case of uncertain situations. The effect of the covariances of the loads and the expected probability value of the compliance constraint are particularly investigated.

The present stage of the research shows that the algorithm is rather stable and provides the convergence to reach the optimum. The applied method gives a wider possibility to the designer to take into consideration more realistic loading description than the deterministic topology design.

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Stochastic techniques for the design of robust and efficient emission trading mechanisms

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Keywords: signal detection, emission trading

We present an integrated modeling framework that allows to assess the efficiency and robustness of Kyoto flexible mechanisms. Stochastic emission detection technique will be combined with a scheme of sequential bilateral emission trading operating under uncertainties to reduce the aggregate cost of mitigation in a fair and mutually beneficial way, which allows to create the stable coalition of the participants. The proposed robust sequential trading mechanisms account for safety constraints, i.e., the risks of underestimating and overestimating actual emissions.

With numerical results using reported data for Europe, we illustrate economic benefits of the discussed integrated approach and show simple ways how it can be applied for the design of emission trading schemes involving natural and anthropogenic emission systems at different spatio-temporal resolutions.

Stochastic structural optimisation based on minimum expected mean square stress rate

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Keywords: structural analysis and design, random model parameters, robust decisions, mean square structural stress rate, deterministic substitute problems, stochastic nonlinear programming

Problems from plastic analysis and optimal plastic design are based on the convex, linear or linearised yield/strength condition and the linear equilibrium equation for the stress (state) vector. In practice one has to take into account stochastic variations of the model parameters (e.g. yield stresses, plastic capacities, external load factors, cost factors, etc.), see e.g. [2,3]. Hence, in order to get robust optimal load factors, robust optimal designs, resp., the basic plastic analysis or optimal plastic design problem with random parameters must be replaced by an appropriate deterministic substitute problem, cf. [1]. Instead of calculating approximatively the probability of failure/survival based on a certain choice of (approximate) failure modes, a direct approach is proposed based on the primary costs (weight, volume, costs of construction, costs for missing carrying capacity, etc.) and the mean square structural stress rate. Based on the mechanical survival conditions of plasticity theory, a quadratic error/loss criterion is developed. The minimum mean square structural stress rate can be determined then by solving a quadratic optimisation problem. For each vector a of model parameters and each design vector x one obtains then an explicit representation of the "best" internal load distribution F*. Moreover, also the minimum expected mean square stress rate can be determined explicitly. The minimum mean square stress rate may be represented by means of a "generalised stiffness matrix". Hence, corresponding to an elastic approach, the expected minimum mean square stress rate can be interpreted here as a "generalised expected compliance function". Based e.g. on the minimisation of the expected primary costs subject to constraints for the expected mean square stress rate, explicit finite dimensional parameter optimisation problems result for finding robust optimal design x*.

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Bags and fuzzy bags: towards another theory of uncertainty

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Keywords: bags, fuzzy bags, theory of uncertainty

Bags which is sometimes called multisets (e.g. Blizard 1989) frequently arises in information processing models. The classical book by Knuth mentions bags, and the bag model has been used for document retrieval.

Given a universe of object symbols, a (crisp) bag has a *count* function for an arbitrary object symbol, which implies the frequency of occurrence of that symbol. Bags have basic relations and operations similar to those for fuzzy sets except that the complement operation does not exist for bags.

Fuzzy bags have been proposed by Yager (1986) and then a complete set of basic relations and operations have been established by Miyamoto (1996, 2001), whereby various applications of fuzzy bags have been made possible.

In this report we overview the theory of bags and fuzzy bags, i.e., fundamental relations such as the inclusion and equality, and basic operations of the union, intersection, and the addition. It is shown that the most basic relation of the inclusion of fuzzy bags requires the nontrivial operation of ordering of the memberships for a particular object symbol. Additional operations include the t-norms and conorms, the extraction, and the α-cuts and ν-cuts, which also employs the ordering. Fundamental properties of these relations and operations such as a commutative property between an operation and the α-cut, a commutative property between the two cuts, and the distributive lattice property of the collection of all fuzzy bags in a particular universe are shown.

How the concept of bags and fuzzy bags easily arises is shown using a typical example of a simple linear processing whereby we introduce two types of functional images, in other words, extension principle of bags. It should moreover be noted that the bags and fuzzy bags do not have the complement operation in contrast with fuzzy sets, since the world is not close for bags; more concretely, the *count* can be arbitrarily large without any ceiling, while fuzzy sets have the memberships have the upper bound of the unity.

The aim of this research is to develop a new theory and model of uncertainty that is different from the probabilistic framework and fuzzy sets. The new theory is, at the same time, related to the both frameworks. In the bag model, the information of the frequency of a particular symbol is assumed that has something in common with the probability model. The bag model is yet subjective, since the information is essentially incomplete. Note that if the maximum of the frequency is known for any object symbol, the information is complete and thee situation can be handled using the probabilistic framework. We therefore should consider the situation of the incomplete information where the maximum frequencies are unknown.

This observation leads us to the estimation of the universe or a conditional universe in which all bags should be handled, where a universe can either be a crisp or a fuzzy bag that include all sub-bags under consideration.

Although the present theory is in its initial stage of development, we show motivations for the new theory, preliminary results, and perspectives for future studies.

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Decision making under catastrophic flood risks

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Keywords: catastrophic risk, catastrophic flood, risk profiling, risk measures, risk functions, indifference curves, decision-making, investments, risk zoning, insurance, selfinsurance

An approach to decision-making under catastrophic risks based on risk profiling is considered [1]. Catastrophic risk is understood as possibility of big, but low probability losses. As risk hedging strategies investment diversification, catastrophe mitigation measures and insurance are considered. The approach assumes, for some selected catastrophic scenarios, to simulate their consequences (damage) as functions of control parameters and to impose expert (stochastic dominance) constraints on acceptable levels of relative losses in such scenarios. The approach is illustrated by a number of one-stage decision-making problems reduced to mixed boolean linear-programming problems.

As an example of binary decision problem under repeating catastrophic risks a problem of investing into a particular profitable plant allocated in a catastrophic risk (for example, flood prone) area is considered [2]. As a risk hedging mechanism a selfinsurance fund is considered, which is replenished by a part of profit and is used for the plant renewal. It is shown, that for assessment of catastrophic risk (probability) to lose the plant it is possible to apply methods of insurance mathematics.

Finally stochastic models of economic growth under repetitive catastrophic risks are explored [3]. The basic task is a quantitative estimation of risk of catastrophic downturn under different investment allocation strategies. As a measure of risk probability of production falling in percents to the initial level is taken. For this probability integral equations are derived, which are similar to integral equations of insurance mathematics and which are explored similarly.

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Catastrophe modeling

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Keywords: catastrophe, risk management

Catastrophe modeling is the art of finding appropriate stochastic models for low-probability-high consequence events. Unlike in other areas of applied statistics, we are confronted with the problem of estimation of quantiles, for which no or very few historic exceedences have been observed. In addition, there is often also an instationarity in the frequency and/or the severity pattern. One may also observe dependencies between inter-event times and severities.

Through several parameterized transformations, the physical event is transformed into an economic loss event by taking into account the exposure and vulnerability patterns of the elements under risk. Also these tranformations are subject to trends and instationarities, for instance due to climate change. We report our modeling experience.

Confidence in the range of variability

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Keywords: limited data, probabilistic, probability density estimation, uncertainty, confidence, reliability

Many mathematical models to predict future outcomes in engineering, sciences and social science, contain uncertain parameters which are not known deterministically. In this presentation, the case will discussed where the input for the uncertainty quantification must be derived from a small number of available data points by using a stochastic approach. Probability distributions are required for all uncertain input quantities of the model. Under such circumstances, there is little credibility for any a priori selected type of distribution as needed in a probabilistic approach for the assessment of the the uncertainties propagation and for reliability estimation.

In the proposed probabilistic approach, the probability densities are established in context with a specified confidence level, as a safeguard against severe underestimation of the true but unknown variability of the input parameters. The use of kernel densities is proposed, where the standard deviation of the kernel densities is a quantitative function of the number independent data points and the required confidence level. Kernel densities are especially suitable to construct joint probability densities for data points with several components, where the observed correlation among the components must be respected. The presented approach allows an extention of the bootstrap procedure to make it reliable also for cases where the number of available data points is extremly limited.

The proposed approach will be applied to an structural reliability problem, where a bivariate probability distribution is derived from the data calibration experiments and used for the assessment of the failure probability (regulatory assessment). The variability of the elasticity is represented by a stochastic field where its characteristic parameters are calibrated such that they fit the established distribution best. It is shown that the proposed approach leads to consistent predictions for the safety assessment, studied for three sets of data containing 5, 20 and 30 data points.

Supply chain management approach by Monte-Carlo estimators

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Keywords: tbd

This paper proposes a stochastic nonlinear programming model and solution algorithm for solving supply chain network design problems by finite series of Monte-Carlo estimators. Our approach distinguishes by two peculiarities. The rule for adjusting the Monte-Carlo sample size is introduced to ensure the convergence and to find the solution of the stochastic optimization problem by a reasonable volume of Monte- Carlo trials. Besides, the accuracy of the solution is treated in a statistical manner, testing the hypothesis of optimality according to statistical criteria. A computational study involving examples of supply chain network are presented to highlight the significance of stochastic model in comparison with recently used methods (Benders decomposition, etc.) as well as the efficiency of proposed solution strategy.

Decision analysis under risk and/or uncertainty with possible applications to public sectors

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Keywords: individual decision making, behavioral (descriptive) model, expected utility paradox, Prospect theory under uncertainty.

Normative (prescriptive) model of decision making prescibes optimal behavior how decision should be made. On the other hand, descriptive model is concerned with understanding how people actually behave when making deciosions.

The expected utility model has been widely used as a normative model of decision analysis under risk for modeling individual decision making. But various paradoxes [1,2] have been reported for the expected utility model, and it is argued that the expected utility model is not an adequate behavioral (descriptive) model. As a model to explain the violations of expected utility hypothesis for the individual decision making consequence dependent non-additive probabilities [3] have been introduced in a measurable value function under risk where probability of occuring each event is postulated to be known. The effective application of this approach to public sectors is mentioned in modeling risks of extreme events with low probability and high consequence.

A measurable value function under uncertainty is also described where basic probability for a set of events is known but probability of occuring each event is not known. It is shown that Ellsberg paradox [2] is consistently resolved by using this model, where Ellsberg paradox is a paradox in decision theory and experimental economics in which people's choices violate the expected utility hypothesis because of the people's tendency of ambiguity aversion. Potential applicability to evaluating a global warming problem is mentioned.

As a special case of a measurable value funtion under uncertainty prospect theory under uncertainty (PTU) [4] is described as an extended Kahneman and Tversky model of prospect theory [5]. An application of PTU to evaluating the sense of security provided by nusing care robots is described.

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An evaluation method of the retrieved physical quantity deriving from the satellite remote sensing using analysis of variance in experimental design

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Keywords: remote sensing, ANOVA, evaluation method

The purpose of the satellite remote sensing is not only observation of the surface on the earth but also measurement of a physical quantity in these days. For example, column density of carbon dioxide (CO2) will be retrieved from signal which is obtained by the sensor onboard satellite. Though there are some constraints which are, for example, existing clouds, satellite remote sensing is able to observe almost all over the surface on the earth. Further, sensor technology is developing rapidly in these days. FTIR (Fourier Transform Infrared Spectroscopy) and Doppler radar will be onboard the satellite. Therefore, amount of a minute physical quantity can be also measured, and it is considered that the necessity to measure a physical quantity from a satellite will increase in future more and more. Then, it is very important to evaluate the accuracy of the obtained physical quantity by satellite remote sensing. The evaluation method, which is established and high efficient, is necessary. We indicate an evaluation method of the obtained physical quantity based on the analysis of variance (ANOVA) in experimental design [1][2].

The observation deriving from satellite remote sensing, which is different from experiment in laboratory, is very wide scale. Therefore, the error which is included in an obtained physical quantity is difficult to evaluate actually. And it is difficult that the observation condition such as temperature profile from surface to top of atmosphere is not able to know accurately. Therefore, in this study, the error of an obtained physical quantity is evaluated by numerical simulation. The retrieved physical quantity is evaluated as follows. First, error factors which become noise of an obtained physical quantity are listed up. Noises and a retrieval process are modeled. And then, levels for each error factor are set. Experiment is designed, and orthogonal arrays are made based on the set levels of factors. We obtained a linear model for an analysis of variance, and experiments are run based on the orthogonal arrays. Last, error of an obtained physical quantity is evaluated by ANOVA. Further, new generation sensor such as FTIR is desired to know the magnitude of error in an obtained physical quantity derived from each error factor since to know the contributions in an obtained physical quantity is important to develop the sensor technology. Then, the contributions to the retrieved physical quantity derived from each error factor are obtained from ANOVA.

I present, for one example, that the column density of carbon dioxide is retrieved by a signal which is obtained by FTIR sensor onboard satellite. The magnitude of the sensor noise in the observed spectrum is calculated by numerical simulation, and retrieval error of CO2 column density is shown. Since the calculation of the spectrum in the retrieval process take a lot of time, the evaluation of the retrieved CO2 column density is large time consuming also. Therefore it is difficult to experiment for many times. Analysis of variance is able to evaluate for the number of minimum experiments, and is established well. Therefore, analysis of variance is efficient for evaluation of a retrieved physical quantity by satellite remote sensing.

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