Algorithmic method in optimization considering unreliability- An overview

Submitted by:Ranjan Pradhan. Asst.professor in Raajdhani Engineering College, Bhubaneswar.

Nilambari Panda. Asst.Professor in Aryan Institute of Engineering and Technology,Bhubaneswar.

DR.Arjun Singh. Asst. Professor in NM Institute of Engineering and Technology,Bhubaneswar.

Arunima Panda. Asst.professor in Capital Engineering College, Bhubaneswar

Abstract

This study presents a short lived assessment on some of the most important developments in the field of optimization under improbability. In exacting, the range and the significance of the papers integrated in this particular topic are analyzed. The value of improbability quantification and optimization technique for producing enhanced models and designs is systematically discussed. The center of the conversation is in three definite study areas, to be precise algorithmic-based optimization, vigorous sketch optimization and model updating. The point of view presented signify that optimization under improbability should be converted into usual in engineering design in the predictable future. Algorithmic aspects play a vital role in examine and modeling pragmatic systems and structures.

Introduction

In most engineering applications, the traditional approach to designing systems is to consider deterministic models and parameters, respectively. Thus, variations in loading conditions, material properties, geometry, boundary conditions, etc. are included in the design process by introducing simplifying hypotheses, e.g. the consideration of extreme or mean values and/or the application of safety factors. These hypotheses are formulated based on past experience and engineering judgment. Despite such a traditional approach has successfully been used in many practical design situations, the assumption of a deterministic model is certainly a simplification, because observations and measurements of physical processes clearly show variability and randomness in the different model parameters. Hence, a proper design procedure must explicitly consider these types of uncertainties, as they may cause significant changes in the performance and reliability of final designs (see, e.g. [31], [100], [113], [133]). For example, final designs obtained by deterministic models may become infeasible when the uncertainty in the system parameters is considered. The application of design procedures which consider uncertainties ensures that the analyzed system will perform within prescribed margins with a certain reliability, i.e. a quantitative measure of the system safety will be available.

Despite of the fact that an adequate level of reliability is a basic objective when designing a system, other design goals may be important as well, e.g. there is an increasing demand for structures which are safer and at the same time more economical. In consequence, engineering practice expects to have optimization procedures available which take into account the effects of uncertainty and which are applicable to realistic problems of the engineering practice.

Procedures which deal with optimization considering uncertainties are significantly more involved than their deterministic counterparts. Optimization processes may require the evaluation of costly objective and constraint functions hundreds or even thousands of times. The associated costs are usually prohibitive, especially under uncertain conditions, e.g. when the system is represented by means of a large and detailed finite element model or when the representation of the loading acting on a structure requires a numerically involved model, such as in earthquake engineering applications. Therefore, special procedures must be applied in order to make the design problem tractable. Such procedures include, for example:

- The use of efficient optimization techniques which require less function calls. These techniques can take advantage of special characteristics of the problem under study by introducing, e.g. sequential approximations, construction of approximate representations of the objective function and constraints using reciprocal and/or hybrid variables, etc.
- The introduction of approximation concepts at different levels of the optimization process.
- The use of appropriate techniques for coping with uncertainty, e.g. simulation techniques that allow to treat realistic uncertainty models involving a large number of uncertain parameters in an efficient manner.
- An appropriate computational implementation n, i.e. computational aspects play a key role, as the systems and structures which are of engineering interest are large and require detailed modeling. In this regard, parallel computing has become a tool which is steadily gaining interest among researchers and engineers.

Procedures are developed to a point where their application to realistic problems is now feasible. This certainly suggests a change of paradigm when performing optimization under uncertainty, as early approaches were restricted to academic examples. On the contrary, the most recent methods developed are being applied to challenging engineering problems. Hence, it is foreseen that optimization would become an integral part in the field of computational stochastic mechanics, allowing to treat realistic design applications within an appropriate and efficient framework.

This article is not intended to present an exhaustive review of the field of optimization under uncertainties but to offer a brief survey on some of the most relevant contributions in the area, namely reliability-based optimization (RBO), robust design optimization (RDO) and model updating. Thus, topics such as non-probabilistic approaches (e.g. Fuzzy analysis) for coping with uncertainty were not considered, as the focus of this Special Issue is on classical probability analysis and Bayesian approaches. In the same way, fields such as life-cycle optimization of structures were not further pursued, as it was intended to show recent advances on basic methods.

As previously pointed out, this volume includes three areas of research in the field of optimization under uncertainties. The first area, *reliability-based optimization*, is concerned with the solution of an optimization problem, where the effects of uncertainties are quantitatively expressed by means of failure probabilities and expected values [36], [42], [58], [117]. The second area addressed in this volume refers to *robust design optimization*, which is a methodology that seeks to determine a design which is relatively insensitive with respect to changes in the loading, structural parameters, geometry, etc.; such a design is referred to as a *robust* solution [33]. The third and final area covered in this survey refers to *model updating* and *system identification*. In this research field, the goal is to reduce the discrepancies that arise when comparing the model predictions with test data [38], [39], [51].

General remarks

The basic goal in any engineering discipline is to design and construct systems or components that satisfy certain performance objectives during their lifetime. Such objectives cover a wide range of possibilities, e.g. control of vibrations induced by wind or traffic loading on bridges, collapse prevention of buildings due to major earthquakes, minimization of the effects of multi-site damage in aerospace structures, etc. In almost any practical design situation it is impossible to comply with

General comments

A general optimization task can be stated by the following mathematical problem:where is the vector of design variables, is the vector of uncertain parameters, is the objective function, , and are functions that define the set of inequality and equality constraints, respectively, and are the functions that define the set of deterministic constraints. The classical solution of

General remarks

Virtual prototyping has gained great attention in several fields of engineering. As a design tool, it allows us to explore different possible configurations of a system in order to choose the most convenient one according to a prescribed design criterion. The time required for testing these different configurations will be relatively short, as the virtual prototype replaces physical testing with a computer-based mathematical model. In a number of engineering disciplines (e.g. aeronautical,

Conclusions and outlook

The brief overview presented in the preceding sections and the succinct discussion of the contributions to this Special Issue indicate that considerable progress has been made in the field of optimization methods considering uncertainties. The different methodologies which have been proposed for coping with uncertainty in optimization are developed to a stage where they are ready to be applied to engineering structures.

A detailed analysis of the different methods for performing optimization

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