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Mathematical Optimization Theory and their Types, Advantages of Mathematical Modeling

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Description

Mathematical optimization or mathematical programming is the selection of the best element from a set of available alternatives based on some criterion. Optimization problems of various types arise in all quantitative disciplines, ranging from computer science and engineering to operations research and economics, and the development of solution methods has long been a topic of study in mathematics.

In its most basic form, an optimization problem consists of maximizing or minimizing a real function by systematically selecting input values from an allowed set and computing the function's value. A large area of applied mathematics is the generalization of optimization theory and techniques to other formulations. More broadly, optimization entails determining the "best available" values of some objective function given a defined domain, which may include a variety of different types of objective functions and domains [1].

Mathematical optimization is a highly effective prescriptive analytics technology that enables businesses to solve complex business problems while making better use of available resources and data. The key features of a complex real-world problem can be captured as an optimization model using mathematical programming. An optimization model is made up of relevant objectives, variables, and constraints to recommend the best possible solution. A math programming solver is a computational engine that reads the optimization model and then returns the best possible solution [2].

Leading companies use mathematical programming technologies, which often result in tens or hundreds of millions of dollars in cost savings and revenue. The following industries and businesses use mathematical optimization:

Finance: Betterment employs optimization to select the optimal asset mix, maximizing after-tax returns while minimizing risk.

Government: The Federal Communications Commission (FCC) used optimization to generate the first two-sided spectrum auction, generating $20 billion in revenue.

Logistics: FedEx reduces costs by optimizing package routing through their shipping network.

Manufacturing: SAP employs optimization to efficiently schedule goods production in factories in order to meet customer orders.

Sports scheduling: To create the best possible league schedules, the NFL employs optimization.

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Continuous Optimization *vs.* Discrete Optimization

Some models can only make sense if the variables take on values from a discrete set, often a subset of integers, whereas other models can take on any real value. Models with discrete variables result in discrete optimization problems, while models with continuous variables result in continuous optimization problems. Continuous optimization problems are easier to solve than discrete optimization problems because the smoothness of the functions allows the values of the objective function and constraint function at a point x to be used to deduce information about points in x's neighborhood. However, advancements in computing technology and algorithm improvements have dramatically increased the size and complexity of discrete optimization problems that can be solved efficiently. Because many discrete optimization algorithms generate a sequence of continuous sub problems, continuous optimization algorithms are important in discrete optimization [4,5].

Unconstrained Optimization *vs.* Constrained Optimization

Another significant distinction is between problems with no constraints on the variables and problems with constraints on the variables. Unconstrained optimization problems arise directly in many practical applications; they also arise as a result of the reformulation of constrained optimization problems in which the constraints are replaced by a penalty term in the objective function. Constrained optimization problems arise from applications with explicit variable constraints. The variables' constraints can range from simple bounds to systems of equalities and inequalities that model complex relationships between the variables. The nature of the constraints can be used to further classify constrained optimization problems.

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