Research on Optimization of Stereo Garage Parking Location Based on Genetic-Tabu Search

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Abstract. In order to solve the disadvantages of long queue and low efficiency of vehicles access in the plane mobile stereo garages. A hybrid algorithm of genetic algorithm to optimize tabu search is proposed to optimize the parking space allocation strategy of the garage. Aiming to shorten the vehicle average waiting time and the working distance of the carrier in the process of vehicle access, the mathematical model of the stereo garage is established through the investigation and data extraction of the actual running stereo garage. We compared the experimental simulation data of the genetic-tabu search hybrid algorithm and the tabu search algorithm. The experimental results indicate that: the Genetic-Tabu search hybrid algorithm has better convergence, which can effectively optimize the location allocation mode of the stereo garage, shorten the vehicle average waiting time and the working distance of the carrier. It has important application value.

1. Introduction

With the rapid development of the social economy, the continuous growth of the number of cars has brought tremendous pressure on urban road traffic. In order to solve the problem of urban parking difficulties, the plane mobile stereo garage has developed rapidly. The plane mobile stereo garage can effectively save land resources and greatly increase the inventory capacity, but it also has the limitations of long waiting time for customers and low efficiency of vehicles entering and leaving the garage.

In order to solve the above problems, Xiaonong Wang[1] and others have established a stereo garage decision-making allocation model, and they used multi-color set theory and fruit fly algorithm to optimize the research. Ying Liang[2] and others used the method of district management to analyze the allocation of stereo garage parking spaces. Li Wei[3] and others used a dual objective optimization method based on hybrid coding and improved genetic algorithm to obtain optimal vehicle access paths.
and sequences. Jianguo Li[4], Jianfeng Li[5], Xiaoqing Wang[6] respectively used genetic algorithm, improved genetic algorithm, genetic-ant colony hybrid algorithm to optimize the path of accessing vehicles. The literature [7-10] optimized and analyzed the queue efficiency[7], access strategy[8,9] and parking space allocation[10] of the stereo garage respectively to strengthen the service capacity of the stereo garage.

After analysis, the genetic algorithm or the improved genetic algorithm has better global search ability and stable search process, but its local search ability is poor. The tabu search algorithm[11,12] has strong local optimization ability, however, the search process is unstable, hence the two algorithms can complement each other.

In this study, we use the vehicle average waiting time, the average waiting queue, the average service time and the working distance of the carrier as the evaluation indicators of the stereo garage. We model and simulate the stereo garage, and analyze the simulation results, so as to provide reference for choosing reasonable operation scheme of the stereo garage.

2. Model establishment

2.1. Plane mobile stereo garage mathematical model

The stereo model of the plane mobile stereo garage is shown in Figure 1. This model is a double I/O port stereo garage model. It is equipped with two carriers and two elevators. The carrier is responsible for the horizontal traverse movement of the vehicle, and the elevator is responsible for the vertical lifting movement of the vehicle.

**Figure 1.** Stereo model of the plane mobile garage.

Since the vehicle access operations on the left and right sides of the plane mobile stereo garage are the same, one side of the garage can be selected as the research object. We establish the mathematical model of stereo garage with the center line of the I/O port as the axis (take the 11-story and 16-column garage as an example), and number each storage location in the model. Its mathematical model is shown in Figure 2.
2.2. Stereo garage queuing model and evaluation indicators

The stereo garage queuing model mainly includes three parts: input process, queuing system and output process. The three-dimensional garage is a service organization. The arrival time and number of vehicles are random. According to the basic idea of queuing theory, the process of storing and receiving vehicles in stereo garage can be regarded as a queuing system, as shown in Figure 3.

Figure 3. Stereo garage vehicle queuing model.

According to the queuing theory, the average waiting time of vehicle, the average waiting queue, the average service time and operating distance of the carrier are used as the evaluation indicators of the stereo garage. We assume that the customer's arrival source number is $N$, the vehicle average waiting queue is $Q$, the vehicle average waiting time is $W$, and the vehicle average service time is $S$, where the $i$-th customer waits for the queue, the waiting time, and the service time are respectively denoted as $Q_i$, $W_i$, $S_i$, the mathematical expression of the vehicle average waiting queue is:

$$Q = \frac{Q_1 + Q_2 + \cdots + Q_N}{N-1} = \frac{\sum_{i=1}^{N-1} Q_i}{N-1} \quad (1)$$

The vehicle average waiting time is expressed as:

$$W = \frac{W_1 + W_2 + \cdots + W_N}{N-1} = \frac{\sum_{i=1}^{N-1} W_i}{N-1} \quad (2)$$

The vehicle average service time is expressed as:

$$S = \frac{S_1 + S_2 + \cdots + S_N}{N} = \frac{\sum_{i=1}^{N} S_i}{N} \quad (3)$$
We define the running distance of the carrier to complete one access task as \( L \). Assuming that the width of the parking space is \( a \) and the height is \( b \), we need to store the vehicle at \((x_a, y_b)\) and pick up the vehicle at \((x_c, y_d)\), then the mathematical expression of the running distance of the carrier is:
\[
L = \sqrt{x_a^2a^2 + y_b^2b^2} + \sqrt{x_c^2a^2 + y_d^2b^2} + \sqrt{(x_a - x_c)^2a^2 + (y_b - y_d)^2b^2}
\]  
(4)

3. Introduction of the algorithm

3.1. Tabu search algorithm introduction

Tabu Search algorithm is a heuristic random search algorithm. The tabu search algorithm starts from an initial feasible solution and selects a series of specific search directions as the trial to move the objective function value to the global optimal solution. The process of tabu search algorithm can be described as: first, a set of neighborhood solutions is generated by the initial solution, and then a certain number of candidate solutions are determined in the neighborhood solution; If the objective function value corresponding to the best candidate solution is better than the current optimal solution, the contraindication criterion is ignored, the candidate solution is replaced with the current optimal solution, and the corresponding object is added to the tabu list. If the candidate solution does not exist, the non-tabu optimal solution is selected as the new current solution in the candidate solution, and the corresponding object is added to the tabu list. Repeating the iterative search process above until the stop criterion is met.

3.2. Genetic algorithm optimizes tabu search algorithm

The nature of the tabu search algorithm is based on neighborhood search, so it has a strong dependence on the initial solution. The choice of the initial solution has a crucial impact on the search process of tabu search. Genetic algorithm is a general algorithm for solving search problems and has great global optimization ability. We use genetic algorithm to find the best individual, and then use this individual as the initial selection value for tabu search, and accelerated its convergence speed and optimization ability.

After basic operations such as selection, crossover and mutation, genetic algorithm can select the optimal individuals. The design steps of genetic algorithm are as follows:

(1) Initial population

According to the actual stereo garage operation data, the population size is initialized, and reasonable genetic operator data parameters are set to ensure the accuracy of the search.

(2) Chromosome coding

We adopt two-segment coding structure, in which the first segment \( X_1 \) represents the sequential encoding of the access vehicle, and the second segment \( X_2 \) represents the location encoding of the stored vehicle. Assuming there are \( m \) deposit vehicle requests and \( n \) pick-up vehicle requests, there are a total of \( K \) parking spaces in the garage, and the code length of the chromosome is \( X_1 + K \). The length of the first segment of the code \( X_1 \) is \( m+n \), the gene positions 1 to \( m \) represent the vehicle storage number, and the gene positions \( m+1 \) to \( m+n \) represent the pick up vehicle number. The length of the second segment code is \( K \), and the gene positions 1 to \( m \) represent the parking space. If \( m=3 \), \( n=2 \), and \( K=7 \), the expression and description of the chromosome are shown in Figure 4:
In the genetic algorithm, the fitness function is used to evaluate the pros and cons of the individual. The individuals with better fitness have more opportunities for genetic selection, while the individuals with poor fitness are eliminated. We set the fitness function $F_s$ to:

$$F_s = \frac{1}{L}$$  \hspace{1cm} (5)

(4) Cross variation

We use roulette to choose the best individual. Assuming that the size of populations is $f$ and the expression of probability $P$ that an individual may inherit is:

$$P = \frac{F_i}{\sum_{i=1}^{f} F_i} \hspace{1cm} (6)$$

Individual $M_x$ and $M_y$ undergo chromosome exchange, and the expression for chromosome exchange at $r$ position is:

$$\begin{align*}
M_{xr} &= W_{xr} (1 - \tau) + W_{yr} \tau \\
M_{yr} &= W_{yr} (1 - \tau) + W_{xr} \tau
\end{align*} \hspace{1cm} (7)$$

Note: $\tau$ is any number between $[0, 1]$.

Chromosome mutations can allow better genetic selection, and the expression of the new gene $M_{new}$ after the mutation is:

$$M_{new} = \beta (M_{max} - M_{min}) + M_{min} \hspace{1cm} (8)$$

Note: $M_{max}$ and $M_{min}$ are the initial individuals with the highest and lowest fitness values respectively, and $\beta$ is any number between $[0, 1]$.

Genetic algorithm searches for the best individual through multiple iterations, and then we use tabu search algorithm to train, which can stabilize the search process and improve accuracy of the search. Figure 5 is a flow chart of genetic algorithm to optimize tabu search algorithm.
4. Data investigation of actual operation of stereo garage

After statistical and analysis of the working data of the plane mobile stereo garage, we find that the vehicle arrival probability obeys Poisson distribution of 4.3car/min, and the vehicle service probability obeys negative exponential distribution of 1.4car/min. There are two service desks in the stereo garage, which are equipped with two carriers and two elevators. The horizontal running speed of the carrier is $V_x=50\text{m/min}$, and the vertical lifting speed of the elevator is $V_y=25\text{m/min}$. The parking space in the garage is 5.3m long, 2.5m wide and 2.4m high. According to the queuing theory, the queuing model of this garage is the dual service desk waiting system queuing model $M/M/2/\infty/n$.

5. Experimental simulation and data analysis

5.1. Tabu search algorithm optimizes location allocation strategy

The simulation is an 11-story and 16-column stereo garage model, and when the carrier runs at the shortest distance, it is determined that the location is optimal at this time. According to the above-mentioned actual operation data of the stereo garage, the number of customer sources is set to 400, the evaluation function is $L$, and 500 iterations of population. If there are 5 vehicles entering the garage and 3 vehicles leaving the garage at a certain time, the access position and order of the vehicles are shown in Table 1.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| Store | Store | Access | Store | Access | Store | Access | Store |
| (2,3) | (4,3) | (10,9) | (5,2) | (7,6) | (6,3) | (2,12) | (9,7) |
Using MATLAB to carry out simulation experiments, the iterative curve after optimization of the tabu search algorithm is shown in Figure 6.

![Figure 6. Tabu search algorithm optimizing iteration curve.](image)

It can be seen from the iterative graph that when the number of iterations is 500, after 350 iterations of evolution, the optimal solution of the population is found. After about 300 iterations, the mean of the population also gradually stabilized, and the moving distance of carrier is 122 m.

5.2. Genetic-tabu search hybrid algorithm optimizes location allocation strategy

We use genetic algorithms to restrict and constrain the choice of initial solutions for tabu search. In this way, the phenomenon of random search can be effectively overcome in the process of searching, and the search process is stabilized. In the experiment, the initial population of the genetic algorithm is 400, the chromosome variation probability $P_m = 0.01$, and the chromosome crossing probability $P_c = 0.8$. The other parameters are set the same as the tabu search algorithm. The iterative curve is shown in Figure 7.

![Figure 7. Genetic-tabu search optimizing iteration graph.](image)

It can be seen from Figure 7 that when the number of iterations is 500, after 280 iterations of evolution, the optimal solution of the population is found. After about 220 iterations, the mean of the population also gradually stabilized, and the moving distance of carrier is 96 m.

5.3. Experimental data analysis

According to the data parameters of the above experiments, the iterative times of the optimal parking space obtained by using tabu search algorithm alone and genetic-tabu search hybrid algorithm
be compared and analyzed. The experimental results are shown in Table 2.

**Table 2.** Simulation algorithm data comparison.

| Simulation times | Tabu search /times | Genetic-tabu search/times |
|------------------|--------------------|---------------------------|
| 1                | 342                | 276                       |
| 2                | 347                | 308                       |
| 3                | 339                | 278                       |
| 4                | 367                | 261                       |
| 5                | 358                | 268                       |
| 6                | 361                | 301                       |
| 7                | 335                | 284                       |
| 8                | 334                | 282                       |
| 9                | 346                | 285                       |
| 10               | 329                | 275                       |
| Average value    | 345.8              | 281.8                     |

Comparing and analyzing the experimental simulation data, we can find that the tabu search algorithm is not very restrictive. However, after using the genetic algorithm to optimize the tabu search algorithm, since the initial value is already the optimal individual, it effectively limits the search range, stabilizes the search process, and speeds up search speed.

Then compare and analyze the evaluation index of the stereo garage under two different algorithms. Table 3 means the experimental simulation results.

**Table 3.** Evaluation index data of stereo garage.

| Evaluation indicators                  | Tabu search | Genetic-tabu search |
|----------------------------------------|-------------|---------------------|
| Customer average waiting time $W$/min  | 4.26        | 2.75                |
| Customer average waiting queue $Q$/car | 4.32        | 2.67                |
| Customer average service time $S$/s    | 8.67        | 6.32                |
| The average running distance of the carrier/m | 124        | 96                  |

According to the data in Table 3, the genetic-tabu search hybrid algorithm compared with the tabu search algorithm, the average waiting time, waiting queue and service time of customers are reduced by 1.51min, 1.65car and 2.35s respectively, the average running distance of the carrier decreased 28m. In summary, the genetic-tabu search algorithm can effectively reduce the waiting time of the customer and the working distance of the carrier, optimize the allocation mode of stereo garage, and strengthen the overall service capacity of the stereo garage.

6. Conclusion

This paper takes the parking space allocation method of the plane mobile stereo garage as the research object. We have established mathematical model of the plane mobile stereo garage. Through the investigation and analysis of the working data of the stereo garage, we have set reasonable experimental parameters and experimental schemes, and compared the allocation method of the
resource location under the tabu search algorithm and the genetic-tabu search hybrid algorithm. The results show that:

1) In the process of location allocation, the tabu search optimized by genetic algorithm has faster search speed and more stable search process.

2) Using the hybrid algorithm of genetic-tabu search, the vehicle average waiting time is reduced by 35.4%, the average waiting queue is reduced by 38.2%, the average service time is reduced by 27.1%, and the working distance of the carrier is reduced by 22.6%. It effectively optimizes the location allocation mode of the stereo garage, shortens the running distance of the carrier, and improves the working efficiency of the stereo garage.

In the future research, the probability of multiple carriers blocking should be considered to make the research results better serve social life.

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