Equipment Layout Scheme in Railway Container Center based on SLP Theory

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Abstract

For the increasing amount of container transportation, railway container station need to be rebuild and expanded. The problem for railway container station layout is of great importance. In this context, the article analyzed the progress and classified the operation area in the research object of railway container station. A non-linear model was set which made the object of maximizing composite relationship of each work area together with the constraint of area restrictions as a guide to systematic layout planning. Due to the NP-hard feature of this problem, the adapted genetic algorithm was created. In the end, this article took Qing-Bai River railway container station as a research example, and obtained a satisfying layout scheme.

Keywords

Railway container station; Systematic layout planning; Adapted genetic algorithm; Operation area flat layout.

1. Introduction

With the rapid development of national economy and great growth in railway freight, the container transportation, as a new form of railway transportation, is developing rapidly. Simultaneously, despite of the rapid growth in container volume, there are some prominent problems. Such as railway container station excessive traffic, container cargo handling time is too long, and its quality of service far from the requirements of modern logistics. Now the railway container transport of our country be confronted with other modes of transport competition, modern container handling station urgent need to build to meet their demand. In order to meet the rapidly growing demand for container logistics services, container freight stations are carrying out renovation and expansion project, the layout of container handling operations station is a very important issue.

Systematic layout planning, or SLP for short..It's an American scholar Richard·Muther, in conclusion based on a large number of plant facilities layout design experience, proposed a facilities planning method which as the main line analysis of relationship between logistics facilities intensity and tightness of the unit operations[1]. SLP is a strong rational theory, by setting the weight ,combined with logistics facilities intensity and tightness of the unit operations to obtain an optimized facility layout plan., so it is very widely used in the field of layout planning.

Medium-scale layout problem is more complex discrete combinatorial optimization problems, with the characteristics of NP-Hard, using common optimization method is difficult to obtain optimal solutions in a short time, therefore, a variety of intelligent optimization algorithms are used to solve the problem. Due to Genetic algorithms has powerful glob-al search and parallel simulation capabilities in the field of discrete combinatorial optimization ， and is widely used. This paper intends to use SLP theory combined with genetic algorithm to study this problem, which the operational planning layout of railway container freight station.

2. Mathematical Model

2.1 Model hypothesis

In container freight station, OD and the types of goods flow are diverse, the relation between the various modes of transport is intricate, the relationship between the various libraries work field and working area is also very complicated.

Analysis for the convenience of modeling, the following assumptions:

(1) Assuming the scope of planning of container handling stations is known, and the plane is approximately rectangular in shape;

(2) In container freight station, plane shape of each libraries work and the operation area of the substantially rectangular;

(3) Assuming each libraries work field all around the work area set aside a fixed width channel;

(4) Assuming goods into and out of the library work area each field sites are located in its center.

2.2 Symbol description

Constant:

R_{ij}^{φ} --- logistics facilities intensity; R_{ij}^{ϕ} --- tightness of the unit operations; λ_i ---The weights in comprehensive correlation; L ---Container freight stations lateral length; B---Container freight stations longitudinal length; l_i ---The lateral length of the work area i; b_i ---The longitudinal length of the work area i; n ---The number of operations area; f_{ij} ---freight traffic volume from operation area i to operation area j; D_{ij} --- The flow of goods between the work area distance; $D_{\min}$ ---The minimum separation distance between the work area.

Variables:

z_{ij} ---0-1variable, represents work area i and work area j is neighbor; x_i, y_i represents the abscissa and ordinate of work area i; m represents the rows of work areas.

2.3 Mathematical Model

In all, taking the maximum of consolidated correlation in operation area (1) and the minimum the distance of goods circulation in operation area (2) as the goal, build a mathematical model to optimize the layout of work area in container freight station:

Model:

$$\max Z_1 = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n}(\lambda_1 R_{ij}^{\varphi} + \lambda_2 R_{ij}^{\phi}) \times z_{ij} \tag{1}$$

$$\min Z_2 = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} f_{ij} \cdot D_{ij} \tag{2}$$

s.t.

$$D_{ij} = |x_i - x_j| + |y_i - y_j| \tag{3}$$

$$x_i + l_i \le L; \forall i = 1,2,\ldots,n \tag{4}$$

$$y_i + b_i \le B; \forall i = 1,2,\ldots,n \tag{5}$$

$$z_{ij} \in \{0,1\}; i, j = 1,2,\ldots,n \tag{6}$$

$$x_i, y_j \ge 0; i, j = 1,2,\ldots,n \tag{7}$$

In the constraints, equation (3) shows the relationship between the distance of flow of goods in the work area and the horizontal and vertical coordinates of the work area; equation (4) shows the restriction on the X axis of the work area layout, which means all the equipment arranged on the line cannot exceed the lateral extent of container handling stations; equation (5) shows the restriction on the Y axis of the work area layout, which means all the equipment arranged on the line cannot exceed the vertical extent of container handling stations; equation (6), (7) shows the variable domain constraints.

3. Algorithm Design

3.1 Coding Method

Using genetic algorithms to solve the layout problem, usually map the solution space into a certain layout problem code strings for various operations. The work areas are firstly ordered from left to right and then from top to bottom in the paper. The way of encoding is the way of expressing the equipment symbol sequence code. If there is insufficient space remained to place a job area, start a new line.

For example, Some equipment layout order is 1, 6, 3, 5, 4, 7, 2, 8, then the code is [1,6,3,5,4,7,2,8]. The digital in the code means the unit serial layout schematic of the work area i, as shown in fig.2, equipment lined up three rows.

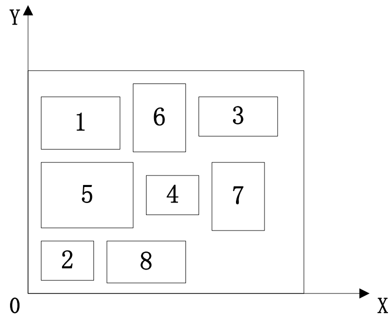


Fig1. Solutions to Motor Train Sets Scheduling problem

3.2 Fitness Calculation

The fitness function is to evaluate the pros and cons of each chromosome in each generation in the evolutionary process. It is the basis of "survival of the fittest" of genetic algorithm operation. According to the objective function and chromosome selection mechanism, set the fitness function:

$$F = Z_1 / Z_2$$

For the work area beyond the X-axis or Y-axis, set the penalty function associated P with the outside range. The fitness function can be expressed as $F = Z_1 / Z_2 - M \cdot P$, M is a suitable positive number and make sure $F > 0$.

3.3 Genetic Strategy

1. Population Initialization

In the application of genetic algorithm, the selection of initial population directly influences the optimization performance, which widely used way of randomly generated currently. But the initial population of randomly generated cannot ensure the reasonableness and the diversity of the population, also unable to determine the efficiency of the algorithm. Therefore [3], using SLP as a combination of heuristic rule and randomly selected to put the 3 sets of programs which SLP formed into the population of chromosome, while other individuals randomly generated.

2. Selection Operator

Using the roulette method selection mechanism and the optimal preservation strategy as auxiliary, both to ensure the convergence of genetic algorithms and avoid the rapid proliferation of local optima [4]. (The individual with the highest fitness in the current population is compared to the individual with the highest fitness in the next generation, if the former gets higher fitness, automatically enter the next generation population), Roulette operator method is shown as follow:

(1) Calculate the sum of all the individual fitness in the population sum. For each individual in the population, first divided by sum, and then implement the accumulation forming an array of $cumFit$.

(2) Generate a random number $rand\_s$ between 0 and 1. Find the first individual in $cumFit$ which is greater than $rand\_s$. Select the individual into the parent.

(3) Repeat steps (2), until the number of individuals in parent population is equal to the number in the initial population.

3. Crossover Operator

Define p_c as the probability of crossover. Take the inversion operator which is commonly used in the parent genetic algorithm to handle the crossover of the equipment arrangement sequence. Set a loop to traverse all individuals in the population. Each time through the loop generates a random number $rand\_c$ which is between 0 and 1. If $rand\_c > p_c$, crossover operation will not be performed and the individual will retain to progeny population. If $rand\_c \le p_c$, the individual crossover operation will be performed as follows:

(1) Set a random crossover point in an individual.

(2) The coding sequences on the left of the crossover point are still unchanged, while on the right are sequentially reversed.

The concrete operation process is shown in figure 3.

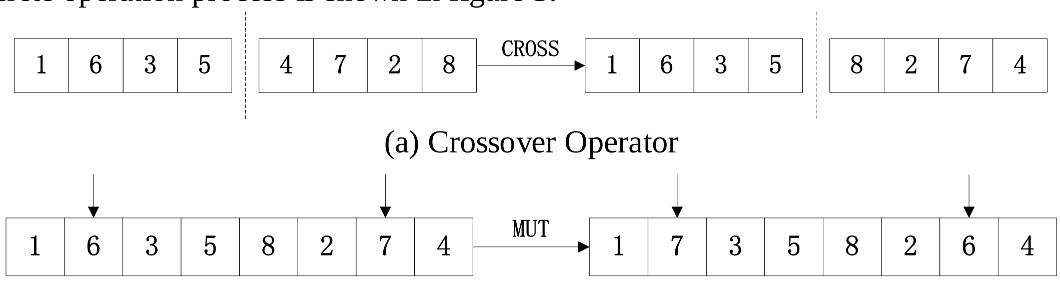
4. Mutation Operator

Define p_m as the probability of mutation. Take the transposition operator which is commonly used in the parent genetic algorithm to handle the variation of the equipment arrangement sequence. Set a loop to traverse all individuals in the population. Each time through the loop generates a random number $rand\_m$ which is between 0 and 1. If $rand\_m > p_m$, crossover operation will not be performed and the individual will retain to progeny population. If $rand\_m \le p_m$, the individual crossover operation will be performed as follows:

(1) Randomly selected two loci in an individual.

(2) Swap the coding sequence vale corresponding to the two gene loci.

The concrete operation process is shown in figure 3.



(a) Crossover Operator

(b) Mutation Operator

Fig2. Genetic Manipulation of Facility Layout Problem

3.4 Algorithm Flow

Genetic algorithm is designed for solving the problem of container freight station operation area layout

Begin

Initializing pop;

While gen≤Maxgen

Fitvalue pop;

Select pop;

Cross pop;
Mut pop;
Gen=gen+1;
End
Output Best;
End

The current optimal solution at the end of algorithm is the initial program of container freight station operation area layout design.

4. Example

The covering area of each operation zone of Qing-Baijiang railway container station , which has a total area of 1200×800m^2, is listed in table 2 .

Table 1 Covering area of each operation zone

Operation zone	Container terminal	Sending	Receiving	Transfer	Auxiliary	Customs inspection	Distribution processing	General office
area（m2）	4000	18000	12000	9000	2000	1000	35000	1500

According to the logistic correlation, the operation zones are divided into five grades form most to least, which are A-, E, I, O, U, and into six grades in the order of highest to lowest according to the correlation between operation zones. Because of the specific operation in the railway container station, the logistic correlation is considered to be more important. So according to the theory of SLP, and take the ration of 2:1, we get the comprehensive correlation between operation zones by formula of $\lambda_1 R_{ij}^{\varphi} + \lambda_2 R_{ij}^{\phi}$ (details seen in table 3).

Table 2 Comprehensive correlation between operation zones

Operation zone	1	2	3	4	5	6	7	8
1 Container terminal	—	A	I	E	U	I	U	U
2 Sending	A	—	E	E	U	I	U	U
3 Receiving	I	E	—	E	U	O	U	U
4 Transfer	E	E	E	—	U	U	U	E
5 Auxiliary	U	U	U	U	—	U	U	U
6 Customs inspection	I	I	O	U	U	—	U	U
7 Distribution processing	U	U	U	U	U	U	—	U
8 General office	U	U	U	E	U	U	U	—

Using Matlab7.0, the parameter value for GA is defined as: popular size=25, maximum number of iteration=200, crossover probability=0.7, mutation probability=0.1. The highest value of fitness is [1, 7, 2, 3, 5, 4, 6, 8], then we get the layout of operation zones (showed in chart 4).

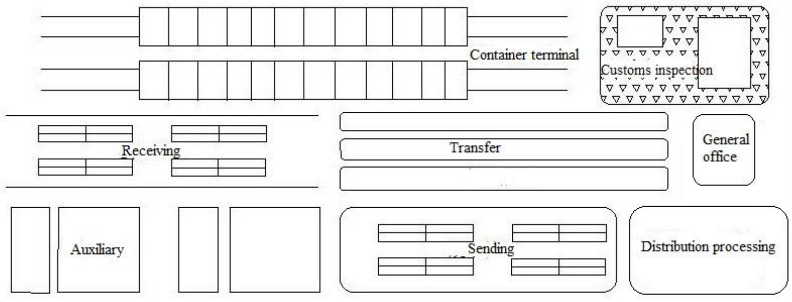


Fig3. Layout of operation zones

5. Conclusion

Taking abstraction of layout of the container operation zone based on the graph theory, considering both logistic volume and operation properties, taking logistics correlation between zones into account, a comprehensive optimization model for layout is presented in this paper; then a search algorithm combined SLP theory and GA is proposed, which overcome solving difficulties because of the nonlinear nature and large scale; finally, a numeral case is proposed to prove the validity and feasibility of the model.

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