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Research on Optimization for Safe Layout of Hazardous Chemicals Warehouse Based on Genetic Algorithm

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Abstract: The security layout and optimization of hazardous chemicals have a great significance for warehousing security and warehouse utilization. In this article, a mathematic model of the warehouse safety layout is established based on the safe distance rules and requirements. The author uses the layered thinking to divide the layout problems into stacking layout optimization and hazardous chemicals optimization. Considering the handling efficiency of the warehouse layout, the modified GA (genetic algorithm) associated with the residual rectangular algorithm is used to optimize storage layout by setting the initial population. Then, the channel positions are decided by the result of stacking layout. The experiment shows that the algorithm can obtain better layout results and improve the utilization of the warehouse on the basis of satisfying the safe distance of hazardous chemicals stacking which has a good application prospect.

Key Words: hazardous chemicals; layout modeling; five-distance; the remaining rectangles; genetic algorithm;

1. INTRODUCTION

The layout optimization of the target in the storage environment has always been a long-standing problem in the engineering field. The traditional layout method represented by the empirical emission and the implicit enumeration method has been unable to meet the needs of the current stage of logistics and warehousing. Not only because of hazardous chemicals toxic, corrosive, radioactive, flammable, explosive and many other features, as well as its irregular display of the serious consequences; but also because of the state of hazardous chemicals stacking way, five-distance (wall distance, stamp distance, light distance, channel distance and column distance) and other aspects of the strict requirements [1,2].

At present, the domestic and foreign research on the optimization of hazardous chemicals is still in the beginning stage. Song [3] proposed the storage of hazardous chemicals and the optimization method of safety layout by introducing the evaluation index of potential life lost, but the layout optimization was more in the sense of storage and distribution of warehouses，and less significance in the guidelines for the placement of hazardous chemicals. Xu [4] through the use of mixed integer optimization method based on the construction program to determine the optimal layout (coordinates and size), to solve the problem of hazardous chemicals engineering plant layout, for the warehouse stacking has a reference. Although the above studies have achieved good results, which is still limited in the warehouse site and macro planning, and no experts and scholars have system research on the security layout and optimization of hazardous chemicals.

This paper attempts to solve the security layout and optimization of hazardous chemicals through the specific layout optimization on the basis of predecessors' research, instead of the existing artificial stacking method in experience. Through the establishment of hazardous chemicals warehouse layout model, the application of residual rectangle arrangement rules, combined with the genetic algorithm, we can get a better hazardous chemicals layout results.

2. LAYOUT MODEL OF HAZARDOUS CHEMICALS STACKING

Hazardous chemicals due to its particularities are required to be placed on the mattress in storage to avoid directly contacting with the ground, hazardous chemicals warehouse layout optimization is divided into mats layout optimization and hazardous chemicals optimization.

In the known size of the warehouse storage of fixed packaging of several types of hazardous chemicals, to ensure that hazardous chemicals classified storage; to ensure safety the mattress for hazardous chemicals should be away to each other after the layout; and stacking area is not allowed overlap.

The mathematical model is as follows:

$$F = \frac{m_i * l_i * w_i}{\sum_{i=1}^{n} X_i \otimes P_i\left(w,s,c,t,l,d\right) + ROAD + M_0} \tag{1}$$

Definition: $X_i \otimes P_i$ indicates the layout of the i-type hazardous chemical and n represents the number of hazardous chemicals.

Among them, F represents the utilization as the evaluation function of layout results; m_i, l_i, w_i represents the number, length, width of the i-type hazardous chemical, ROAD represents the main channel; M0 represents other lands, such as pillars, etc. w, s, c, t, l, d are the wall distance, staking distance, light distance, zenith distance and column distance; the evaluation function is used to evaluate the layout results. The layout of the hazardous chemicals shown in Fig. 1, v_p, v_i, v_j are stacking units, z_0 indicates columns.

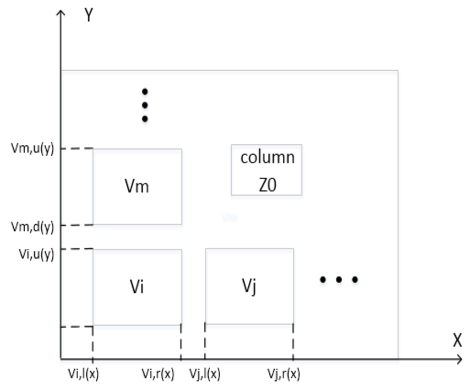


Fig. 1. Overlooking schematic diagram of hazardous chemicals warehouse layout

For the sake of simplicity, we change the formula (1) to the following formula. The objective function is to evaluate the spatial utilization after the hazardous chemical layout (f):

$$f = \frac{n * l * w}{H * W} \times 100\% \tag{2}$$

Note: H is the height of the stacking area.

Constraints:

$$s.t.\begin{cases} \sum_{i=1}^{m} d_{v_p(x)} + \sum_{i=1}^{m-1} s\left(d\right) \le W \\ \sum_{j=1}^{n} d_{v_q(x)} + \sum_{j=1}^{n-1} s\left(d\right) \le L \\ \text{stamping distance:}\begin{cases} v_{j,l(x)} - v_{i,r(x)} \ge s\left(d\right) \\ v_{p,d(y)} - v_{i,u(y)} \ge s\left(d\right) \end{cases} \\ \text{wall distance:}\begin{cases} v_{i,l(x)} - v_{0,y(x)} \ge w\left(d\right) \\ v_{i,d(y)} - v_{0,u(y)} \ge w\left(d\right) \end{cases} \\ \text{column distance:}\begin{cases} z_{0,d(y)} - v_{j,u(y)} \ge c\left(d\right) \\ z_{0,l(x)} - v_{p,r(x)} \ge c\left(d\right) \end{cases} \end{cases} \tag{3}$$

Symbolic description:

L,W ——the length and width of the rectangular warehouse;

l,w——the length and width of each stacking unit;

$ROAD$, $road$ ——the width of the main channel and auxiliary channel in the warehouse;

$w(d)$, $s(d)$, $c(d)$, $t(d)$, $l(d)$ ——wall distance, staking distance, light distance, zenith distance and column distance;

m,n——the number of stackings;

To solve the layout problem, the heuristic algorithm is used to optimize the order of the layout, and then layout according to a certain rule. Through the analysis of layout results, the optimal solution is continuously optimized. The research of warehouse layout is mainly carried out in two aspects: layout rule and layout algorithm.

3. LAYOUT ALGORITHM OF STACKING ELEMENTS FOR HAZARDOUS CHEMICALS

The layout algorithm is the process of laying the rectangle in a known space according to certain rules. The existing layout algorithms have BL algorithm, genetic algorithm and remaining rectangle method.

The BL algorithm was proposed by Baker in the early 1980s, this method is from the bottom left corner of the rectangle to be arranged, according to the most down and left principles of the layout until all the rectangles finished[5], the disadvantage of this approach is sometimes it can't get the optimal layout scheme, likely to cause gaps of useless, and easy to occur the phenomenon of the higher left side.

Xu [6] used the genetic algorithm with crossover and mutation probability adaptive change to solve the problem of rectangle layout by combining the residual rectangle strategy, which can improve the efficiency of the algorithm. Liu [7] can improve the rectangular layout efficiency of the determined sequence by improving the remaining rectangle method.

For the layout of hazardous chemicals warehouse, because the hazardous chemicals are placed on the mats, the same kind of hazardous chemicals use the same mats and belong to the same rectangular. The use of residual rectangle method can be a better use of the remaining space, improve the layout efficiency. The residual rectangles are as follows:

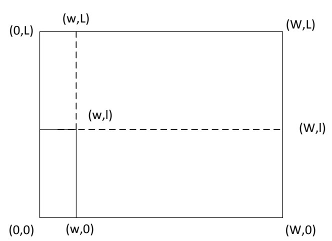


Fig. 2. Schematic diagram of the residual rectangular method

(1) The residual rectangle at the initial time is the entire rectangular warehouse, expressed as the matrix collection, $rest = [r1\ \ r2\ \ r3\ \ r4]$ where the first two numbers represent the coordinates of the lower left corner of the rectangle, and the latter two numbers represent the rectangle width and height $rest = [0\ \ 0\ \ W\ \ L]$.

(2) Set the location of the mat $a = [a1\ \ a2\ \ a3\ \ a4]$. $a1$, $a2$ represents the lower left corner of the mat. $a3$, $a4$ means the mat width and height.

(3) When a rectangle of the size w*l is placed, the residual rectangle sets change, the residual rectangles are set $rest = [\begin{matrix} w & 0 & W-w & L \\ 0 & l & W & L-l \end{matrix}]$, and the residual rectangles of the lowest horizontal line are preferred when the next rectangle is placed.

Repeat the above operation to update the residual rectangle collection until all the rectangles layout are finished.

4. OPTIMIZATION ALGORITHM FOR WAREHOUSE STACKING LAYOUT OF HAZARDOUS MATERIALS

For the layout problem, there are a variety of optimization algorithms, but each has its own advantages and disadvantages: enumeration method for the smaller enumeration of the problem can be faster to find the optimal solution, but does not apply to the enumeration of large space; heuristic algorithm is more efficient to solve these problems, but for each problem to be solved to develop its corresponding heuristic rules, the lack of versatility; genetic algorithm has strong global search ability and good robustness, it is possible to have a phenomenon of early maturation, and it can be prevented through reasonable set of initial population.

Quan [8] combined simulated annealing method with the residual rectangular method to improve the efficiency of the layout, but it cannot be guaranteed that the optimal solution is obtained every time; Zheng [9] combined the genetic algorithm with simulated annealing method to optimize the efficiency by optimizing the crossover mutation probability rule, but it is more complicated in program realization. Tong [10] combined the residual rectangle method and ant colony algorithm to improve the layout efficiency, proved the efficiency of the layout rules of the remaining rectangular method, but did not mention the optimization effect of the genetic algorithm.

Based on this, this paper improves the rules of generating an initial population of genetic algorithm in chapter 4.2, optimizes the rules of crossover and mutation probability in chapter 4.3, and improves the optimization efficiency of the genetic algorithm.

4.1 Fitness Function

The criterion of genetic algorithm to evaluate the merits of the population is the fitness function value of the population, the definition of the fitness function has an important effect on the population, which is related to the accuracy of the algorithm. In genetic algorithms, the maximum value of the fitness function is generally used as the target for optimization. Therefore, in this paper, the objective function can be directly used as a fitness function.

4.2 Initial Population

We numbered rectangular mats from 1 to M and determined the arrangement of each rectangular mat (horizontal or vertical), repeated N times, and obtained the initial population in size of N. The fitness function is sorted, and the population with the highest fitness is selected as the optimal individual to enter the next generation optimization.

In the initial population, the arrangement of the rectangular mat is generally randomly generated, and the resulting layout results are complex. Considering the dangerous nature of dangerous chemicals and the convenience of handling, the layout results should be as neat as possible. Therefore, this article proposed a way that the width ratio determines the rectangular arrangement

$$n = \begin{cases} floor(\frac{l}{w}) & \mathrm{mod}(l, w) \le \frac{1}{2} \\ ceil(\frac{l}{w}) & \mathrm{mod}(l, w) > \frac{1}{2} \end{cases} \tag{4}$$

Among them, $floor(\frac{l}{w})$, $ceil(\frac{l}{w})$ ceil towards negative infinity direction, floor to the positive infinity direction.

n rectangles as a group, and after the first rectangular mat layout is randomly determined, it is followed by a n-1 rectangle mat, such as sequence [0 1 <u>1 0 0</u> <u>0 1 1</u> <u>1 0 0</u> 0].

4.3 Genetic Operator

1)selection operator

In this paper, the most widely used roulette selection operator is used to determine the probability of reserving it as the next generation population by using the proportion of the fitness value of each individual in the population. The individuals with the highest fitness value are saved to offspring individual.

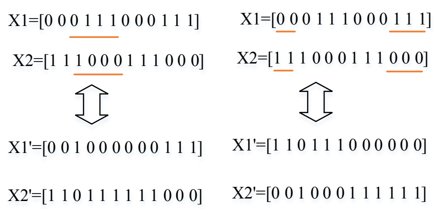
2)crossover operator

The crossover operator plays an important role in the genetic algorithm, to generate new offspring by cross individual parent population, thus increasing the diversity of the offspring population, increasing the global search ability of the algorithm. This paper adopts circular intersection algorithm.

The cross operation occurs under a certain probability, setting the crossover probability P_c in advance, producing a random number $rand$ between [0,1], and crossing operation if $P_c < rand$, otherwise the opposite.

For the two individuals in the population of N, randomly generate m, n, $m, n \in N$,when $m < n$, the genes of two individuals in the m-th to n-th exchanged; when $m > n$, the genes in the first to n-th，and m-th to N-th exchanged; when $m = n$, m, n is regenerated. This can ensure that the end of the gene is also involved in the exchange, to ensure the integrity of the operator cross.

There are two paternal chromosomes:X1= [0 0 0 1 1 1 0 0 0 1 1 1], X2= [1 1 1 0 0 0 1 1 1 0 0 0].



(m=3, n=6) (m=10, n=2)

Fig. 3 Sketch map of cross operator

3)mutation operator

The generation of the offspring in the genetic algorithm depends mainly on the crossover and mutation operator, and the crossover operator to complete the search of the whole space, and the mutation operator is the auxiliary operator, usually the probability of mutation is small, between 0.0001 ~ 0.1. In this paper, we use single point variation to generate new individuals.

Repeat the above process until the set number of iterations, and then stop the algorithm to complete the optimization process.

In the warehouse layout application, the channel location is determined according to the layout result. In the layout process, the stacking between the stackings and the width of the channel between the two hazardous chemicals can be set according to the actual situation.

5. EXPERIMENT AND CONCLUSION

5.1 Experimental Parameters

(1) population quantity

Simulation in MATLAB, the number of 59, 5.5*3.5 size of the mat into the 45*50 rectangular warehouse, the objective function is the utilization. Respectively, when the population number is 20,30,40 iteration 50 times to calculate, and then get the objective function curves shown in Fig.4.

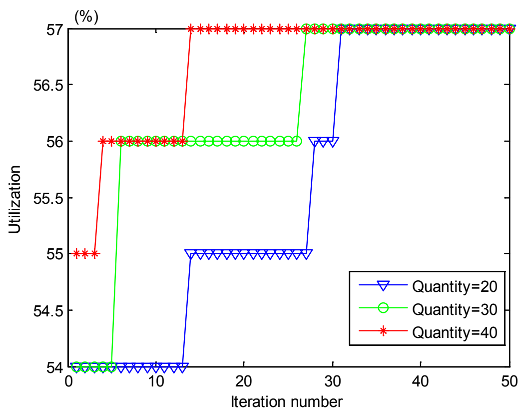


Fig. 4.Population number - objective function convergence curves

It can be seen from the figure that when the number of population is 40, the optimal objective function value can be achieved when the number of iterations reaches 14 times. The results show that the genetic algorithm of the improved initial population can be better optimized with a small size population.

(2) crossover rate

Simulation in MATLAB, the number of 59, size 5.5*3.5 of the mat are put into the 45*50 rectangular warehouse. The objective function is the utilization. Respectively, in the population number of 40, crossover probability of 0.2,0.3,0.4,0.5,0.6,0.7,0.8 iteration 50 times to calculate, and then get the objective function curves shown in Fig.5.

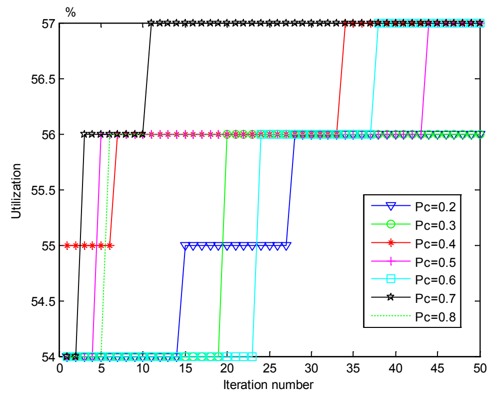


Fig. 5.Cross probability - objective function convergence curves

It can be seen from the figure, when the crossover probability of 0.5,0.6,0.7, the objective function can achieve the best result. The Optimal objective function can be quickly found when Pc = 0.7.

5.2 Warehouse Layout Experiments

We selected a hazardous chemicals warehouse in Tianjin as a research object, the warehouse size: 38*74, hazardous chemicals A Packing: 1.75*2.75*4 (LWH), Quantity: 78, wall distance: 0.3； Hazardous chemicals B Packing: 1.25*3.75*4 (LWH), Quantity: 78；Hazardous chemicals C Packing: 0.75*2.25*4(LWH), Quantity: 198； Hazardous chemicals D Packing: 1*3*1 (LWH), Quantity: 94. All is in meters.

The different types of hazardous chemicals determine the stackings unit size according to their characteristics and handling methods. Through the experimental analysis, when two chemicals stacked together as a stacking unit when the warehouse occupies the highest utilization rate. For the above-mentioned hazardous chemicals, A, B, C three kinds of hazardous materials using this stacking method, D kinds of dangerous goods each stacking for a stacking unit, the number of mats to be used is as follows: A: the mats size: 3.5*5.5, the number: 39; B: the mats size: 2.5*7.5, the number: 39; C: the mats size: 1.5*4.5, the number: 94; D: the mats size: 1*3, the number: 94. All size are in meters.

Set the genetic algorithm parameters: population number $N = 40$, genetic iteration number $NN = 50$, crossover probability $p_c = 0.7$, $p_m = 0.05$, the resulting layout shown in Fig.6, the objective function convergence curve as shown in Fig.7.

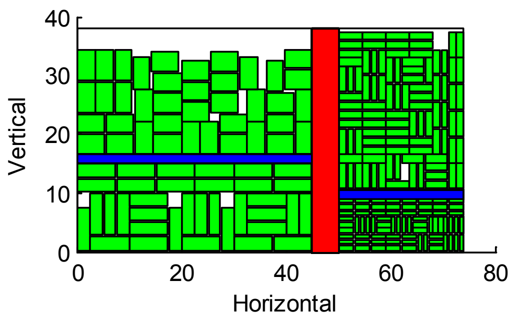


Fig. 6. Layout result diagram

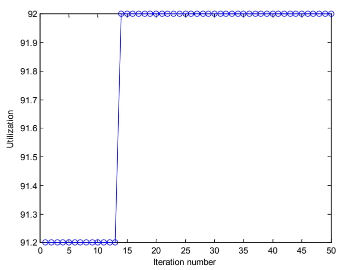


Fig. 7. Objective function convergence curve

Through the genetic algorithm to get the layout optimization results shown in Fig. 6, the middle area in red is the main-channel, with the width of 5m, the channel in blue is the auxiliary-channel, with the width of 1.5m, on the left-below corner is the A species of hazardous materials layout results. Above A is the B species of hazardous materials layout results. On the right, the upper part of the channel indicates the layout results of D species of hazardous materials, and the rest is the layout results of C species of hazardous materials. Besides, the utilization rate of these 4 types of hazardous materials occupied warehouse is 92%.

6. CONCLUSION

Based on the simulation model, the optimization of the initial population of the genetic algorithm and the remaining rectangular algorithm are used to optimize the layout of the hazardous chemicals warehouse, under the requirement of satisfying the five-distance effect. This method saves the layout space and improves the utilization rate of the warehouse. Considering that there is more than one index of utilization in the actual layout application process, the algorithm needs to be improved in the objective function setting to achieve multi-objective optimization.

REFERENCE

[1] Liu Xiangdong. Discussion on the problems and countermeasures of safety management of dangerous goods warehouse inpetrochemical enterprises[J]. Enterprise Journal, 2016, (14): 154.

[2] State Administration of Work Safety. Commonly used chemical dangerous goods storage rules [J]. State Administration of Work Safety.

[3] Song Zhanbing.Study on planning and location and safe layout of dangerous chemical storage area based on potential life loss [J]. China Safety Science and Technology, 2013 (11): 37-42.

[4] Gang Xu and, Papageorgiou L G. A Construction-Based Approach to Process Plant Layout Using Mixed-Integer Optimization[J]. Industrial & Engineering Chemistry Research, 2007, 46 (1): 351-358.

[5] Burke E K, Kendall G, Whitwell G. A New Placement Heuristic for the Orthogonal Stock-Cutting Problems[J]. Operations Research, 2004, 52 (4): 655-671.

[6] Xu Huajie, Tan Hongsen, Hu Xiaoming.Study on nesting method based on AGA and centralized residual rectangular region strategy [J] .Application Research of Computers, 2016, 33 (11): 3235-3239.

[7] Liu Lu. Based on the genetic algorithm of sheet metal nesting system[D]. Xi'anUniversity of Technology, 2014.

[8] QuanXuefeng, Shen Jitao. Rectangular element nesting based on simulated annealing residual rectangle algorithm [J]. Software, 2016, 37 (3): 27-29.

[9] ZHENG Ming-yue.Application of hybrid genetic algorithm in the layout of rectangular parts[D]. HefeiUniversity of Technology, 2013.

[10] Tongke. Group intelligent algorithm research and application [D].JiangnanUniversity, 2011.