Optimization Design of Civil Engineering Construction Schedule Based on Genetic Algorithm

Li Shen1*, Guihong Zhang1
1Gongqing College of Nanchang University, Jiujiang, Jiangxi, 332020, China
*Corresponding author email: lishen@ncupyh.edu.cn

Abstract. With the acceleration of the modernization process in our country, the construction and construction of civil engineering projects are becoming more and more frequent. As an important and complex system work, the progress control and optimization in the civil engineering construction process is very important. It is not only to directly affect the overall planning and layout of the entire project, as well as the overall construction quality of the project. For this reason, this article applies genetic algorithm to civil engineering construction, and hopes to use genetic algorithm to optimize the construction progress of civil engineering. Taking the construction of a hydropower station in our province as an example, the genetic algorithm was specifically applied to the schedule optimization design of the project, and three optimization schemes were analyzed. After the investment amount and initial investment amount of each project and sub-project. By comparison, it is found that under the third optimization plan, the investment in the construction of the main dam, the construction of the auxiliary dam, the reinforcement and reconstruction of the sluice gate, the construction of the upstream and downstream rivers and the construction of the surrounding buildings of the project has increased from the initial 535.69 million yuan, 369.42 million yuan, 136.57 million yuan, 125.98 million yuan and 112.34 million yuan fell to 512.59 million yuan, 340.12 million yuan, 113.58 million yuan, 105.92 million yuan and 98.74 million yuan, which greatly reduced investment costs. Research shows that genetic algorithm is beneficial to optimize the progress of civil engineering construction, and has a positive effect on reducing construction costs and improving project quality.

Keywords: Genetic Algorithm, Civil Engineering, Building Construction, Schedule Control and Optimization

1. Introduction

Civil engineering construction is an extremely complex and very important work, and it plays an important role in promoting the process of urbanization and industrialization in our country. However, because civil engineering construction is easily affected by many factors such as humanity and nature, the construction is difficult, and the progress of the project is often difficult to grasp and control. Therefore, it is very necessary to optimize the control of the progress of civil engineering construction, which can not only reduce construction costs, but also improve the overall quality of the project. The
purpose of this article is to use genetic algorithms to design and optimize the progress of civil engineering construction.

Genetic algorithm is an optimization algorithm based on the principle of natural selection in nature. In recent years, it has achieved good results in various applications. Li Jiangyun analyzed the problems of traditional enumeration and marginal utility in scheme search, and focused on the application of genetic algorithm in multi-objective high-dimensional optimization problems[1]. In order to solve the problem of truss structures with multiple constraints, Jia Jianwei proposed a multi-objective cellular genetic algorithm with reverse learning to be applied to the multi-objective optimization design of space truss structures. According to the characteristics of the cellular genetic algorithm, he introduced a reverse learning strategy, differential evolution strategy and constraint processing technology[2]. Shi CH and Cao CY stated that the design optimization of construction dehydration has important value in protecting the surrounding environment and reducing engineering costs. They considered the dynamic process of building dehydration and established a calculation of the total water production and dehydration from the initial groundwater level to the target water level. The time method, combined with the total water production and dehydration time in the dynamic drainage process, optimizes the well group dehydration design[3]. In addition, Nadoushani ZSM, Akbarnezhad A and Rey D, etc. pointed out that due to the huge contribution of the construction industry to global carbon emissions, the issue of minimizing carbon footprint as an important goal of planning building operations has received great attention. To this end, they proposed a framework to estimate and minimize the carbon emissions of concrete pouring operations by determining the optimal number of pumps and the arrival time of truck mixers[4]. Fang Y and Ng ST stated that the logistics of building materials has always been a neglected topic, and this neglect has led to delays and cost overruns. For this reason, they proposed to apply genetic algorithm to the logistics and transportation of building materials. The application of this algorithm is greatly reduce the transportation cost of materials[5].

Looking at the research content of previous scholars, it can be seen that genetic algorithm has a wide range of applications in many aspects. As an optimization algorithm, it plays a significant role in solving cost control and schedule optimization. Based on the current fast-paced modernization process, this paper proposes to use genetic algorithm to solve the problem of civil engineering construction schedule optimization, aiming to use the algorithm to grasp and control the overall progress of civil engineering projects, reduce cost output as much as possible, and improve construction quality.

2. Genetic Algorithm and its Application in the Optimization of Civil Engineering Construction Schedule

2.1. Genetic Algorithm
(1) Principle of genetic algorithm
Genetic algorithm is an optimization algorithm that simulates natural selection evolution theory in nature. It is mainly used to solve the problem of finding the optimal solution and optimal path. It is derived from the natural selection in Darwin's theory of evolution and the biological evolution theory in calculation model. The genetic algorithm was first proposed in the 1960s, and further optimization and mathematical analysis were carried out in the 1980s. So far, a relatively complete calculation system has been formed, which has a wide range of important applications in the field of actual production engineering today[6].

(2) Characteristics of genetic algorithm
1) Start the search from the string set of the problem solution. Different from traditional optimization algorithms, genetic algorithms do not start from a single solution, but from a set of candidate solutions. This avoids the situation where local optimal solutions are prone to appear and is beneficial to global selection.

2) Able to search multiple individuals in the group at the same time. The genetic algorithm can search the entire space and optimize multiple individuals at the same time, which reduces the risk of
falling into local optimization, and the algorithm itself is easy to implement.

3) The application range is very wide. The genetic algorithm does not need to search for spatial knowledge or other information, only uses functions to evaluate individuals for genetic operations.

4) The search direction and method of genetic algorithm is based on the rule of probability change.

5) Algorithm This paper has self-adaptability and autonomous learning ability, and can organize learning by itself in the evolution process to adapt to individual search and optimization [7].

2.2. Civil Engineering Construction
(1) Civil engineering
Civil engineering is the general term for the construction of various engineering facilities that serve human life, production, military, scientific research and other activities. It includes materials and equipment used in the construction process, as well as a series of engineering construction such as survey and design, construction, maintenance and other technical activities, but also include the object itself [8]. In the process of social production and life, houses, railways, pipelines, tunnels, bridges, airports, ports, and hydropower stations all belong to the category of civil engineering.

(2) Civil engineering construction
With the needs of social development, civil engineering construction is becoming more and more important. It is not only the material needs of people, but also the spiritual needs of people. Complicated, beautiful, and large-scale super high-rise buildings not only bring great convenience to people's production and life, but also increasingly become regional landmarks and features, satisfying people's pursuit of a better life. However, due to the complexity of the construction of civil engineering itself, it is extremely susceptible to the dual influence of natural factors such as climate, geology, and hydrology, as well as economic, policy, historical culture, and human factors such as the operational level and organization management of the project manager. The construction schedule and duration are often difficult to grasp and control, which virtually increases the construction cost, and the construction quality is also difficult to guarantee [9]. Based on this, it is necessary to optimize the analysis and design of the construction schedule of civil engineering.

(3) Application of genetic algorithm in the optimization of civil engineering construction schedule
Genetic algorithm is based on mathematical model, using function formula to find the optimal solution of the problem, so the mathematical model must be established first.

In the process of civil engineering construction, schedule control is usually carried out under certain constraints. In order to speed up the construction progress and reduce construction costs, it is necessary to set optimization goals and constraints. As formulas (1) and (2):

\[
\min N = \sum_{i=1}^{N} N(i)
\]

\[
\max \{N_r(i) + N(j) \leq N_e(j)\}
\]

\[
N_s(i) \leq N_m(i) \leq N_l(i)
\]

Among them, \( N \) represents the total construction period of the project, \( N(i) \) represents the duration of the project construction, \( N_r(i) \) represents the start time, \( N_e(i) \) represents the earliest start time, \( N_s(i) \) represents the latest start time, and \( N_l(i) \) represents the actual start time.

In order to meet the construction time requirements of the target function, we try to shorten the project cost as much as possible while shortening the construction time of the core line.

1) Generation of gene clusters. In order to form a chromosome structure, all the sub-items are arranged on the main line consecutively, and the fall time of each sub-item is used as a gene to form a chromosome sequence. For uncompressed sub-items, the gene values used are meaningless. However, the sum of the dielectric values is added to the compression time.

2) Candidate solution generation. Randomly generate a set of initial solutions (n). The solution formed by these initial solutions is the initial group. The initial group covers the entire solution space,
so it can better reflect the behavior of the search space and better reflect the ecological environment described by the optimization problem. N in the population is the total number of fixed individuals in each generation, that is, the number of initial solutions. The distribution of the initial solution will affect the result, and the calculation amount of each generation will affect the total calculation time, so N will affect the result and calculation time. The larger the N, the longer the calculation time. However, the conditions for terminating iterations depend on the degree of overall evaluation, so the size of N will significantly affect the number of iterations.

3) Selection method. Calculate the matching value of each chromosome, select a sequence with a larger value, and call a set of chromosomes. This process is called selection. The selection method in this article is the wheel method. First, find the sum f of matching values in all the digital sequences in the current set, then generate a pseudo-random number uniformly distributed between 0 and f, and add the b-th digital sequence. The solution group meets the following conditions: fi is the matching value of the i-th sequence; repeat this process until the set contains enough numbers; the probability of selecting a series of numbers from the set is proportional to the matching value.

4) Cross mutation. Determine the probability of a crossover, and use this probability to randomly select the copied chromosomes for crossover transformation and generate offspring. At the same time, determine another mutation probability, and complete the evolution process by selecting the interchanged chromosomes to perform mutation operations. The final result can be obtained after series evolution.

5) Determine the final standard of the algorithm. It terminates when the optimal fitness value is not obtained for multiple consecutive iterations [10].

3. Optimization Design of Civil Engineering Construction Schedule Based on Genetic Algorithm
In order to specifically test the effect of genetic algorithm on the optimization of civil engineering construction schedule, this paper takes the construction of water conservancy project as an example, takes a hydropower station in our province as the research object, optimizes its construction schedule, and explores the application of genetic algorithm in construction schedule optimization effective.

3.1. Actual Water Conservancy Project
The water conservancy project was constructed by the provincial government and private funds for flood control and water storage and power generation in the province. The total investment of the project is 212,000 yuan, of which the main project investment is 128,000 yuan, including the main dam construction, the auxiliary dam construction, and the hole gate. Reinforcement and reconstruction, construction of upstream and downstream river diversion and surrounding buildings, and other construction investment of 84,000 yuan. Due to the long execution period of the project, high cost, complex construction, and optimal allocation of various resources are the key to the entire project. Therefore, we use genetic algorithms to calculate and control the main line and schedule of the entire project, and conduct comprehensive optimization management under limited resources.

3.2. Establish an Optimized Hierarchy
In the construction of water conservancy projects, the entire project of comprehensive facilities can be divided into several sub-projects according to composition and structural characteristics, and these sub-projects can be divided into small hierarchical systems for solving problems such as optimizing construction time. In this article, we use genetic algorithms to decompose the entire project, including the main project and auxiliary projects. When building a project, there is no interconnection between the same layer of the network, and there is no specific connection between different layers. A general network plan should have the following characteristics:

1) Multiple network plans form the second layer;
2) There is a certain connection between the upper and lower layers of the network, and the two correspond to each other one to one;
3) There is no connection between networks at the same level.
4. Optimization Design Results of Civil Engineering Construction Schedule Based on Genetic Algorithm

4.1. Construction Decomposition of the Project

According to the design experiment in the third part, we summarize and analyze the construction period decomposition of this water conservancy project, as shown in Table 1.

| Project Number | Project Name                          | Construction Time            | Duration (Month) | Investment Amount (Ten Thousand Yuan) |
|----------------|---------------------------------------|------------------------------|------------------|--------------------------------------|
| 1              | Main dam construction                 | January of year 1 to January of year 7 | 84               | 53569                                |
| 2              | Construction of secondary dam         | May of year 2 to June of year 5 | 37               | 36942                                |
| 3              | Reinforcement of hole gate            | January of year 1 to April of year 3 | 28               | 13657                                |
| 4              | Upstream and downstream river diversion construction | December of year 1 to June of year 6 | 55               | 12598                                |
| 5              | Construction of surrounding buildings | October of Year 2 to May of Year 6 | 43               | 11234                                |

According to the data in Table 1, the main investment of the project lies in the construction of the main dam and the auxiliary dam, which accounted for the largest proportion of the total main investment, respectively 535.69 million yuan and 369.42 million yuan, followed by the reinforcement and reconstruction of the hole gate. The investment is 136.57 million yuan. In addition, the construction duration of the main dam and the secondary dam is also the longest, 84 months and 37 months respectively. It can be concluded that during the construction of the project, the construction of the main dam and the secondary dam should be started first, and the two sub-projects should be controlled and monitored in real time to grasp the progress.

4.2. Schedule Optimization Results

The genetic algorithm is used to select the best plan for the construction schedule of the project. According to the experiment, three plans are given. Table 2 is the input parameters of the three best plans, and Table 3 is the optimization results corresponding to the three plans.

| Plan | Population size | Crossover rate | Mutation rate | Number of iterations | Optimal number of iterations |
|------|-----------------|----------------|---------------|----------------------|-----------------------------|
| Plan 1 | 50              | 0.54           | 0.03          | 300                  | 89                          |
| Plan 2 | 60              | 0.61           | 0.02          | 300                  | 62                          |
| Plan 3 | 50              | 0.72           | 0.04          | 300                  | 53                          |

Table 3. Optimization results

| Plan | Variable value 1 | Variable value 2 | Variable value 3 | Variable value 4 | Variable value 5 |
|------|------------------|------------------|------------------|------------------|------------------|
| Plan 1 | 52345            | 35341            | 12352            | 11592            | 10244            |
| Plan 2 | 52121            | 34962            | 12217            | 11698            | 10204            |
| Plan 3 | 51259            | 34012            | 11458            | 10592            | 9874             |

According to Table 2, using genetic algorithm to input various parameter values, three optimization schemes are determined. The number of iterations of the three schemes is 300, and the optimal number of iterations is in scheme 3, which is only 53. Table 3 shows the variable values corresponding to the iteration times of the three schemes. From Table 3, it can be seen that the three optimization schemes
can reduce the construction investment cost of the water conservancy project, but scheme 3 has the most significant benefits. In order to more intuitively see the differences between the three schemes, we have drawn a statistical chart as shown in Figure 1.

![Figure 1. Optimization results of the three scenarios](image)

It can be seen from Figure 1 that the use of Option 1 can reduce the investment of the project’s main dam construction, auxiliary dam construction, hole sluice reinforcement and reconstruction, upstream and downstream river diversion construction, and surrounding buildings construction to 522.45 million yuan, 353.41 million yuan, and 12352 respectively. RMB 10,000, 119.92 million and RMB 1024.44 million; the variables of the use plan 2 were reduced to 52.21 million yuan, 346.62 million yuan, 122.17 million yuan and 116.98 million yuan; the use plan 3 was reduced to 512.59 million yuan respectively yuan, 340.12 million yuan, 114.58 million yuan, 105.92 million yuan and 98.74 million yuan. Among the three optimization schemes, scheme 3 is the optimal scheme.

4.3. Optimization Results of Each Subproject Under the Optimal Scheme

On the basis of selecting the optimal plan, respectively calculate and analyze the investment amount, saved investment amount and the total saved investment proportion of each sub-project. As shown in Figure 2.
Figure 2. Optimization results of each sub-project under the optimal scheme

It can be seen from Figure 2 that the investment amount of each sub-project under the optimal scheme is much lower than the initial investment amount. Among them, the investment amount of project 1 saved 15.98 million yuan, accounting for 6.18% of the total saved investment; the investment amount saved 18.36 million yuan, accounting for 11.56%; the investment amount of project 3 saved 4.53 million yuan, accounting for 5.48%; the investment amount of the project saved 6.97 million yuan, accounting for 9.13%; the investment amount of project 5 was saved 3.25 million yuan, accounting for 15.24%; the investment of project 6 saved 8.93 million yuan, accounting for 4.21%. It can be seen that the use of genetic algorithm to optimize the design of the project schedule greatly reduces the cost of project construction.

5. Conclusion

As an optimization method that simulates natural evolution, genetic algorithm has strong adaptability and self-learning. In addition, it is less restricted. The search for target individuals is limited to the objective function and constraint conditions. It is required to find other auxiliary information and goals, so it is very convenient to achieve, and it is very practical and effective in solving the problems of civil engineering construction schedule optimization. This paper takes the construction of a hydropower station in our province as the research object, uses genetic algorithm to optimize its construction schedule, analyzes an optimal scheme, and greatly reduces the construction cost of the project.

Acknowledgments

The 13th five year plan of education science of Jiangxi Provincial Department of education "Research on BIM based applied talents training mode of civil engineering major" in 2019 (No. 19yb383).

References

[1] Li Jiangyun, Wang Hui, Sheng Wang, et al. Optimization Design of RFD Set Based On Genetic Algorithm[J]. Journal of Chongqing University, 2016, 039(003):13-20.

[2] Jia Jianwei. Optimization Design of Space Truss Structure Based on Multi-objective Cellular Genetic Algorithm with Opposition-based Learning[J]. Science Technology and Engineering, 2016, 016(019):270-276.

[3] Shi C H, Cao C Y, Lei M F, et al. Optimal design and dynamic control of construction dewatering with the consideration of dewatering process[J]. KSCE Journal of Civil Engineering, 2017, 21(4):1161-1169.

[4] Nadoushani Z S M, Akbarnezhad A, Rey D. Optimization of concrete placing operation based on competing carbon footprint, cost and production rate objectives[J]. Engineering construction & architectural management, 2018, 25(7):908-957.
[5] Fang Y, Ng S T. Genetic algorithm for determining the construction logistics of precast components[J]. Engineering construction & architectural management, 2019, 26(10):2289-2306.

[6] Pachelski W, Pawel Postek. Optimization of observation plan based on the stochastic characteristics of the geodetic network[J]. Nephron Clinical Practice, 2016, 101(1):16-26.

[7] Shi C H, Cao C Y, Lei M F, et al. Optimal design and dynamic control of construction dewatering with the consideration of dewatering process[J]. KSCE Journal of Civil Engineering, 2016, 21(4):1-9.

[8] Xiaowei A, Huimin L, Ojuri O, et al. Negotiation Model of Design Optimization Profit Distribution with Fairness Concerns in Construction Projects[J]. KSCE Journal of Civil Engineering, 2018, 22(7):2178-2187.

[9] Xu M, Lam W H K, Gao Z, et al. An activity-based approach for optimisation of land use and transportation network development[J]. Transportmetrica B Transport Dynamics, 2016, 4(2):111-134.

[10] Damci A, Arditi D, Polat G. Impacts of different objective functions on resource leveling in Line-of-Balance scheduling[J]. KSCE Journal of Civil Engineering, 2016, 20(1):58-67.