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Research on New Scheduling Optimization of Three-Dimensional Garage Based on Genetic Algorithm

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ABSTRACT*-This paper introduces a three-dimensional garage. in order to get the satisfaction of customers, this paper puts forward a new scheduling optimization objective–satisfaction degrees. first of all, this paper defines a new concept-maximum waiting time of customer and finds it satisfies normal distribution through questionnaires. secondly, this paper determines the function relation between the maximum waiting time of customer and satisfaction degrees, establishes a mathematical model with satisfaction as the objective function, and uses an improved genetic algorithm to find the optimal scheduling result, which maximizes customers'satisfaction degrees in a series of scheduling orders. finally, this paper compares between the optimal result that the customers'satisfaction degrees are optimization objective and the optimal result that the minimum average waiting time of customer are the optimization objective, and it finds that the latter cannot achieve the maximum satisfaction degrees of the customer, which proves the feasibility of the scheduling strategy that satisfaction degrees are the optimization objective.*

KEYWORDS: *Three-dimensional garage, Scheduling optimization, Normal distribution, Maximum waiting time of customer, Minimum average waiting time of customer, Genetic algorithm, Satisfaction degrees*

1. Introduction

As the number of cars increases in China, the traffic pressure is gradually changing from dynamic to static [1], and the difficulty of parking is especially outstanding. The traditional self-propelled parking cannot satisfy the needs of society, therefore, the three-dimensional garage has become one of the best solutions to solve the problem of urban parking [2]. Lifting and transferring cubic garage is nowadays one of the most widely used type of three-dimensional garage, noted for its high construction speed, high degree of automation, low construction cost, cyclic utilization etc [3]. Now it is widely used in shopping malls, hospitals, companies of dense traffic zones. Lifting and transferring cubic garage is an important type of three-dimensional garage of the future trend.

Although the three-dimensional garage is widely used in various locations nowadays, it still cannot be accepted by customers due to the long waiting time [4]. The scheduling strategy that the minimum average waiting time of customer is optimization objective can reduce the customer waiting time and improve the customer satisfaction, to some extent, but it still has much room for improvement [5-11]. In this paper, the customer satisfaction is taken as the optimization objective, and achieves the highest level through the new scheduling strategy, thus getting the recognition of customers.

2. Introduction three-dimensional garage structure

Lifting and transferring cubic garage uses a crane to take cars to the second floor of the garage at the entrance, and make cars be stored to the designated parking location through the car loading device. The process for taking cars is opposite to that of storing. The car loading device mainly consists of two parts the comb structure and the transverse moving plate, in which the comb structure is responsible for lifting or lowering the car and the transverse moving plate determines the movement of the car loading device on the second floor of the garage. As the comb structure has independent running space in the second floor of garage, the positions of comb structure will not affect the movement of the car loading device when it is not loaded with cars.

The first floor of the garage will still be traditional self-propelled parking, so this paper only optimizes the scheduling order of the second floor.

Its structure is shown in figure 1 and 2(0: Entrance; 1-10:Corresponding garage locations).

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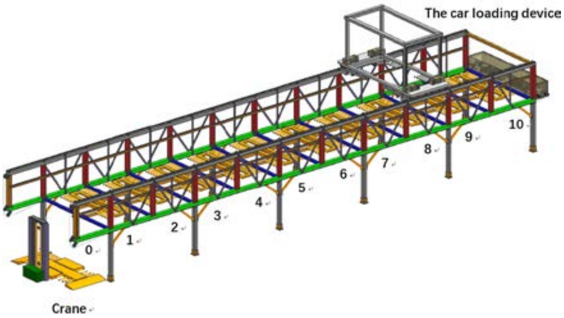
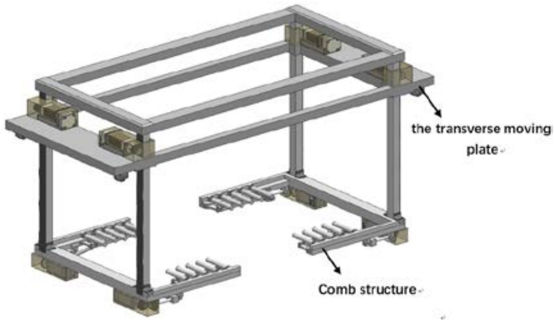


FigureSchematic diagram of stereo-parking garage structure



FigureStructure diagram of car loading device

3. Site survey and check analysis

In this paper, the improved genetic algorithm is used to find out the scheduling order of which the customers'satisfaction degrees are highest in a scheduling command. As the customers'satisfaction degrees are closely related to their waiting time in the scheduling process, it is necessary to define the relationship between the customers'waiting time and their satisfaction degrees.

3.1 Site survey

This paper selects the car owners near Yuhuangding of Yantai city as the research objective. A total of 256 car owners are randomly selected and asked to fill out the questionnaires about their maximum waiting time which is accurate to a specific minute. For instance, if the maximum waiting time for a customer is 0-60 seconds, the customer will fill in 60 seconds. At the same time, since the results are rather discrete, this data is combined with the maximum waiting time of students in the cafeteria (The entire process time from starting to queue until the inability to endure the length of the queue to leave).

The data are sorted and shown as follows:

Maximum waiting time schedule

Maximum waiting time(S)	Number of people	Proportion
0-20	0	0
20-40	0	0
40-60	2	0. 0078
60-80	2	0. 0078
80-100	5	0. 0195
100-120	11	0. 043
120-140	13	0. 0508
140-160	34	0. 1328
160-180	41	0. 1602
180-200	45	0. 1758
200-220	42	0. 1641
220-240	36	0. 1406
240-260	14	0. 0547

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Table 1 Maximum waiting time schedule

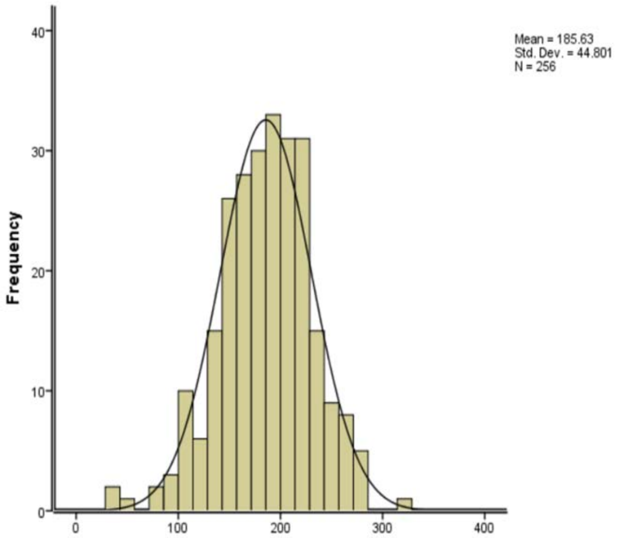
Maximum waiting time(S)	Number of people	Proportion
260-280	9	0. 0352
280-300	1	0. 0039
300-320	0	0
320-340	1	0. 0039
340-360	0	0
360-380	0	0
380-400	0	0
400-420	0	0
420-440	0	0
440-460	0	0
460-480	0	0
>480	0	0

3.2 Check Analysis

According to the statistical data, SPSS is used to test the normal distribution of the data. The specific test results are as follows:

Table 2 Statistics

Maximum waiting time		
N	Valid	256
	Missing	0
Mean		185. 63
Median		187. 00
Mode		175
Skewness		-. 281
Std. Error of Skewness		. 152
Kurtosis		. 496
Std. Error of Kurtosis		. 303
Sum		47522



Maximum waiting time

Fig. 3 Frequency distribution histogram

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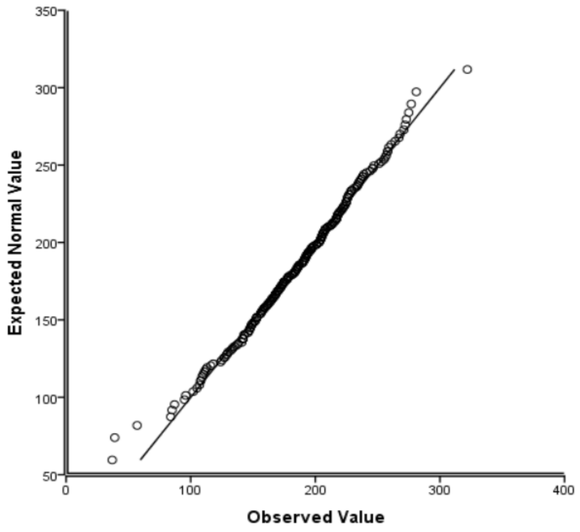

Fig. 4 Normal Q-Q Plot of maximum waiting time

Table 3 One-Sample Kolmogorov-Smirnov Test

Maximum waiting time		
N		256
Normal Parametersa, b	Mean	185. 63
	Std. Deviation	44. 801
Most Extreme Differences	Absolute	. 032
	Positive	. 030
	Negative	-. 032
Test Statistic		. 032
Asymp. Sig. (2-tailed)		. 200c, d
a. Test distribution is Normal.		
b. Calculated from data.		
c. Lilliefors Significance Correction.		
d. This is a lower bound of the true significance.		

According to the data obtained by SPSS, it can be known that:

a. Sig 0. 2>0. 05.

b. Kurtosis 0. 496<1, Skewness-0. 281<1.

c. Normal Q-Q Plot is almost a straight line.

As the data distribution meets the above conditions, the data follows the normal distribution of X~N (186, 47^2).

4. Application of improved genetic algorithm

The main difference is the crossover operator between the improved genetic algorithm and the traditional genetic algorithm. As the traditional crossover operator does not conform to the working characteristics of the three-dimensional garage, the improved OX crossover operator is chosen [12]. The improved OX crossover operator can maintain population diversity at the end of the genetic algorithm iteration, speed up the convergence speed of the algorithm, avoid premature of the algorithm, and keep algorithm from falling into the locally optimal solution.

4.1 Chromosome Coding and Generation of Initial Population

The coding form of improved genetic algorithm is mixed number coding (binary number coding+decimal number coding), the coding length are even numbers. The date range of binary number coding is a positive

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integer r [0, 1], where 0 stands for taking car and 1 stands for storing car. The data range of decimal number is a positive integer [1, 10], which corresponds to each location number of the garage.

A individual segment is as follows:

0 2 1 8 0 3 1 2

Taking Number Storing Number Taking Number Storing Number

The initial population is randomly generated through matlab, but all individuals in the population should follow the following constraints:

a. The odd positions on the individuals can only be binary positive integers.

b. The even positions on the individuals can only be [1, 10]decimal positive integers.

c. If there is already a car stored on a location number, the next operation can only take the car for the same location number. If the customers want to store a car in the same location number, he needs to wait until the end of the taking operation.

d. As the encoding is a short-time scheduling operation sequence, for the same location number, there will be no taking command after the car is stored. For the same location number, it can only be taking command before storing command for cars.

If the individual segment has the same location number, it can only appear in the following format:

0 K…1 K

Taking Number Storing Number

Where K is any positive integer in [1, 10].

4.2 Determination of Objective Function and Transformation of Fitness Function

In this paper, the quotient of the satisfaction degrees and the customers total number is the individual objective function in the scheduling operation sequence. Let the objective function be $f(x)$, and $f(x)$ can be expressed by:

$$fx = \frac{\sum_{i=1}^{M} y_i}{M} \tag{1}$$

Where y_i is the individual satisfaction of the ith customer and M is the total number of customers in the scheduling operation sequence.

This paper states the customer satisfaction:when a customer has a waiting time of T_x, and the customer's satisfaction is $1-P\{X \le T_x\}$. The T_x satisfies a normal distribution of X~N(186, 472), and y_i is represented by the following formula:

$$y_i - 1 - \int_{-\infty}^{T_x} w(x)dx \tag{2}$$

Where T_x is the waiting time of the customer and $w(x)$ is the probability density function of the normal distribution, which satisfies:

$$w(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}, -\infty < x < +\infty \tag{3}$$

$$\mu=186,\quad \sigma=47$$

The satisfaction of best individual is highest in the population. As the objective function needs to calculate the maximum of the satisfaction, the fitness function can be expressed as: $F(x) = f(x) - C_{min}$, $f(x) \le C_{min}$, C_{min} is the minimum number estimation of the objective function[13], C_{min} is 0. 01.

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According to the running characteristics of the garage, this paper summarizes the working process of the garage into the following four aspects:

a . With the rising the crane, the car of one floor is transported to the second floor, vise versa.

b . The car loading device takes a lateral move, and the car loading device moves to the entrance position of the second floor or moves to the operating position.

c . The comb structure rises to take the car, and the comb structure lifts the car to a specific height to avoid interference between the car of the car loading device and the car of the parking location number during operation.

d . The comb structure descends and the car loading device moves to the operating position, and the comb structure stores the car in the designated parking location number.

The time spent for each car scheduling process in this paper should consist of the above four processes. The crane rise time is a_1, the crane fall time is a_2, the transverse motion time of car loading device is a_3, the comb structure rises and takes the car time is a_4, the comb structure descends to store car time is a_5. Among them, a_1, a_2, a_4, a_5 are constants, and $a_1 = a_2$, $a_4 = a_5$.

In the sequence of an scheduling operation, when the ith customer takes the car, the time spent is:

$$t_{xi} = \begin{cases} a_1 + a_3 + a_4 + a_5, \text{ storage operation} \\ a_2 + a_3 + a_4 + a_5, \text{ saking operation} \end{cases} \tag{4}$$

Assume that the distance between any two adjacent parking location number, and the distance between the first location number and the entrance are equal. The traverse motion of the car loading device is a uniform motion, and the traverse motion time between two adjacent parking location number is t_h. Therefore a_3 can be expressed by the following formula:

$$a_3 = \begin{cases} |h - h'| t_h + h' \bullet t_h, \text{ storage operation} \\ h \bullet t_h + h' \bullet t_h, \text{ taking operation} \end{cases} \tag{5}$$

h is the current position where the car loading device is located, and h' is the pre-operated parking position. The positive integers of h and h' are[1, 10].

The waiting time T_{xi} of the customer i and spending time t_x of previous customers satisfy the following relationship:

$$T_{xi} = \begin{cases} \sum_{0}^{i} t_{xi}, \text{ the } ith \text{ customer takes the car} \\ \sum_{0}^{i-1} t_x (i-1), \text{the } ith \text{ customer stores the car} \end{cases} \tag{6}$$

4.3 Selection of genetic operators

The genetic operators consist of a selection operator, a crossover operator, and a mutation operator. Genetic operators are the core part of the algorithm. Genetic operators select individuals based on fitness, pair crossover and mutation to obtain optimal results.

The selection operator uses roulette selection, which determines the possibility of the individual is to be selected as the next generation of individual based on the fitness of the individual. The selected probability is the quotient of the fitness value of single individual to the total fitness value of all individuals in the population. The mathematical formula is as follows:

$$P_i = \frac{F_i}{\sum_{i=1}^{N} F_i} \tag{7}$$

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Where i is one of the individuals and N is the total number of individuals in the population. Therefore, the higher the individual's fitness, the greater the probability of being selected into next generation.

In order to adapt the crossover operator to the characteristics of the three-dimensional garage, this paper uses a new type of OX crossover operator. As the coding is mixed number coding, the two genes in a chromosome act as a whole. In the crossover process, the two genes must be operated as a whole. The specific description is as follows:

a . The two parent individuals are z_1 and z_2 , randomly selecting two crossing points and taking out the all genes between the two crossing points as O_1 , O_2 .

b . Erase the same genes as O_1 in the parent individual z_1 . If there are not the same genes, the largest storage gene of z_1 is erased, and C_1 is obtained. C_2 is the same as above.

c . As a gene segment, O_2 is inserted into the middle of any two integral genes of C_1 successively, and a series of descendant individuals O_1 was obtained. In the same way, a series of descendant individuals O_1 are obtained.

d . The two optimal individuals are selected from the series of individuals as the descendant individuals after crossover operation.

The specific operation process is as follows:

z_1 :1 6 1 9 1 8 0 1 0 10 0 7 0 2 1 3 1 4

z_2 :0 4 0 3 1 2 1 7 0 6 1 9 1 8 1 1 1 5

Two crossing points are randomly selected, such as the 5th position and the 9th position, then O_1 and O_2 are:

O_1 :1 8 0 1 0 10

O_2 :1 2 1 7 0 6

According to the principle of crossover operation:

C_1 :0 1 0 10 0 7 0 2 1 3 1 4

C_2 :0 4 0 3 1 2 0 6 1 1 1 5

O_2 is successively inserted between any two adjacent integral genes of C_1 , including the beginning position before and after the last position, then it can get 7 descendant individuals O_1 series. Similarly, inserting O_1 into C_2 successively can obtain 7 descendant individuals O_2 series. In the two series, two optimal individuals are selected as the descendant individuals of the crossover process.

The mutation operator adopts the method of single point mutation. A mutation point and swap genes are selected randomly on both sides. If the even-numbered positions of genes on both sides are equal, swap the two genes after the mutation

A_x :1 3 0 2 1 2 0 10 1 9 0 8

If the mutation point is selected at the 5th position, the individual obtained after exchange are:

B_x :1 3 0 2 0 10 1 2 1 9 0 8

5. Experimental Verification And Data Comparison

There are 10 storage locations on the second floor of the garage. In this paper, Scheduling optimization strategy is only used for the second floor of the three-dimensional garage. Suppose that in a certain period of time, four cars are pre-taken out of the garage, six cars are pre-stored in the garage, and the initial position of the vehicle loading device is at garage location 3. Four pre-taking cars are in garage location 1, 2, 4, 6. The customer satisfaction is taken as the optimizing objective in the scheduling operation.

The operation parameters of the three dimensional garage are in accordance with national elevator operation standards, and the specific values are as follows:

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$a_1 = a_2 = 8S$, $a_4 = a_5 = 7S$, $t_h = 10S$

Matlab genetic algorithm toolbox was used to simulate the example. The initial population number was 100, the crossover probability was 0. 80, and the mutation probability was 0. 01.

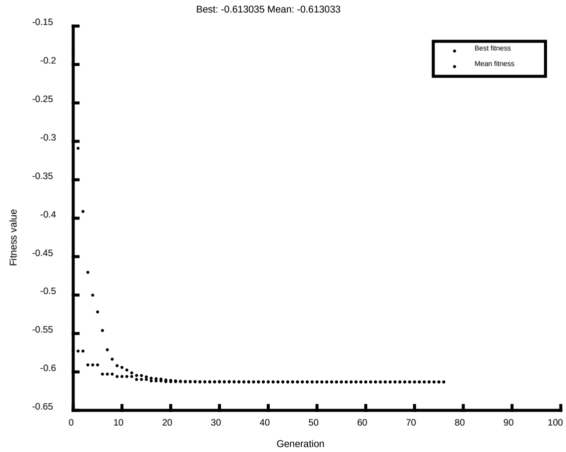

Fig. 5 Simulation experiment results

The ordinate of figure 5 represents the satisfaction of the optimal individuals of each generation of population in the genetic operation, while the abscissa represents the times of the genetic operation. Based on the above results, it can be seen that after 76 generations of genetic operation, the population has obtained rather good convergence. The maximum satisfaction is 0. 61, and the corresponding scheduling sequence is obtained. Shown in table 4.

Table 4 Optimized scheduling sequence table

Line 1-4	Line 5-8	Line 9-12	Line 13-16	Line 17-20
0	1	1	1	0
2	1	2	5	4
0	1	0	1	1
1	2	6	6	4

Customers are most satisfied with this scheduling sequence.

The crossover strategy is adopted for scheduling ope-

Ration to minimize the average waiting time of custoers, and the scheduling sequence table is shown in table 5.

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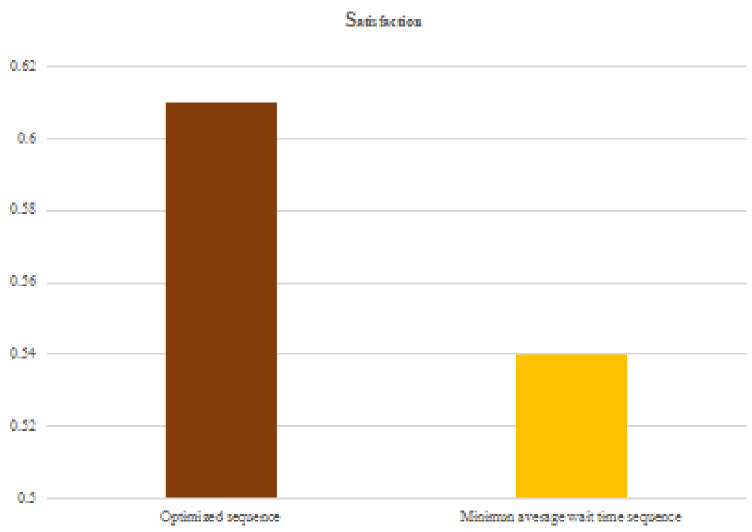

Fig. 6 Data comparison

Table5 The scheduling sequence table with the shortest average wait time

Line 1-4	Line 5-8	Line 9-12	Line 13-16	Line 17-20
0	1	1	1	1
2	1	3	4	5
0	1	0	0	1
1	2	4	6	6

Customer satisfaction with this scheduling sequence is 0. 54.

6. Conclusion

In this paper, customer satisfaction is taken as the optimizing objective, and the scheduling sequence of the highest customer satisfaction in certain period of time is solved by improved genetic algorithm. Compared with other strategies that take the average waiting time of customers as the optimizing objective, the new optimization strategy emphasizing the satisfaction more follows the principle of FCFS, effectively avoiding the phenomenon of early arrival to late service, and can satisfy the requirements of more customers and achieving much customer satisfaction, which has certain practical significance. If this optimization strategy is put into the actual operation of the three-dimensional garage, it can effectively relieve customers'irritation of the long waiting time for scheduling operation during rush hours.

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