



Optimization and Mechanical Design



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Opinion

Engineering is a profession whereby principles of nature are applied to build useful objects. A mechanical engineer designs a new engine, or a car suspension or a robot. A civil engineer designs a bridge or a building. A chemical engineer designs a distillation tower or a chemical process. An electrical engineer designs a computer or an integrated circuit. The process of determining the best design is called optimization. Thus we may wish to design the smallest heat exchanger that accomplishes the desired heat transfer, or we may wish to design the lowest-cost bridge for the site, or we may wish to maximize the load a robot can lift, so optimization is a process that can be seen in almost every aspect of life, Engineering requires optimization so that they can design faster planes and cars, that use less fuel, lighter, stronger, and more comfortable. Engineers have been optimizing designs since the beginning, but recent advances in computing have made numerical optimization techniques a more effective way than the original trial-and-error and experience-based optimization. The computational costs increase highly nonlinearly as the number of design variables increases [1-4].

In design, construction, and maintenance of any engineering system, engineers must take many technological and managerial decisions at several stages. The goal of all such decisions is either to minimize the effort required or to maximize the desired benefit. Since the effort required or the benefit desired in any practical situation can be expressed as a function of certain decision variables, optimization can be defined as the process of finding the conditions that give the maximum or minimum value of a function. So In optimization of a design, the design objective could be simply to minimize the cost of the production or to maximize the efficiency of production. An optimization algorithm is a procedure which is executed iteratively by comparing various solutions till an optimum or a satisfactory solution is found. With the advent of computers, optimization has become a part of computer-aided design activities [5-9].

There is no single method available for solving all optimization problems efficiently. Hence several optimization methods have been developed for solving different types of optimization problems. The optimum seeking methods are also known as mathematical programming techniques. Many problems in today's world rely on the trial-and-cut method which in return takes a considerable time

to obtain the optimal solution. Nevertheless, solving engineering problems involve many conflicting objectives. Optimization is a method of obtaining the best result under the given circumstances. It plays a vital role in machine design because the mechanical components are to be designed in an optimal manner. While designing machine elements, optimization helps in several ways to reduce material cost, to ensure better service of components, to increase production rate, and many such other parameters. Engineering problems with optimization objectives are often difficult and time consuming, and the application of nature or biology-inspired algorithms in combination with the conventional optimization methods has been very successful in the last several decades [9-12].

Extensive application of design optimization techniques is made in the field of structural design, as well as in a limited number of specific weapon design problems. Biology-derived algorithms are applicable to a wide variety of optimization problems. For example, optimization functions can have discrete, continuous, or even mixed parameters without any a priori assumptions about their continuity and differentiability. Most engineering design problems, especially in shape design, aim to reduce the cost, weight, and volume and increase the performance and quality of the products. Finite element analysis (FEA) in structural engineering is forward modeling as the aims are to calculate the displacements at various positions for given loading conditions and material properties such as Young's modulus (E) and Poisson's ratio (ν). This forward FEA is widely used in engineering design and applications. The usage of optimization in engineering is getting larger every day as the computational capabilities of the computers are increasing.

Design variables are parameters that the designer might "adjust" to modify the artifact he is designing. There are many types of design variables. Independent design variables are the actual quantities the designer deals with directly, such as geometry, material properties, production volume, surface finish, configuration of components, lubrication properties and many more. Independent design variables are usually called just design variables or design parameters. Dependent variables are variables the designer cannot directly assign values he works with them through the design parameters. The dependent variables are usually named characteristics or attributes of the design [13-15].

Topology optimization methods solve a material distribution problem to generate an optimal topology. It is usual for each finite element within the design domain to be defined as a design variable, allowing a variation in density. Usually, topology optimization methods are used to tackle practical design problems with traditional manufacturing processes in mind, such as casting and machining. Topology optimization is a powerful approach for determining the best distribution of material within a defined design domain. Many real-world optimization problems are solved subject to sets of constraints, a constrained optimization problem may be distinguished as a Linear Programming Problem (LPP) and Nonlinear Programming Problem (NLP). There are many traditional methods in the literature for solving NLP. However, most of the traditional methods require certain auxiliary properties (like convexity, continuity etc.) of the problem and most of the traditional techniques are suitable for only a problem (for example Quadratic Programming Problems, Geometric Programming Problems etc.). Keeping in view the limitations of traditional techniques researchers have proposed the use of stochastic optimization methods and intelligent algorithms for solving NLP which may be constrained or unconstrained. Some examples are: Genetic Algorithms, Ant Colony Optimization, Chaos Optimization Algorithm, Particle Swarm Optimization, Differential Evolution etcetera.

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