

Analysis of the Principle and Application of Optimization

Chenhao Xu*

Department of Applied Mathematics, University of California, Santa Barbara, United States

*Corresponding author: chenhaoxu@ucsb.edu

Abstract. As a matter of fact, optimization approaches are widely used in lots of fields to find the best solutions for certain issues in recent years. In reality, the optimization refers to the use of optimization algorithms or models to find the overall or local optimal goal of the optimization problem under certain constraints. The optimization principle has been widely applied in various practical fields, such as power system engineering design, internet fields, production management, logistics planning, financial investment. With this in mind, this article will introduce and analyze the principle of optimization and applications of optimization principles in some fields. To be specific, the equations, solutions as well as the effectiveness of the applications will be analyzed and demonstrated. According to the analysis, the current limitations as well as the prospects will be given at the same time. Overall, these results shed light on guiding further exploration of implementation for optimization.

Keywords: Optimization; operation; logistic planning.

1. Introduction

Optimization mainly focuses on the distribution and management of limited resources, and achieves the optimal goals. When dealing with an optimization problem, the first step is to set optimization problems based on relevant and limited conditions. Optimization problems generally include decision variables, constants, objective functions, and other components. Once the optimization problem is established, optimization problem can be solved through different optimization algorithms. While there are so many different algorithms, there is no classification of the better or worse algorithms, but rather the use of the most suitable algorithm based on specific analysis of the problem.

All these optimization algorithms make optimization tightly related to people's life. For example, in the financial field, Cai and Zhu indicate that there is an important positive relationship between financial efficiency and the rationalization and advancement of industrial structure, and the optimization of industrial structure is of great significance for stable economic growth under the new normal. A steadily developing economy can improve people's living standards [1]. Nevertheless, Li and Ding point out that in this rapidly changing era, optimization problems are inevitably active in people's actual lives, which makes optimization problems complementary to computer science and brings convenience to people's lives, while algorithm is an extremely important part of computer science [2]. In addition, optimization plays a crucial role in many other fields, such as aerospace, management, and life sciences. Liu also claims that although the principle of optimization has not changed much over the years, it can still adapt well to the changes in development in different eras and has played a helpful role in the development of social and economic structures to a certain extent, with extraordinary guiding significance [3]. In short, optimization has played a crucial role in the historical process of human development, which has also laid the foundation for the research significance of optimization. This passage mainly focuses on the introduction of the principle of optimization and analysis of some applications in different fields based on the optimization.

2. Basic Description

The principle of optimization is to construct a mathematical model based on real-world problems under limited conditions and obtain an optimal solution for the final goal. The process of optimization always contains the following steps. First, define the objective function which can indicate whether

the problem needs to be minimized or maximized. Second, determine constraint conditions that can represent the limited situations of the practical problem. Third, determine optimization variables which usually are the parameters need to be optimized. Optimization variables are also under some constraint conditions, otherwise the final value or range of optimization variables will be meaningless. Then determine the optimization methods. Finally, evaluate if the optimal solution meets the requirements through inspection and implementation.

Optimizing the objective function mainly depends on the specific selection of optimization algorithms and practical problems. Nowadays, with the passage of time, various algorithms have been proposed, such as, Gradient Descent, Stochastic Gradient Descent, Mini-Batch Gradient Descent, Newton's Method and so on. For example, in researcher Weidong Guo's optimization and simulation research on the objective function of vehicle vibration model, Guo claims that when optimizing the objective function, only optimizing a single objective function is too one-sided to make the car comfortable for passengers and drivers during driving [4]. Therefore, researcher Guo accords the practical situations to adopt Genetic Algorithm to optimize the objective function. After obtaining the optimal solution, Guo utilized matlab/simulation software to simulate the optimization results which ultimately led to the conclusion that the optimization results were feasible. Moreover, researchers Xinxin Hu and Lijin Wang also follow the similar steps. The purpose of Hu and Wang's research is to optimize the Status Index Curve Model. In order to achieve more accurate measurements and smaller estimation errors, Hu and Wang uses Particle Swarm Optimization to optimize the objective function. Hu and Wang explicate that compared to Genetic Algorithm, the advantage is that Particle Swarm Optimization is simple and easy to implement, and there are not many parameters that need to be adjusted [5]. Besides these advantages, Particle Swarm Optimization is an uncertain optimization algorithm with probability which is good at dealing with the Status Index Curve Model with complex structures. Particle Swarm Optimization has low computational complexity such that find the global optima quickly. These advantages fully prove that to optimize the Status Index Curve Model, Particle Swarm Optimization is the relatively best optimization algorithms. And Particle Swarm Optimization admittedly helps Hu and Wang to obtain optimization results with higher accuracy and smaller errors. From Guo's and Hu and Wang's researches, Undoubtedly, analyzing the actual problems and the objective functions that need to be optimized before making suitable optimization algorithm choices is crucial for achieving ideal optimization results.

3. Application in Logistics Planing

With the popularization of online shopping and online payment, nowadays online trade is active in people's daily lives, and this phenomenon is also driving logistics management towards systematization. The researchers Guoqing Jiang, Yong Pan and Feiyue Hu propose that a large number of studies have shown that logistics transportation costs generally exceed half of the total transportation costs [6]. Therefore, optimizing logistics distribution paths is crucial for enterprises to save logistics costs and improve their competitiveness [6]. Jiang, Pan and Hu consider the factors such as customer satisfaction evaluation, individual vehicle load limitations, delivery distance, customer accepting range of delivery time, and delivery time to create a mathematical model for optimizing logistics delivery paths [6]. Researchers Jiang, Pan and Hu point out that logistics distribution path optimization is a typical multi constraint combination optimization problem, belonging to the NP complete (Non deterministic Polynomial Complete) problem, and it is difficult to obtain a global optimal solution using only a single algorithm [6]. Hence Jiang, Pan and Hu adopt a combination optimization method Genetic Algorithm-Ant Colony Optimization (GA-ACO) by combining Genetic Algorithm and Ant Colony Optimization. By using this combination optimization method GA-ACO, researchers can efficiently take advantages of each independent algorithm and at the same time can make up for the disadvantages of other algorithms.

Ant Colony Optimization can find the optimal solution of a problem through the search behavior of the population and has good global search ability, while genetic algorithm can also achieve global

search through operations such as selection, crossover, and mutation, so that the combination of the two algorithms can find the optimal solution of the problem in a shorter time. In addition, Ant Colony Optimization can adapt to different environments and problems by simulating the search behavior of ants to find the optimal solution. At the same time, genetic algorithm also has strong adaptability and can adjust and adapt to different characteristics of the problem. Therefore, GA-ACO should better adapt to different problems and environments. Jiang, Pan and Hu believe that since Genetic Algorithm and Ant Colony Optimization have similar advantages, using GA-ACO should bolster their advantages highly [6]. In order to verify the effectiveness of using GA-ACO in optimizing logistics delivery paths over using a single Genetic Algorithm or Ant Colony Optimization, researchers Jiang, Pan and Hu designed comparative experiments (seen from Table 1).

Table 1. Comparison of Comprehensive Performance of Different Logistics Delivery Path Optimization Algorithms

Evaluating indicator	GA	ACO	GA-ACO
Number of times to find the optimal path	45	48	65
Average algebra	465	440	365
Experimental optimal average distance/km	563.075	572.776	543.075
Average time consumption/s	120.25	100.17	90.12

The data fully demonstrates that the data obtained by using GA-ACO is the best among the three optimization algorithms, no matter the data on the number of times finding out the optimal path and average algebra, or the data on optimal average distance in the experiment and average time consumption. Hence, when dealing with the Logistics Delivery Path Optimization problems, using GA-ACO effectively can avoid the defect of using a single GA or ACO to fall into local extreme points, and has the least time consumption, good stability, and optimization efficiency. For the final result, researchers Jiang, Pan and Hu concludes that there are obvious advantages in solving the Logistics Distribution path Optimization, and the optimal solution of logistics distribution paths can be obtained, which has certain practical significance [6].

4. Application in Investment Portfolios

Optimization also has applications in investment portfolios. The core of an investment portfolio is to maximize benefits under certain risks or minimize risks under certain returns. In the continuous development and changes of the capital market, how to effectively optimize investment portfolio management to reduce risks in the financial market has become a challenge for many investors. According to Wang and Yi's research result, the weight of investment portfolios has an inseparable impact on corporate earnings management behavior [7]. What's more, Qi et al. also point out that in order to solve the effective boundaries in portfolio theory, accurately calculating the weights of each asset has become a top priority in portfolio management [8]. Hence, to start optimizing investment portfolios, the weight of investment portfolios is crucial. Others use three different portfolio models: the standard portfolio model, the portfolio model with constraints, and the portfolio with market value constraints. Then they analyze and determine three different constraint conditions according to three portfolio models. Qi et al. adopt Genetic Algorithm to solve the effective boundaries of three different investment portfolios separately. However, during the experiments, Qi, Lin and Wang find that using Genetic Algorithm in dealing with Portfolio Problems has some drawbacks. As shown in Fig. 1, when the x-axis of the figure number of stocks increases, the y-axis of the figure efficiency of genetic algorithms decreases, and the efficiency of investment portfolios with market value constraints remains low regardless of the number of stocks. The Researchers Qi, Lin and Wang conclude that the decrease in efficiency of genetic algorithms for increasing the number of stocks may be due to the parameter settings of Genetic Algorithm [7]. Genetic algorithm can avoid falling into local optima, solve objective functions with multidimensional structures, and have parallelism, which is still worth further research in large-scale investment portfolios with multiple objectives

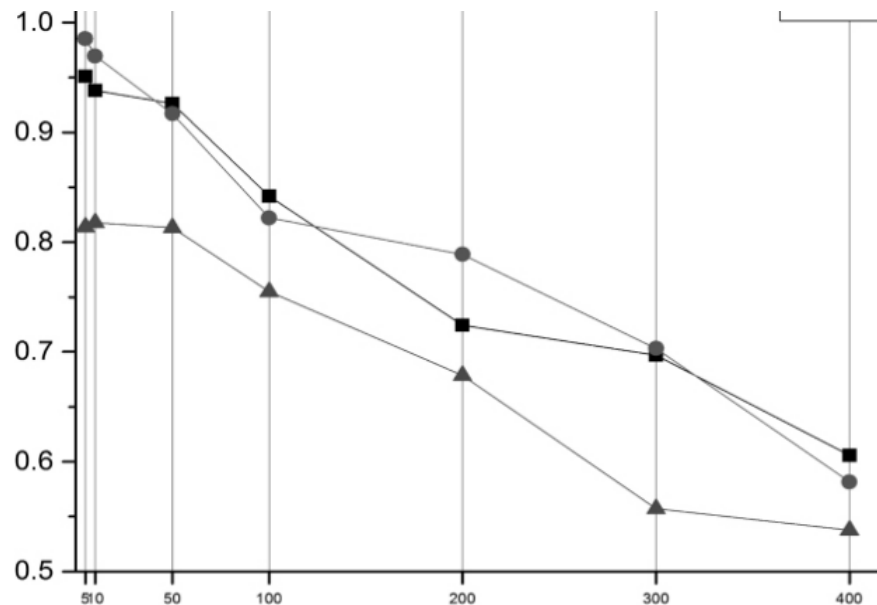


Fig. 1 Number of Stocks and Algorithm Efficiency

Moreover, Li et al. conduct further research on multi-objective large-scale investment portfolios [8]. Li, Song and Zhang utilize the multi-objective optimization algorithm with decision-maker preferences KR-NSGA-II for multi-objective optimization of investment returns and risks [9]. Li, Song and Zhang point out that unlike the classical fast and elitist non-dominated sorting genetic algorithm-II (NSGA-II), KR-NSGA-II only search for the optimal solution on the Pareto surface of interest to decision-makers, and KR-NSGA-II typically do not have a unique optimal solution, but rather a set of Pareto optimal solutions [9]. These solutions balance and compromise between different objectives, saving investors a lot of time and energy. After empirical analysis of different stock numbers, Li et al. found that KR-NSGA-II only search for three optimal portfolios of securities that investors are most likely to like, so investors do not need to make complex and difficult choices, greatly improving efficiency [9]. As a result, Li et al. validate the feasibility of multi-objective optimization algorithms KR-NSGA-II in helping investors effectively select the optimal investment portfolio in a large number of investment portfolios through experiments [9]. However, Pareto only assumes optimization in situations where investors' preferences are unknown, so developing new algorithms that can search for investment portfolios with investor preferences rises a problem for the future investment portfolio optimization.

5. Application in Architectural Structural Designs

In the field of architecture, optimization is also an important technology that can help designers, engineers, and architects improve design efficiency, reduce costs, reduce resource waste, and improve building performance. Liu points out that traditional architectural structural design is mostly based on the personal experience of the designer, and there is no unified standard for design schemes. Most of them are only within a reasonable range, and the optimal indicators have not been found, resulting in significant waste [10]. Hence using optimization algorithms for optimizing the architectural structural design is necessary to cater to the trends and changes of the times. However, with the development of technology and the emergence of various new materials, there are more and more factors needed to be considered in the architectural structural design optimization. Shao et al. state that traditional Genetic Algorithms are prone to premature convergence and falling into local optima during the iteration process, resulting in instability and high randomness in the final optimal solution [11]. Therefore, they improved the traditional genetic algorithm from two aspects: calibration of fitness value functions and population diversification to achieve the final optimization effect. The mathematical model Shao, Jiang and Wang establish is based on a truss structure as an example, with the cross-sectional size of the optimized cross-sectional area as the design variable. The target

structure is to minimize the overall weight of the truss structure by using stress constraints or constrained node displacement lever constraints. After improving the traditional Genetic Algorithm, Shao et al. effectively expand the optimization space and solve the problems of premature convergence, poor accuracy, and high randomness. Shao et al. apply the improved Genetic Algorithm to optimize the structural design. It is concluded that optimization results show that the optimal solution meet the actual engineering needs of architectural structural design optimization, and the structural design's practicality is greatly improved, which has scientific reference significance [11]. Besides, Ke et al. mainly focus on dealing with technical issues such as barrier thickness, multiple peaks, and initial point not in feasible region by using a different optimization algorithm Response Surface Methodology (RSM) [12]. RSM is suitable for problems with low non-linearity, where the linear response surface has high approximation accuracy and can handle multiple independent variables. RSM can also provide accurate mathematical descriptions of dependent variables, making dependent variables easy to optimize and analyze.



Fig. 2 3D Structure Model.

Jiao et al. construct a 3D structure model for a 10-story frame structure as shown in Fig. 2. According to the requirements of the frame structure specifications, Jiao et al. take the structural stiffness ratio, bearing capacity ratio, and period ratio as constraints. They also set the maximum inter story displacement angle of $1/550$ in the X and Y directions of the structure as the optimization purpose.

Table 2. Sensitivity of each variable and optimization results

Group number	Variable number	Type	Sensitivity (%)	Initial value(mm)	Optimization value (mm)
1	1	Width	-20.789	600	800
	2	Length	-38.522	800	1100
3	5	Width	-18.911	600	800
	6	Length	-33.577	1000	1100
4	7	Width	-21.088	600	800
	8	Length	-35.312	800	1100
7	13	Width	-1.518	600	400
	14	Length	30.282	600	400
8	15	Width	-2.199	600	400
	16	Length	28.892	600	400
10	19	Width	5.307	600	400
	20	Length	15.289	600	400

As shown in the Table 2, the sensitivity of each variable showed in the third column increases significantly in the cross-section of the left corner column, such as in the first and fourth groups. The reason is that the left side stiffness of the structure is weak, leading to a greater torsional effect.

Increasing the left corner column can most effectively improve the torsional stiffness of the structure [12]. The overall indicators of the structure before and after optimization are shown in Table 3. It can be seen that the seismic displacement angles in the X and Y directions after optimization are 1/658 and 1/747, respectively, which are significantly increased compared to before optimization, solving the problem of overall stiffness being too high. At the same time, the displacement ratio of the first floor is reduced to 1.18, significantly reducing the torsional effect. [12] Jiao, Liang and Jia conclude that RSM can be used to optimize the architectural structural design, the goal of saving materials and improving seismic performance is achieved [12].

Table 3. The overall indicators of the structure before and after optimization

	Before optimization	After optimization
X-direction seismic displacement angle	1/986	1/658
Y-direction seismic displacement angle	1/872	1/747
Maximum Y-direction displacement ratio	1.5	1.18
First cycle	1.486s (X-direction)	1.931s (X-direction)
Second cycle	1.437s (Y-direction)	1.697s (Y-direction)
Third cycle	1.150s (Torsion)	1.553s (Torsion)

6. Limitations and Future Outlooks

With the rapid development of technology in today's world and the increasingly fierce competition among individuals or enterprises, the role of optimization has become increasingly important. From the application of optimization in three different fields mentioned earlier, it can be seen that optimization plays a important role in many applications, but many optimization methods still have some limitations and challenges. Although algorithms need to be chosen based on specific optimization problems, traditional optimization algorithms may not be able to cope with the new problems that arise in this era of big data. Optimizing algorithms requires a significant amount of time and computational resources when dealing with large-scale and complex problems. This makes them potentially infeasible or inefficient in practical applications. In addition, many optimization algorithms lack theoretical support, which makes it difficult for users to conduct mathematical analysis and comparison on them.

In the future, it is hoped to improve optimization methods through more innovative methods and cutting-edge technology to achieve more efficient optimization. In many application scenarios, data is limited and many factors such as investor preferences and customer satisfaction are difficult to fully convert into data. Therefore, the generalization ability of optimization models is crucial. Future research will need to focus on developing optimization models that can be generalized to unknown scenarios to improve the model's adaptability. With the development of artificial intelligence, optimization may also become more intelligent and automated. Through continuous optimization of performance and functionality, future optimization algorithms may be able to more comprehensively adapt to the environment and handle high-dimensional, complex, and multi data problems, and even automatically analyze and design optimization models. However, in addition to theoretical and technical research, one also needs to pay attention to the impact of optimization technology on society. With the widespread application of optimization technology, the impact of optimization on society and economy is also increasing. Therefore, it is necessary to study and develop corresponding standards to ensure the reasonable and safe use of optimization, which may involve how to balance social and ethical considerations while ensuring the efficiency of optimization.

7. Conclusion

In conclusion, some effective optimization methods and optimization strategies have been summarized from the application introduced in the article, such as combination optimization algorithms for multidimensional models or improved optimization algorithms based on optimization

problems. In the era of big data, even though many problems are always complicated with many or complex factors that make it difficult to accurately model or optimize with a single optimization algorithm, researchers are still constantly planning and improving experiments to pursue better and more adaptive optimization methods. It is believed that with the intelligence of researchers, the future optimization algorithm and optimization efficiency will be improved. this article introduces the principles of optimization and optimization applications in three different fields. The research of this paper has a great significance for promoting the application of optimization in different fields and improving the overall efficiency of enterprises and society.

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