Optimal Algorithm of Expressway Maintenance Scheme Based on Genetic Algorithm

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***Abstract*—The genetic algorithm (GA), characterized by parallelism and global optimization capabilities, is well-suited for solving optimization problems related to expressway maintenance schemes. In this study, we improved GA operators and algorithm parameters within the existing maintenance scheme optimization model, thereby enhancing the operational efficiency of the GA. Building on this foundation, an optimization algorithm for expressway maintenance schemes was developed. Subsequently, MATLAB was employed to program the algorithm and solve the expressway maintenance scheme problem. When compared with the solution results in the reference, the proposed approach achieved a reduction of approximately 3.6% in maintenance costs and an improvement of about 47% in operation speed, verifying the algorithm's reliability and effectiveness. Finally, visualization of the algorithm program was enabled using MATLAB App Designer and MATLAB Compiler. This method can be popularized and applied in aspects such as expressway maintenance decision-making and optimization of building maintenance schemes.**

***Keywords*—Genetic algorithm (GA); expressway; scheme optimization; MATLAB; program development**

I. Introduction

With the rapid development of the worldwide transportation industry, expressway mileage has increased, encouraging global economic growth [1-3]. The transportation network has evolved into a vital national asset [4]. The development and construction of expressways have greatly improved our quality of life [5]. However, due to the influence of traffic load and environmental effects, the expressway's surface state would deteriorate with time [6]. Maintaining the expressway regularly and repairing pavement defects can ensure people travel safely. Good road conditions help to ensure the country's or region's sustainable economic growth [7]. The maintenance cost of the expressway is expensive, and the maintenance decision-making is very complicated. However, a country's financial resources are often limited. If appropriate conservation strategies are not adopted, budget utilization will be reduced, and road conditions will not be effectively improved [8]. Therefore, it is necessary to allocate the maintenance scheme of the expressway reasonably and maintain the expressway on the premise of cost-saving.

In recent years, the problem of pavement maintenance has received extensive attention from scholars globally. Extensive research on the monitoring of pavement conditions, evaluation of pavement conditions, pavement optimization, and other related issues have been conducted, which has promoted the rapid development of the field of pavement maintenance. Cano-Ortiz et al. [7] pointed out the importance of synthesizing a machine-learning algorithm to develop efficient pavement condition monitoring technology. They summarized and introduced different methods of pavement condition monitoring and evaluation based on the machine learning algorithm and evaluated the advantages and disadvantages of the pavement evaluation model from a theoretical point of view. Shon et al. [9] proposed an autonomous condition monitoring-based pavement management system (ACM-PMS), which uses self-driving vehicles to collect road condition data in real time, thus realizing the independent state detection of the road surface. The mathematical framework was used to evaluate it, and the results showed that the system has the advantages of good accuracy and low social cost. Li et al. [10] proposed a vision-based pavement condition detection strategy, which uses the combination of machine learning and image processing to identify the pavement condition, which provides a basis for pavement maintenance decision-making. Staniek and Czech [11] investigated the use of self-correcting neural networks in diagnosing traffic conditions. They suggested a road condition detection method based on a neural network algorithm, established a road detection station based on stereo vision technology and formed a road condition diagnosis system. The system has high precision, reliability, wide application range, and low cost in road condition diagnosis. Zhang et al. [12] pointed out that the 3D detection method of road conditions has higher accuracy and practicability than 2D and traditional manual detection methods. They proposed an automatic detection method for pavement defects, which uses a 3D laser to scan the pavement condition to obtain information such as pavement cracks and deformation. The test results showed that the detection accuracy of this method is high, and the error of pavement defect location is small. Nik et al. [13], aiming to reduce cost, reduce detection error, and improve analysis accuracy, applied a hybrid genetic algorithm (GA) and particle swarm algorithm to propose a layout scheme of pavement detection units, which can significantly reduce the time cost of pavement detection personnel. Zakeri et al. [14] proposed a digital imaging system based on a quadcopter, which can detect pavement cracks in disaster-stricken areas and analyze and process the data. The system has high mobility, stable and reliable signal output, and can operate stably in various complex environments. Radopoulou and Brilakis [15] pointed out that the maintenance decision of pavement needs to rely on the latest pavement data, and the current road condition data collection method cannot be extended to all areas due to the high cost. There is an urgent need for a low-cost road condition data collection method that can be updated in real-time. They proposed a way for car cameras to collect data and detect road conditions. The test results show that the method has high accuracy. Kheirati and Golroo [16] pointed out the defects of the pavement condition index used to evaluate the pavement condition in the current road management system. They developed a new pavement condition index: Universal Condition Index (UCI), using the machine learning model, which considers factors such as road roughness, damage degree, and road safety, achieving better comprehensiveness, economy, and practicability. Sholevar et al. [4] pointed out that although machine learning technology has some limitations, relying on its robust learning algorithm, machine learning technology still has a decisive advantage in road condition assessment. They summarized the technology of using machine learning to evaluate road conditions, elaborated on the application of various machine learning methods in road condition evaluation, and pointed out future research directions. Hanandeh [17] employed GA and an artificial neural network to develop the evaluation model for the road pavement quality index in Jordan, using surface rating, present serviceability rating, and pavement age as variables. The results demonstrated that the GA model performs better than the neural network model. Li et al. [8] proposed a preventive maintenance strategy for expressway pavement, which realized the maintenance of expressway pavement in specific areas using an artificial neural network algorithm to mine the database. They used a back propagation and a hybrid neural network model to predict highway pavement performance and GA to optimize the model's parameters. Chen and Zheng [18] demonstrated that the future pavement maintenance decision problem is a multi-objective optimization. The multi-objective optimization method is versatile in handling complicated problems, and its application in pavement maintenance has gained much attention. They reviewed the most advanced multi-objective optimization methods employed in the pavement maintenance management system's decision-making module and the accompanying multi-objective optimization models, decision-making tools, and optimization methodologies. Simultaneously, the need to make informed decisions in pavement care was underlined. Santos et al. [19] pointed out that environmental factors and sustainability should be considered when formulating pavement maintenance plans. They proposed a pavement management decision-making system based on multi-objective optimization—the method comprised a multi-objective optimization module, pavement life evaluation module, and decision-making module. Thus, the greenhouse gas emission during highway maintenance was reduced based on reducing the cost of highway maintenance. Yang et al. [20] proposed a new pavement management system with a built-in multi-objective GA. Thus, the formulation of the optimal maintenance scheme for the expressway was realized. The design minimized pavement maintenance costs while improving highway pavement service levels, supporting pavement engineers in making maintenance decisions. Hamdi et al. [21] pointed out that most existing road networks lack monitoring data and evaluation information. Road maintenance costs are relatively insufficient, which is not conducive to developing the national or regional economy. They introduced GA based on multi-objective planning of pavement. They studied the pavement maintenance strategy with the damaged condition, which can improve the service level of pavement and reduce the cost of pavement maintenance. Naseri et al. [22] used two global optimization algorithms, GA and water cycle algorithm, for maintenance planning of large-scale road networks and developed a new index to evaluate equity in the pavement maintenance schedule, reducing the cost of pavement maintenance planning fluctuations. Their research showed that preventive maintenance of pavements is critical for reducing maintenance costs and improving pavement health. According to Chootinan et al. [23], the decline of highway pavement performance is unknown. Using deterministic formulation in pavement maintenance planning will result in considerable variances in the outcomes. They suggested a pavement maintenance scheme planning method based on GA that considered the unpredictability and uncertainty of pavement performance decline during the planning period. Li [24] summarized the factors affecting highway pavement performance, combined with domestic and foreign norms and industry standards, to determine the evaluation index of pavement performance. She introduced the life cycle cost analysis theory and conducted an in-depth study using Rough Set Theory to evaluate pavement performance. The Grey System Theory model is used to predict pavement performance and GA to optimize expressway pavement maintenance schemes. After that, she put forward an expressway pavement maintenance scheme optimization strategy based on life cycle management. Liu et al. [25] proposed an expressway maintenance strategy optimization algorithm under a specified service level. They studied the minimum cost model under the specified service level and the solving model based on GA and proved the practicability of the algorithm by solving the existing case. In addition, overloading, according to Rifai et al. [26], is a major cause of pavement deterioration. They took budget and overloading as restrictions after thoroughly examining the characteristics of increased pavement roughness produced by overloading and the limitation of pavement maintenance expenses. They created a two-objective optimization model using GA. The objective optimization model proved its feasibility through case analysis. Jha and Abdullah [27] assessed that, like highway surfaces, highway appendages, such as guardrails, also need regular maintenance to improve the overall life cycle of the highway. They used GA to develop a Markovian model that can prolong the expressway's whole life cycle, and a calculation example was used to prove the method's effectiveness. Elmansouri et al. [28] utilized sixteen criteria from the Distress Identification Manual, comparing Pavement Condition Index and Multi-Criteria Decision-Making to assess road pavement. Their study confirmed MCDM's reliability in indicating pavement deterioration, similar to PCI results. Vrtagic et al. [29] utilized a Multilayer Perceptron model along with machine learning techniques and optimization methods to predict and manage pavement deformation at road intersections. Their study highlights the impact of heavy vehicles and braking on road wear and uses real-time traffic data for dynamic pavement degradation modeling. The findings suggest that controlled traffic flow and optimized intersection wait times can significantly enhance road conditions, reduce maintenance costs, and improve safety, showcasing the potential of AI in road infrastructure management.

Genetic algorithm is a global optimization adaptive probability search algorithm developed by drawing lessons from natural selection and genetic evolution mechanisms in biology. It has the characteristics of self-organization and self-study [30-34]. This optimization method can be applied to the processing and solution of multi-objective optimization problems [35-37]. The research results of Mortezaei Farizhendy et al. [38-40] have proved the feasibility of GA in solving the multi-objective decision-making problem of maintenance scheme selection. Currently, GA has been widely used to solve the problems of pavement condition detection, pavement quality evaluation, pavement performance prediction, pavement maintenance planning, and significantly to develop and optimize maintenance schemes for pavements.

In summary, GA has specific positive significance in expressway maintenance scheme optimization. However, at present, the research on the formulation and optimization of expressway pavement maintenance schemes is not comprehensive, the existing pavement maintenance algorithms have low operational efficiency, and most of them lack the visualization of the algorithm program, so the intuition and convenience of the algorithm are significantly reduced.

This study proposed an optimization algorithm based on GA to facilitate the optimization of the expressway maintenance scheme and reduce its maintenance cost. The optimization algorithm can formulate the maintenance scheme according to pavement performance prediction and evaluation results. In addition, this study realized the visualization of the algorithm through MATLAB.

II. Mathematical Model

Under the condition that the performance index the expressway needs to meet has been given, this study took the maintenance methods of different road sections at different times as control variables. Then, the minimum sum of the required cost was taken as the solution goal. That is to choose the most economical and feasible scheme to repair the damaged pavement and ensure that the expressways meet the performance indicators stipulated by the relevant state departments after maintenance.

$$\text{Min} \sum_{t=1}^{T} \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} (x_{ij}^{k}(t) \times C_i^k \times (1 + r_c)^{-t}) \quad (1)$$

$$\text{s.t} \sum_{k=1}^{5} x_{ij}^{k}(t) = 1$$

$$\forall 1 \le t \le T,\ 1 \le i \le I,\ 1 \le j \le J_I \quad (2)$$

$$x_{ij}^{k}(t) \in \{0,1\}$$

$$\forall 1 \le t \le T,\ 1 \le i \le I,\ 1 \le j \le J_I,\ 1 \le k \le 5 \quad (3)$$

$$ROG_i^t \ge ROG_i^D,\ \forall 1 \le i \le I,\ 1 \le t \le T \quad (4)$$

$$ROP_i^t \le ROP_i^D,\ \forall 1 \le i \le I,\ 1 \le t \le T \quad (5)$$

where,

T - The number of planning years, referring to the maintenance planning time range of the expressway, $1 \le t \le T$;

I - The number of roads that need to be maintained in the road network, $1 \le i \le I$;

J - The number of road sections that need to be maintained for the i-th road in the road network, $1 \le j \le J_I$;

K - The number of maintenance measures. Different maintenance measures are adopted according to the degree of damage to the expressway, $1 \le k \le 5$;

$x_{ij}^{k}(t)$ - If the k-th maintenance measure is adopted in the j-th section of the i-th road in the road network that needs to be maintained in the t-th planning year, the value is 1. Otherwise, it is 0;

C_i^k - The cost of adopting the k-th maintenance measure for the i-th road in the road network. Various maintenance measures and corresponding expenses in the mathematical model are shown in Table I;

r_c - The interest rate used to change future payments to present value, subject to inflation, is 4% in this study;

ROG_i^t - The excellent and good road rate of the i-th road in the road network in the t-th planning year, the calculation equation is Eq. (6):

$$ROG_i^t = \frac{\sum_{j=1}^{Ji} L_{ij} \times G_{ij}^t}{\sum_{j=1}^{Ji} L_{ij}},\ 1 \le i \le I,\ 1 \le t \le T \quad (6)$$

ROP_i^t - The weak and poor road rate of the i-th road in the road network in the t-th planning year, the calculation equation is Eq. (7):

$$ROP_i^t = \frac{\sum_{j=1}^{Ji} L_{ij} \times P_{ij}^t}{\sum_{j=1}^{Ji} L_{ij}},\ 1 \le i \le I,\ 1 \le t \le T \quad (7)$$

ROG_i^D - Excellent and good road rates stipulated by relevant departments;

ROP_i^D - Weak and poor road rates stipulated by relevant departments.

TABLE I. Pavement Maintenance Measures and Corresponding Costs

Maintenance measures	Routine maintenance	Medium repair and mat coat	Medium repair and sliding layer	Heavy repair and rebuild	Heavy repair and reinforce
Fees standard (10^4CNY/KM)	5	20	15	50	40

The objective function Eq. (1) in the model represents solving the sum of the minimum maintenance cost of each road section of the expressway during the planning period, and the constraints Eq. (2) and Eq. (3) represent the choice of maintenance measures. Constraints Eq. (4) and Eq. (5) indicate that the expressway needs to meet the performance indicators specified by the relevant departments after maintenance.

III. MODEL FOR GA

Genetic algorithm was used to solve and optimize the expressway maintenance scheme in [25]. In this study, the algorithm was improved based on it, and the improved solution process is shown in Fig. 1.

A. Coding of Genes

Genetic algorithm's gene coding methods mainly include binary coding, floating-point, symbol coding methods, etc. In this study, the symbol coding method was used to number all maintenance measures because it is more suitable for solving the optimization problem of the expressway maintenance scheme. This study coded "routine maintenance" as 1, coded "medium repair and mat coat" as 2, coded "medium repair and sliding layer" as 3, coded "heavy repair and rebuild" as 4, and coded "heavy repair and reinforce" as 5. The string Ji composed of these characters represents the maintenance measures of different sections of each road. The character set consisting of n strings represents the maintenance measures for all sections of the road network (n is the number of roads in the road network), as depicted in Fig. 2.

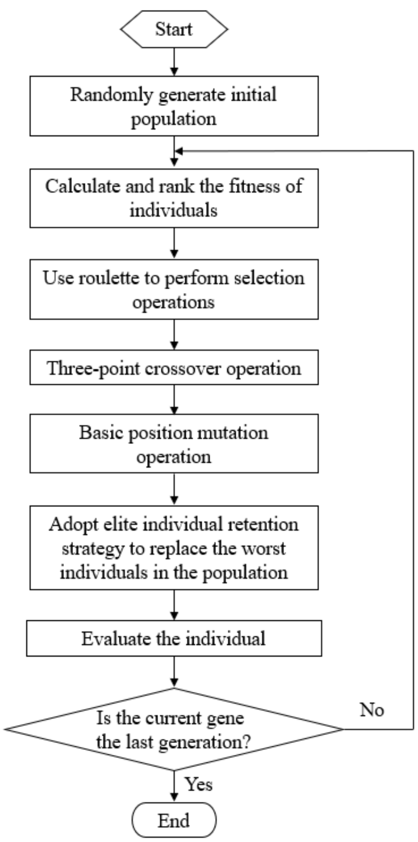

Fig. 1. Flow of GA.

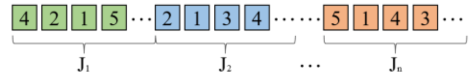

Fig. 2. Gene coding.

B. Initialize the Population

The methods of initializing the population in GA mainly include randomly generating and selecting samples from a set of constraint solutions obtained from certain constraints to generate the initial population. Due to the different maintenance conditions of expressways in different areas, this study randomly generated the initial population to increase the feasibility and practicability of applying the solution model to solve engineering cases.

C. Fitness Function

The primary issue with GA is that it is simple to converge on optimal local solutions [41]. Due to the peculiarities of the expressway maintenance scheme optimization problem, the fitness function of GA in this research comprised two parts. The objective function of the mathematical model was the fitness function when the individual met the necessarily defined performance metrics. The fitness function consisted of the objective and the penalty functions when the individual failed to satisfy the set performance metrics. The penalty function was used to diminish the fitness of individuals in the population that did not meet the limitations instead of directly eliminating them. Consequently, under the assumption that the development direction of the algorithm has little impact, the variety of the population can be ensured to prevent the algorithm from converging prematurely.

D. Selection, Crossover, and Mutation Operations

The selection methods in GA include roulette, random sampling, tournament method, etc. [42, 43]. In this study, the proportional selection operator was used to select contemporary individuals by roulette, and the individuals with high fitness were chosen to the greatest extent. At the same time, this study improved the selection operator, adopted the elite individual retention strategy, calculated and sorted the fitness of all individuals in the parent generation, and selected the individual with the best fitness, the elite individual. Kept it directly in the offspring population, and the individuals with the worst fitness in the offspring population were replaced. This method can avoid the destruction of the excellent genes of the parent generation due to crossover and mutation operations, thereby improving the efficiency of GA to find the optimal solution.

Crossover operation refers to replacing and recombining two-parent individuals' gene structures to produce new individuals. In reference [25], the two-point crossover operator was employed for crossover operation. Nevertheless, due to the enormous population size necessary to optimize the expressway maintenance scheme using GA, the population evolution pace was slow, and the solution efficiency was low when this method was applied. The crossover operator was updated in this study. Adopting the three-point crossing model gave the chromosomes additional options during the crossover, aided the algorithm in escaping the ideal local solution, and enhanced operating efficiency. These are the specific implementation steps: Three random crossing locations are set in the two paired chromosome coding strings, dividing the two-parent genes into four random pieces. As depicted in Fig. 3, a portion of the chromosomes in the two-parent genes are exchanged to create two-child genes. A comparative study of the example's solution results demonstrated that the strategy might increase the efficiency of the algorithm solution. It is more suitable for tackling the expressway maintenance scheme optimization problem.

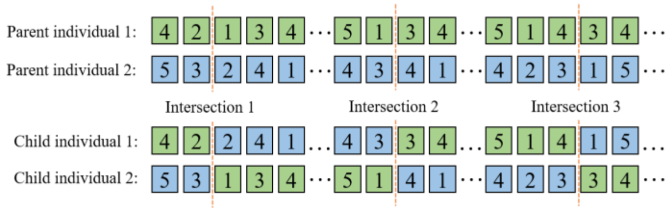

Fig. 3. Crossover operation.

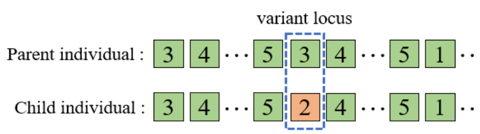

Fig. 4. Mutation operation.

The mutation operation means randomly selecting genes at some positions on the chromosome and replacing them with their alleles to form a new individual. The common ways of mutation are basic position mutation, uniform mutation, boundary mutation, non-uniform mutation, gaussian mutation, etc. In this study, the method of basic position mutation was used to randomly select a locus in the gene for mutation, as shown in Fig. 4.

IV. Results and Discussion

Based on the mathematical and GA models, this study completed the programming of the expressway maintenance scheme optimization algorithm using MATLAB. The algorithm can formulate maintenance schemes based on expressway performance prediction and evaluation results. This study used the algorithm to solve the case study in the reference [25] and compared the decision optimization results to analyze whether the algorithm is reliable.

In [25], the authors selected six sections of an expressway, each with a length of 1 km, and collected their pavement performance testing data for five consecutive years. The performance test data of each road section in the fifth year is shown in Table II, and the performance test data of the sixth road section over the years is shown in Table III. Then the grey system theory model was used to predict the pavement performance, and the rough set theory was used to make a fuzzy comprehensive evaluation of pavement condition [24, 25]. The evaluation results of road conditions are shown in Fig. 5. On this basis, this study developed and optimized the maintenance scheme.

TABLE II. Performance Test Data of each Road Section in the Fifth Year

Road section	Index				
	PCI (Pavement Condition Index)	RQI (Riding Quality Index)	PSSI (Pavement Structure Strength Index)	SRI (Skidding Resistance Index)	RRD (Road Rutting Depth)
1	80.4	96.3	76.9	88.7	11.1
2	90.0	96.1	75.8	90.3	10.6
3	93.8	97.2	97.8	88.4	10.1
4	88.4	96.2	91.2	90.9	12.5
5	98.4	96.5	86.7	92.7	12.2
6	77.0	88.5	92.6	87.5	7.6

TABLE III. Performance Test Data of the Sixth Road Section Over the Years

Index	Year				
	First	Second	Third	Fourth	Fifth
PCI	91.0	88.0	85.0	81.0	77.0
RQI	96.2	95.4	94.2	91.0	88.5
PSSI	99.3	98.7	97.8	95.3	92.6
SRI	94.5	93.2	91.4	89.7	87.5
RRD	33.3	20.0	16.7	11.1	7.8

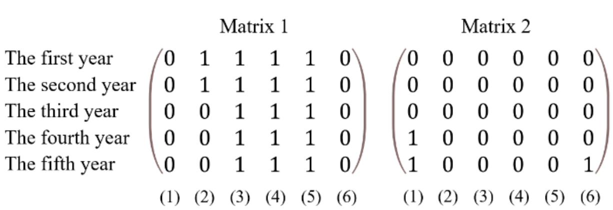

Fig. 5. The evaluation result of the pavement condition.

The evaluation findings for pavement are categorized into five grades: excellent, good, medium, weak, and poor. Matrix 1 determines whether or not the annual evaluation results of each road segment are excellent or good. The second matrix indicates whether the annual evaluation results for each road segment are weak or poor. For instance, the evaluation of the third road segment of the fifth year is excellent or good, whereas the assessment of the sixth road segment is weak or poor.

TABLE IV. Parameters of GA

Parameters of GA	This paper	Ref. [25]
Population size	300	200
Number of iterations	200	200
Crossover rate	0.9	0.6
Mutation rate	0.4	0.1

Combined with the specific characteristics of the optimization problem of the expressway maintenance scheme, many experiments were carried out, and the parameters of GA were set, as shown in Table IV. Input the road condition evaluation result into the algorithm program. The final cost optimization situation is shown in Table V, the maintenance scheme distribution is shown in Table VI, and the comparison between this study and the maintenance costs given in [25] is shown in Fig. 6. In addition, the fitness value convergence trends in this study and in [25] are shown in Fig. 7 and Fig. 8, respectively.

It can be seen from Table V that the total cost of the initial maintenance scheme was CNY-3,243,123. After using the expressway maintenance scheme optimization program to solve the problem, the program obtained an optimal solution in the 63rd generation. The corresponding cost of the best maintenance scheme was CNY-1,335,547. Compared with the cost of the initial maintenance scheme, it was reduced by about 59%. Compared with the cost of the maintenance scheme in [25], it is reduced by about 3.6%.

In the maintenance schemes allocation table, 1 represents "routine maintenance", 2 represents "medium repair and mat coat", 3 represents "medium repair and sliding layer", 4 represents "heavy repair and rebuild", and 5 represents "heavy repair and reinforce". It can be seen from Table VI that only routine maintenance is required for the expressway in the next five years to meet the performance requirements. Compared with the fitness value convergence trend in [25], it can be seen that the operation speed of the algorithm in this study was improved by about 47%. It showed that after modifying the operators of GA and optimizing its parameters, the solution efficiency had been improved, ensuring the expressway maintenance scheme optimization algorithm was reliable and practical.

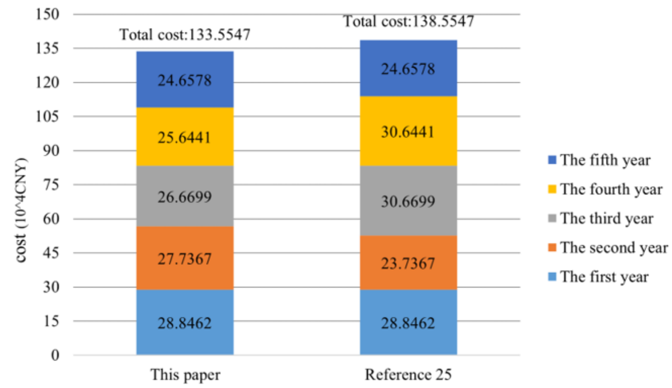

Fig. 6. Comparison of maintenance costs between this study and reference [25].

TABLE V. COST OPTIMIZATION

Algebra of genetic operation	Total cost (10^4CNY)	Cost of every year (10^4CNY)				
		The first-year	The second- year	The third- year	The fourth- year	The fifth- year
1	324.3123	72.1154	60.0962	66.6747	55.5623	69.8638
2	338.0100	76.9231	60.0962	75.5647	55.5623	69.8638
3	309.8619	52.8846	60.0962	75.5647	55.5623	65.7542
4	314.2866	48.0769	69.3417	66.6747	72.6584	57.5349
5	312.4966	72.1154	64.7189	66.6747	55.5623	53.4253
……						
63	133.5547	28.8462	27.7367	26.6699	25.6441	24.6578
……						
200	133.5547	28.8462	27.7367	26.6699	25.6441	24.6578

TABLE VI. ALLOCATION OF MAINTENANCE SCHEMES

Year	Road section					
	1	2	3	4	5	6
The first year	1	1	1	1	1	1
The second year	1	1	1	1	1	1
The third year	1	1	1	1	1	1
The fourth year	1	1	1	1	1	1
The fifth year	1	1	1	1	1	1

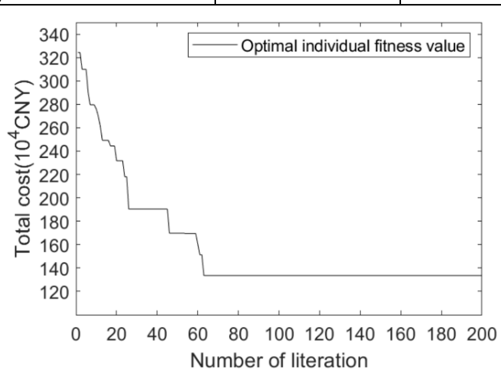

Fig. 7. The convergence trend diagram of fitness value in this study.

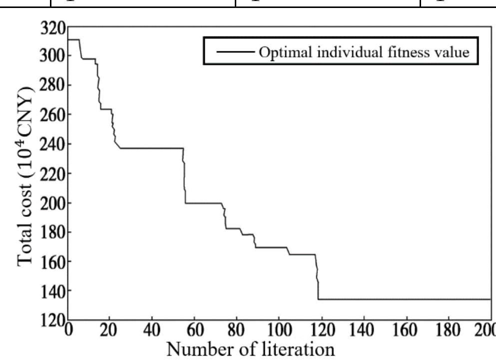

Fig. 8. The convergence trend diagram of fitness value in reference [25].

V. Visual Program Development

MATLAB is a modern computer language used for data analysis, deep learning, visualization, interactive programming, etc. [44]. MATLAB App Designer integrates the functions of setting visualization components and program behavior and provides a visual interface for code, thus realizing human-computer interaction.

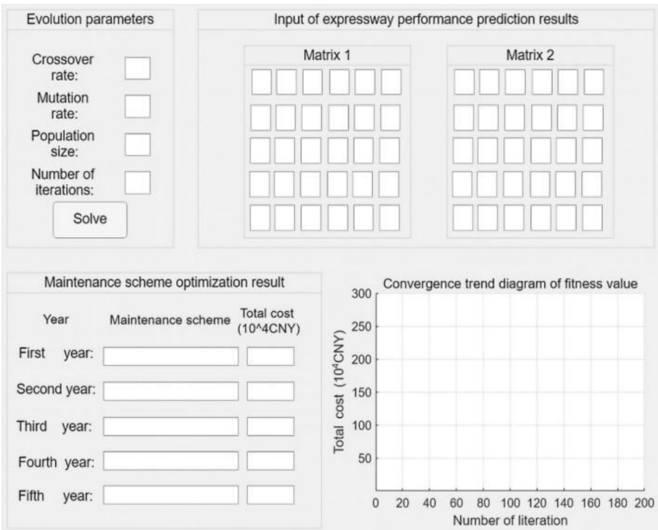

Fig. 9. The interface of the expressway maintenance scheme optimization program.

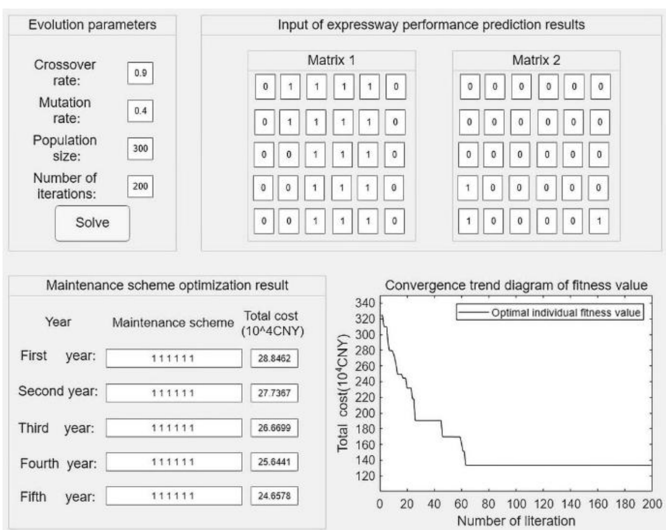

Fig. 10. Output diagram of program operation result.

This study used MATLAB to compile the optimization algorithm program of the expressway maintenance scheme. Still, it will inevitably encounter the following problems in the application process. First, the algorithm program must be run in MATLAB, which puts higher requirements for users' computer hardware equipment. Secondly, in the use process, it is necessary to input algorithm parameters and road condition information in the program's code, which requires users to have a specific programming basis and be familiar with the algorithm program. Finally, the acquisition of the operation results of the algorithm program is more tedious and not intuitive, requiring users to use MATLAB software skillfully and have strong operation ability. These problems raise the threshold of use and, to some extent, hinder the promotion and application of expressway maintenance program optimization algorithms in practical engineering.

To solve the above problems and to increase the feasibility and convenience of using the algorithm to solve other engineering problems, a desktop application was created using MATLAB App Designer and MATLAB Compiler. The program has a built-in expressway maintenance scheme optimization algorithm, which can run independently and takes up less memory to reduce users' hardware requirements, facilitate users to input algorithm parameters and road condition information, and obtain the optimal maintenance scheme. The main interface of the program is shown in Fig. 9. The result of solving the calculation example using this program is shown in Fig. 10.

First, the evolution parameters of GA and the prediction and evaluation results of expressway pavement performance are input into the program interface. Then click the solve button in the interface, and the program will automatically execute the code of the built-in maintenance scheme optimization algorithm. Finally, the program will output the annual maintenance scheme, corresponding cost, and fitness value convergence trend diagram during the planning period. The program interface is a friendly, interactive, intuitive, and straightforward operation.

VI. Conclusion

This study improved the selection operator, crossover operator, and algorithm parameters of the existing maintenance scheme optimization model, and developed a GA model suitable for solving the expressway maintenance scheme optimization problem. Based on the mathematical model for expressway maintenance scheme optimization and the GA model, an optimization algorithm for expressway maintenance schemes was designed. After solving existing cases using this optimization algorithm, better maintenance schemes were obtained.

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