Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 103 (2017) 36 – 43

Procedia Computer Science

XIIth International Symposium «Intelligent Systems», INTELS'16, 5-7 October 2016, Moscow, Russia

Uncertain programming in preliminary design of technical systems with uncertain parameters

G.S. Veresnikov*, L.A. Pankova, V.A. Pronina

Institute of Control Sciences V. A. Trapeznikov Academy of Sciences, 65 Profsojuznaja Street, Moscow 117997, Russia

Abstract

The work is devoted to preliminary design of technical systems with uncertain parameters in absence of statistic. Optimization models with uncertain variables as the uncertain multiobjective programming models of B. Liu are considered. We offer the uncertain programming models with different ranking criteria and present technique of solving problems of uncertain programming. Decision of the preliminary aerodynamic design problem as the problem of uncertain programming are described.

Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"

Keywords: preliminary design, uncertain parameter, uncertain programming, optimization model.

1. Introduction

The preliminary design of complex technical systems is prolonged iterative decision-making process, involving not only the automation of the calculation, but also solving optimization problems. The parameters of technical systems are real, limited, optimization problems are multicriteria and of large dimension, objective functions and constraints are often nonlinear.

Most of the parameters in the preliminary design phase can not be clearly defined at the time of the decision, i.e. they are imprecise, or uncertain. In this case the use of traditional methods for calculating with the exact values may lead to unacceptable solutions[1]. There is a problem of the preliminary design of complex technical systems with imprecise (uncertain) parameters.

* Corresponding author.
E-mail address: veresnikov@mail.ru

Peer-review under responsibility of the scientific committee of the XIIth International Symposium "Intelligent Systems"
doi:10.1016/j.procs.2017.01.007

Uncertainty can be aleatory and epistemic. Aleatory uncertainty arises when parameters are characterized by variability recorded in the results of observations (statistics). Epistemic uncertainty arises when there is no sufficient number of observations and information obtained from experts.

To represent epistemic uncertainty more than 20 "uncertainty theories" have been developed, which partly contradict each other and partly complement each other[2]. Since 2002 the scientific direction named "imprecise probability" arises (http://www.sipta.org/). This direction united many of these theories for modeling the judgment of experts about random parameter (epistemic uncertainty of aleatory uncertainty, i.e. second-order uncertainty[3]).

In this paper we consider the optimization problem, where the parameters only with epistemic uncertainty.

To account for epistemic uncertainty in optimization problems any theory must provide:

- The formal representation of the uncertainty;
- The method of propagation of uncertainty from parameters to functions;
- The models and the appropriate decision-making methods.

In fuzzy[4] and possibilistic[5] programming there are effective methods for propagation of epistemic uncertainty from parameters to functions which are linear with respect to parameters. In this case the linear fuzzy and possibilistic models are reduced to linear mathematical programming models. For nonlinear (with respect to parameters) functions authors do not know efficient algorithms of fuzzy and possibilistic programming.

Some papers on imprecise probabilities describe approaches for propagation of uncertainty from parameters to functions. However, appropriate methods require large computational cost and are not suitable for practical engineering analysis[6].

In engineering practice traditional stochastic models are mainly used, even when probabilities are known inaccurately.

The theory of uncertainty proposed by B. Liu in 2007 (and improved in 2009)[7,8] is a new tool for the representation of epistemic uncertainty and manipulation with it. Hereinafter, the term "uncertainty" will be used only in the context of this theory.

For monotonic (with respect to independent parameters) functions there are effective methods of propagation of uncertainty from parameters to functions. Models of uncertain programming are reduced to the equivalent models of mathematical programming.

The methods of uncertain programming based on this theory have already found rather broad application[9-12]

Section 2 contains the necessary information from the theory of uncertainty proposed by B. Liu. Section 3 discusses the optimization models with uncertain variables. The generalized model of uncertain programming is offered. In section 4 the technique for solving problems of uncertain programming is described. Section 5 shows how to use the model of uncertain programming for solving one of the task of the preliminary aircraft design.

2. From uncertainty theory[13]

Let U be nonempty universal set, A be σ-algebra on U. Every $\Lambda \in A$ is called an event. Each event Λ is associated with the number of $M\{\Lambda\}$, defining the uncertainty measure of the event and satisfying to three axioms.

Normality Axiom: $M\{U\} = 1$ for the universal set U.

Duality Axiom: $M\{\Lambda\} + M\{\Lambda^c\} = 1$ for any event Λ ($\Lambda^c = U \setminus \Lambda$).

Subadditivity Axiom: for every countable sequence of events Λ_1, Λ_2, we have $M\left\{\bigcup_{i=1}^{\infty} \Lambda_i\right\} \le \sum_{i=1}^{\infty} M\left\{\Lambda_i\right\}$.

Definition. Let U be nonempty universal set, A be σ-algebra on U, M be the measure of uncertainty. Then the triplet (U, A, M) is called the space of uncertainty.

Product Axiom: let (U_k, A_k, M_k) be uncertainty spaces for $k = 1,2,\ldots$, then the product uncertainty measure M is an uncertain measure satisfying

$$M\{\prod_{k=1}^{\infty} \Lambda_k\} = \bigwedge_{k=1}^{\infty} M\{\Lambda_k\} \ (\wedge \overset{def}{=} \inf) \text{ for any } \Lambda_k \in A_k,\ k = 1, 2, \ldots \quad (1)$$