Chapter 32

Handling Optimization Under Uncertainty Using Intuitionistic Fuzzy–Logic–Based Expected Value Model

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ABSTRACT

Uncertainty in parameters during deterministic optimization studies can have large impact on the outcome of the optimization result. It is pragmatic that these parameters are uncertain as they have direct link with real life scenarios, e.g. fuel price appearing as a parameter in objective function or constraints. However, their variability is ignored while solving the problem in a deterministic optimization framework. While mitigating the above mentioned scenario, it is, therefore, necessary to investigate the development of uncertainty handling techniques for a realistic optimization problem. In this work, we propose intuitionistic fuzzy expected value model (IFEVM), which assumes uncertain parameters as intuitionistic fuzzy variables and derives the solution out of an equivalent transformed deterministic formulation while defining the expected values of the objective functions and constraints. Intuitionistic fuzzy parameters can be regarded as a superset of the conventional fuzzy set where the aspect of non-determinacy of a fuzzy member to a set is additionally taken into account. The proposed IFEVM technique has been applied on two examples: first, with the Binh-korn’s multi-objective test function where uncertain parameters are linearly related and next with a real life case study of industrial grinding operation having multiple numbers of non-linearly related uncertain parameters. The technique has been further applied to these case studies considering three different levels of risk scenarios e.g. optimistic, pessimistic and intermediate approaches. The IFEVM technique is fairly generic and advantageous, can be applied to any kind of system for handling uncertainty in parameters.

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INTRODUCTION

During the past century, the field of optimization, which is not only a potent methodology of modeling and problem solving but also has found a broad range of applications in industry, engineering, management science and operation research, has been developed extensively and converted into a mature area of research. Optimization refers to the analysis of a problem, in which a single solution (for single objective optimization) or a set of trade-off solutions (for multi-objective optimization), called decision variables, must be chosen from a range of feasible solutions. Solutions are compared for their supremacy based on certain criteria met, known as the objective function, and the feasible solutions are the solutions that satisfy all the constraints defined in the optimization problem. One of the main criticisms of the optimization is, however, that it often produces the solutions that are not robust to uncertainties in the parameters or constants present in the optimization problem. Traditionally, these uncertainties can be handled by over designing or over estimating the parameters or by replacing the uncertain parameters by their nominal values. These methods are either costly or lead to suboptimal, sometime infeasible solutions. Investigations on development of uncertainty handling techniques while solving optimization problems are, therefore, necessitated. Based on the nature of parameters or constants, e.g. deterministic or stochastic, optimization methods can be classified into two categories. First one is the deterministic optimization problem where parameters are deterministic in nature and in this case, the optimization problem can be solved with deterministic or certain values of the parameters. For the second case, the case of optimization under uncertainty (OUU), all or some of the parameters are assumed as non-deterministic or stochastic in nature and the uncertain optimization problem can be solved by first associating a distribution based information e.g. probability with it and next converting it into an equivalent deterministic optimization problem to find the solution for a particular realization of uncertainty. There are several methods available in the literature which performs the above mentioned transformation, namely, two stage stochastic programming (TSSP), chance constrained programming (CCP), fuzzy mathematical programming (FMP), stochastic programming (SP), and expected value model (EVM) to name a few (Liu, 2009 and Sahinidis, 2004).

LITERATURE REVIEW

The OUU methods such as SP, CCP and EVM surmise the uncertain parameters as probabilistic variables i.e. in these cases the probability distribution information about the uncertain parameters is either known or can be estimated. The TSSP, the most popular version of SP technique, deploys decision variables into two stages. For any decision made by a decision maker while picking up the values for the first stage variables, the recourse decisions are made in the second stage that compensate the effects of the first stage decisions. Calculations related to uncertain parameters are reserved only for the second stage which adds an expectation term to the objective function for several scenarios considered for the realizations of the uncertain parameters. Generally, the values of first stage variables have to satisfy all realizations of uncertain parameters in the second stage which can make this approach reasonably conservative or sometime leads to difficulty in finding a feasible solution. Though SP has been successfully applied for several problems, the well-known drawback of SP is that the problem size increases exponentially with the increase in the number of uncertain parameters. To surmount the demerits of the TSSP, designers resort to CCP, proposed by Charnes and Cooper (1959), where uncertain parameters are postulated as
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