Optimal Design of Medicine Cabinet Based on 0-1 Integer Programming

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Abstract: The medicine cabinet design problem is to divide a cuboid space into small cuboid spaces according to the size of medicine boxes to form grooves for medicine boxes storage. The purpose of the optimization design of the medicine cabinet is to obtain an optimized design scheme, so that the medicine cabinet can store the maximum amount of medicine and achieve the optimal applicability. Medicine cabinet is an important equipment for medicine storage and sales in pharmacy. Through the application of automatic transmission medicine storage cabinet, the work efficiency of drug sorting can be greatly improved, and the labor cost and waiting time for patients to take medicine can be saved.

1. Introduction

However, there are many kinds of medicine, thousands of specifications of medicine boxes. The specifications of medicine grooves are different from medicine boxes. Thus, it brings great difficulties to the optimal design of medicine cabinet. In this paper, considering the size constraints of medicine groove, a multi-objective optimization model is established to make the space utilization as large as possible and the specifications and types of medicine storage tank as few as possible. In addition, considering the balance of the utilization rate of the medicine storage groove, the utilization rate of each medicine groove is maximized by minimizing the standard deviation of storage amount of each specification type of medicine groove.

In addition, aiming at this problem, this paper proposed a method based on genetic algorithm. Besides, we also proposed a fast solution algorithm for the optimal design of medicine cabinet, and tests it on the experimental dataset. The experimental results showed that this algorithm can quickly get an ideal optimization design scheme of drug storage cabinet, and according to the requirements of users, a satisfactory design scheme is obtained by adjusting the weights of different optimization objectives.

2. Introduction

The optimization problem of medicine cabinet design aims to divide the medicine cabinet into medicine storage grooves of different specifications by horizontal and vertical baffles, so that the medicine cabinet designed has the maximum medicine storage capacity, simple (the number of specifications is as small as possible) and strong applicability (applicable to different kinds of medicines). The design of medicine cabinet shall enable to hold each kind of medicine. At the same time, by reasonably designing the size of the medicine grooves, the medicine box will not be side-by-side, rollover, overturn and other abnormalities in the grooves, so as to avoid the medicine box getting stuck in the grooves.

With the continuous improvement of human medical and health level, the types of medicines for treating various diseases are also increasing. Meanwhile, the specifications of medicine boxes of different drugs are different. Therefore, the optimal design of medicine cabinet is of great significance for medicine storage, pharmacy management and saving hospital operation cost. The optimal design of medicine cabinet is an inevitable trend for the hospital pharmacy to realize automatic and digital management and improve the modernization of pharmacy management [1].

Because each medicine groove in the medicine cabinet is only used to store one kind of medicine. Therefore, the optimization problem of medicine cabinet can be transformed into a two-dimensional

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programming problem. The rectangular area on the front of medicine cabinet is divided into several rows and columns of medicine cells matrix. The width and height dimensions of medicine grooves at different positions are different to store different kinds of medicines. Considering the normal transmission of the medicine box in the medicine groove, each medicine box is suitable for medicine grooves of specific sizes to avoid overlapping, rollover, overturning and other phenomena that may lead to blockage. The goal of optimal design of medicine cabinet is to make the space utilization as high as possible and accommodate as many medicines as possible.

However, due to the wide variety of medicine and different sizes, it is impossible to design a medicine groove in the same medicine cabinet, which is fully suitable for each kind of medicine box (no space redundancy). At the same time, too many types of medicine grooves will lead to too complex design of medicine cabinet and high production cost. If the types of medicine grooves are too small, some medicine boxes cannot be loaded into the medicine storage cabinet or the medicine storage volume is too small. It can be seen that the optimization task of drug storage cabinet is a multi-objective optimization problem.

In order to facilitate the design, we limit the width and height of the drug storage tank to integer values, so the optimal design of the drug storage tank is a typical integer programming problem. Although there are many sizes and specifications of medicine boxes, the numerical distribution range is relatively limited only from the perspective of height and width. Considering the width and height distribution range of the medicine box, the optimal design of the medicine cabinet can be realized through limited optional width and height. Genetic algorithm is widely used in this kind of integer programming problem [2-7]. Thangiah et. al. [3]studied on the optimal phasor measurement unit placement problem in power system. The proposed an optimal model to find the scheme of phasor measurement unit placement with the least number of phasor measurement units for power system observation. And, the genetic algorithm was used in solving this model. Chang et. al [5] studied on the siting problem of recycling drop-off stations problem. They proposed a optimization model of siting and routing of recycling drop-off stations based on fuzzy multi objective nonlinear integer programming method. A specific genetic algorithm method was design to solve the optimization problem.

The optimal design of drug storage cabinet is of great significance for medicine storage and sorting automation, and has broad market value. In this regard, people have made some research on this problem and published important works [8,9]. Wei et. al. [10] considered the constraints of overlapping, rollover, and rotation, and proposed a model based on radix theory of set for optimal design of medicine design. Consiering the width redundancy and width types of grooves, they proposed a double-objective optimization mode. Li et. al. [11] reasonably classified the width of the medicine box by cluster analysis and dichotomy to obtain the design scheme of the medicine cabinet with the least vertical partition spacing. After considering the width redundancy and height redundancy, combined with cluster analysis and marginal analysis, the design scheme of the medicine storage cabinet was finally obtained. Wang et. al. [12] classified the medicine boxes into several classes based on the k-means clustering method. And They proposed a 0-1 programming model based on the clustering results. This method effectively reduced the amount of calculation, but sacrifices the degree of optimization to a certain extent. However, these methods don't consider the medicine cabinet problem comprehensively. They to simple to achive a satisfactory design result. Moreover, these works were lack of verification for the design result.

For the optimization of medicine cabinet design, we solve it in two parts. One is to optimization selection of types of medicine grooves in designed medicine cabinet. The other is to calculate the number of each type of medicine grooves according to the drug storage demand and the width and height of the medicine cabinet. The proposed optimization model considers the balance of the spatial utilization rate of the medicine cabinet, the quantity of the medicine groove types and the balance of utilization rate of medicine grooves. Then, an optimization model is proposed for the medicine cabinet design.

Firstly, according to the sizes of the medicine boxes, the width and height constraints of the medicine grooves suitable for different kinds of medicine boxes are analyzed. Secondly, the 0-1 control variable is used to express the matching relationship between each medicine box and the optional specification medicine groove, and an optimization objective function of spatial redundancy is established. Considering the actual storage demand, the space redundancy of the medicine box is weighted by using the actual sales volume of each medicine. Finally, the number of medicine groove types and the standard deviation of the number of medicines stored into each type of medicine groove is calculated. The standard deviation of the medicine capacity of medicine groove is used to measure the utilization rate of the medicine cabinet scheme. Through the balance coefficient, three different optimization items are summed to establish the objective function of multi-objective optimization. The contributions of this paper is listed as follows:

(1) In this paper, the medicine storage capacity and specification quantity of the medicine cabinet are considered at the same time, and a multi-objective optimization model is proposed. The model establishes the optimization objective function of the medicine cabinet design through the balance parameters by calculating the spatial redundancy of medicine cabinet and the specification quantity of the medicine grooves. In addition, considering the balance of the utilization rate of the drug storage tank, the final optimization model is established.

(2) A global search algorithm for the optimal solution of the optimization problem of medicine cabinet design based on genetic algorithm is proposed. In this problem, the optimization problem of medicine cabinet design is transformed into the selection problem of medicine groove with given specification. The design scheme is expressed through 0-1 string, and then the search for the optimal solution is realized through crossover, variation and selection.

(3) In this paper, the proposed model in this paper is tested on a set of medicine boxes data and their sales data. The experimental results fully verify the effectiveness of the proposed optimization model. Based on the proposed method, the model can quickly obtain the design scheme of medicine cabinet suitable for 1919 different medicine boxes. The spatial redundancy rate is only 0.5%.

3. Constraint in Medicine Cabinet Design

In the optimization problem of automatic transfer medicine cabinet design, an important problem is to avoid side-by-side overlap, rotation and rollover of medicine boxes in the medicine groove. Therefore, when selecting the appropriate storage groove for each box, it needs to meet certain width and height constraints.

Define a medicine box as $\left(l_k, w_k, h_k\right), k = 1, 2, \cdots, N$, where l_k denotes the length of the *k*-th medicine box. w_k denotes the width of the *k*-th medicine box. h_k denotes the height of the *k*-th medicine box. $l_k \geq h_k \geq w_k$. In order to ensure the side-by-side overlap, rollover or horizontal rotation of the medicine box during the transfer process in the medicine groove. Through geometric analysis, this paper establishes the constraints of each medicine box on the width and height of the medicine groove.

Firstly, the problem of side-by-side overlap of medicine boxes is considered. In order to avoid two medicine boxes appearing side by side in the medicine groove, the relationship between the width of the corresponding medicine box and the medicine groove shall meet the following requirements: $x < 2w_k (i = 1, 2, \cdots, n)$.

Secondly, the horizontal rotation of the medicine box is considered. In order to avoid the horizontal rotation of the medicine box, the width of the medicine groove needs to meet the following requirements: $x < \sqrt{{w_k}^2 + {l_k}^2}$.

Rollover is the most likely of all abnormalities. Assuming that the weight distribution of the medicine box is symmetrical in the three directions of length, width and height, the critical situation of the overturning of the medicine box is shown in Figure 1. In this figure, the blue rectangle represents the normally placed medicine box, and the red dotted rectangle represents the state of the medicine box about to be overturned. Due to the uniformity assumption of the mass distribution of the medicine box and the symmetry of its shape, the center of gravity of the medicine box is at its diagonal center. According to the principle of turnover, the medicine box is in the critical state of lateral turnover when the diagonal is perpendicular to the horizontal line of the medicine storage tank. According to the geometric principle in Figure 1, it can be calculated that in order to avoid rollover, the width of the medicine groove needs to meet the following requirements: $x \le 2 \times \frac{w_k \times h_k}{\sqrt{w_k + h_k}}$.

In addition, it is worth noting that $2w_k > 2\frac{w_k \times h_k}{\sqrt{w_k + h_k}}$. Comprehensively consider the problems of side-by-side overlap and rollover, we have $x \le 2 \times \frac{w_k \times h_k}{\sqrt{w_k + h_k}}$.

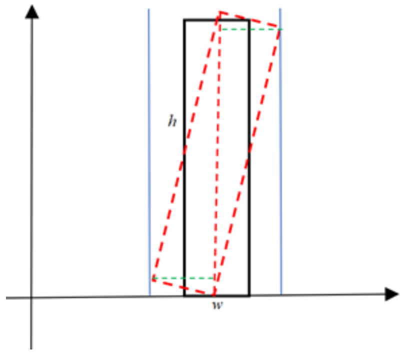


Fig.1 Schematic Diagram of Medicine Box Turnover Principle

In addition, in order to ensure that the medicine box can move normally in the medicine storage tank, a space of at least 2mm needs to be reserved between the medicine box and the baffle of the medicine groove. Therefore, the width of the medicine groove shall meet the following constraint: $x \ge w_k + 2$. The width of the medicine groove shall meet the constraint: $y \ge h_k + 2$.

4. Optimization Model for Medicine Cabinet Design

In the design of medicine cabinet, the medicine grooves in the same row is of the same height, and the medicine grooves in the same column is of the same width. The optimal design scheme of medicine cabinet can be expressed by the set of width and height data of medicine grooves. From the mathematical point of view, by discretizing the width and height of the medicine grooves, the optimization problem of medicine cabinet design is transformed into a typical 0-1 integer programming. In this section, an optimal selection model of width and height specifications of medicine grooves based on integer programming is established, and the optimal scheme of medicine groove types is solved. Then, the solution method of the optimization model is proposed based on the genetic algorithm. That is to say, in this section, we aim to find a set of medicine grooves of different size, by which can store all the medicine with the least spatial redundancy.

4.1 Formulation of Medicine Cabinet Design

In practice, the specifications of medicine boxes are diverse. In order to avoid side-by-side, rotation, rollover, and other conditions, the medicine boxes have different requirements for the specifications of medicine grooves. At the same time, in order to facilitate design, production and drug storage, it is hoped that the fewer the types of medicine groove specifications, the better. If there is a medicine groove of a certain specification, which can be applicable to all given types of medicine boxes, it will be more convenient to product medicine cabinet. However, due to the variety of medicine boxes, this expectation is unrealistic. In this section, we analyze the design of drug storage cabinet from the perspective of mathematics, and establish the optimization model for optimal medicine cabinet design.

Although there are many kinds of specifications of medicine boxes, the width and height of the medicine boxes are distributed within a certain range. Define that the maximum and minimum width values of all medicine boxes are $w_{\max}$ and $w_{\min}$. $h_{\max}$ and $h_{\min}$ denote the maximum and minimum height values of all medicine boxes respectively. Therefore, width of medicine groove ranges on $[w_{\min}+2, w_{\max}+2]$. And, height of medicine groove ranges on $[h_{\min}+2, h_{\max}+2]$. Discretize the width and height values of the medicine grooves. That is to say, we design the width and height values of the medicine grooves by integers. Define $\mathbf{X}=\{x_1, x_2, \cdots, x_m \mid x_i \in [w_{\min}+2, w_{\max}+2]\}$ and $\mathbf{Y}=\{y_1, y_2, \cdots, y_n \mid y_j \in [h_{\min}+2, h_{\max}+2]\}$ the sets of width and height of medicine groove respectively. Let $box_k=(l_k, w_k, h_k)$ denote the *k*-th medicine boxes. $groove_{ij}=(x_i, y_j)$ denotes the medicine groove with width x_i and height y_j. Then the matching relationship between box_k and $groove_{ij}$ is defined as in function (1).

$$q_{ijk}=\begin{cases}1, \text{ if } \; dw_k \le x_i \le uw_k, dh_k \le x_i \le uh_k \\ 0, \text{ else}\end{cases}, \qquad (1)$$

where dw_k and uw_k respectively represent the lower limit and upper limit of the width of the medicine groove which is used to store the *k*-th medicine boxes. dh_k and uh_k respectively represent the lower limit and upper limit of the height of the medicine groove which is used to store the *k*-th medicine boxes. q_{ijk} is a variable. $q_{ijk}=1$ means that the *k*-th medicine box can be put into $groove_{ij}$. Otherwise, $q_{ijk}=0$ means that the *k*-th medicine box cannot be put into $groove_{ij}$.

In addition, it should be noted that for any medicine box, it can be loaded into medicine grooves of various specifications. While, in the problem of medicine cabinet design, only one specification of medicine groove is selected for each medicine box. The selection method is as follows:

$$p_{ijk}=f(w_k, h_k, x_i, y_j)=\begin{cases}1, \;\; \text{if} \;\; (i,j)=\arg\max\left\{q_{ijk}\dfrac{w_k * h_k}{x_i * y_j}\right\} \\ 0, \;\; \text{else}\end{cases}, \qquad (2)$$

where $p_{ijk}=1$ denotes put the *k*-th medicine box into the medicine groove $groove_{ij}$. Otherwise, $p_{ijk}=0$ means that the *k*-th medicine box is not put into $groove_{ij}$. According to meaning of function (2), we can see that for each medicine box, we select the smallest medicine groove that meets the width and height constraints to reduce spatial redundancy.

Therefore, the optimization problem of medicine cabinet design is transformed into an optimization problem of 0-1 integer programming. According to the design needs, an effective optimization objective function is established to realize the selection of specifications of medicine groove.

$$\min/\max \quad z(\mathbf{X}, \mathbf{Y}, \mathbf{p}, \mathbf{W}, \mathbf{H})$$

where $\mathbf{p}=\{p_{ijk}\}$. $\mathbf{W}=(w_1, w_2, \cdots, w_N)$ denotes the set of widths of all medicine boxes. $\mathbf{H}=(h_1, h_2, \cdots, h_N)$ denotes the set of heights of all medicine boxes. Finally, the storage scheme of all medicine boxes and the required specification scheme of medicine groove are obtained. Then, we have

$$\begin{aligned}\mathbf{X}'&=\left\{x_i \,\middle|\, \sum_{j=1}^{n}\sum_{k=1}^{N} p_{ijk} \ge 1\right\} \\ \mathbf{Y}'&=\left\{y_j \,\middle|\, \sum_{i=1}^{m}\sum_{k=1}^{N} p_{ijk} \ge 1\right\}\end{aligned} \qquad (3)$$

Therefore, the key of the optimization model of medicine cabinet design is how to establish an effective optimization objective function according to the actual demand. In this regard, the optimal selection of the width and height specification scheme of the medicine groove is studied in 3.2.

4.2 Objective Function

In section 3.1, the optimization problem of medicine cabinet design is analyzed. In this section, we study the optimization of the specifications of medicine groove and establish an optimization objective function based on 0-1 integer programming. For the optimization of medicine cabinet design, the following objects are mainly considered: (1) The minimum amount of space redundancy. Space redundancy means that after the medicine boxes are loaded into the corresponding medicine grooves, the redundant space in the medicine groove shall be as small as possible. So that the space in the medicine cabinet can be used as much as possible. (2) The quantity of medicine groove types shall be the least.

In order to make the design and production convenient, the specifications of medicine groove should be as few as possible. (3) Balanced utilization. In the process of medicine cabinet design solving, the most appropriate (minimum spatial redundancy) medicine groove is selected for each medicine box. Therefore, the quantities of medicine boxes contained in each medicine groove should be balanced as much as possible in order to make full use of each medicine groove.

In addition, the following constraints need to be considered in the medicine cabinet design: (1) The medicine cabinet should be able to store all kinds of medicine boxes, that is to say, each medicine box can find at least one medicine groove which meet the constraints. (2) In the process of calculation, only one medicine groove is selected for each type of medicine box for storage. The optimization objective function is established as follows:

$$\min \quad z(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H}) = z_1(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H}) + \alpha z_2(\mathbf{p}) + \beta z_3(\mathbf{p})$$

$$s.t.\begin{cases} p_{ijk} = 0 \ \ or \ \ 1 \\ \sum_{i=1}^{m}\sum_{j=1}^{n} p_{ijk} = 1, \forall k = 1,2,\cdots,N \\ dw_k \le x_{ij} \le uw_k \\ dh_k \le y_{ij} \le uh_k \end{cases} \tag{4}$$

where $z_1(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H})$ denotes the spatial redundancy. $z_2(\mathbf{p})$ denotes the types number of medicine groove. $z_3(\mathbf{p})$ denotes the utilization balance. α and β are balance parameters. $\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ijk} = 1$ means that the k-th medicine box only select one medicine groove. The spatial redundancy is the primary goal of the optimization of the medicine cabinet design. It is defined as follows,

$$z_1(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H}) = \frac{1}{N}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{N} p_{ijk} v_k \left(x_{ij} * y_{ij} - w_k * h_k\right) \tag{5}$$

where v_k denotes the weight of the k-th medicine box based on the sales volume of the k-th medicine. In other words, the greater the sales volume of medicines (the greater the storage demand), the higher the corresponding weight. According to the definition in function (5), we use the average spatial redundancy of the medicine groove as the objective function of spatial redundancy optimization. v_k is defined as follows,

$$v_k = \frac{s_k}{\sum_{i=1}^{N} s_k} \tag{6}$$

The optimization objective function of types of medicine groove is defined as follows:

$$z_2(\mathbf{p}) = \sum_{i=1}^{m} sign\left(\sum_{j=1}^{n}\sum_{k=1}^{N} p_{ijk}\right)\sum_{j=1}^{n} sign\left(\sum_{i=1}^{m}\sum_{k=1}^{N} p_{ijk}\right) \tag{7}$$

where $sign(\cdot)$ is an illustrative function, which is defined as follows,

$$sign(x)=\begin{cases}1, & if \quad x\geq 1\\ 0, & else\end{cases} \tag{8}$$

The optimization objective function of the utilization balance of the medicine grooves is defined as follows,

$$z_3(\mathbf{p})=\sqrt{\frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}sign\left(\sum_{k=1}^{N}p_{ijk}\right)\left(\sum_{k=1}^{N}p_{ijk}-\overline{p}\right)} \tag{9}$$

According to the optimization objective function in formula (7), we use the product of the number of width types and height types as the optimization objective of the number of types of medicine grooves. In formula (9), the standard deviation of the number of medicine types stored in each groove is defined as the optimization goal of utilization balance.

For this problem, we design a solution method for the optimization of medicine groove type selection based on genetic algorithm.

4.3 Solution Model Based on Genetic Algorithm

The optimization of medicine groove type selection is a typical 0-1 integer programming problem. Genetic algorithm is a widely used optimization method for this kind of problems. The specific calculation method is as follows:

(1) Coding

According to the analysis of the specification of the medicine boxes, the width and height of the medicine boxes distribute in a certain quantity range. In this paper, the width and height variables of the medicine grooves are discretized. The designed width and height of the medicine grooves are taken as integers. The width and height of the drug storage tank are limited and countable. Then, the size of chromosome is defined as $ChromosomeSize=S_1+S_2$. S_1 denotes the number of optional width values of medicine grooves. S_2 denotes the number of optional height values of medicine grooves. The chromosome is encoded by a 0-1 string. As shown in Figure 2, the chromosome consists of two parts. The first *m* sites represent the width and the last *n* sites represent the height. The *k*-th site of the chromosome $Chromosome(k)=1$ means that corresponding width/height of medicine groove is designed.

Fig.2 Chromosome Coding Diagram

(2) Crossover

For the above coding methods, the crossover operation commonly used in genetic algorithm is adopted. Firstly, a gene site is randomly selected. Then, the genes of the two chromosomes are crossed at the selected gene site to form a new chromosome.

(3) Mutation

For mutation operation, the traditional mutation operation in genetic algorithm is also used. First, a gene site was randomly selected. Then, the value of the selected site is changed by $Chromosome'(k)=\left|1-Chromosome(k)\right|$, where $Chromosome'(k)$ is the value after mutation.

(4)Selection

According to the optimization objective function in formula (4), the optimization objective function value z of each chromosome is calculated. Since the optimization model is to find the minimum value of the objective function, the objective function value is transformed as follows,

$$z'=\left(z_{\max}-z\right)+0.5$$

where z' is the transformed objective function value, which is used to express fitness value.

Then, the population individuals are naturally selected through the “roulette” rule. In the process of solving the objective function, we introduce a penalty term for the case that the constraints are not satisfied. The model in formula (4) is rewritten as follows:

$$\min \quad z(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H}) = z_1(\mathbf{X},\mathbf{Y},\mathbf{p},\mathbf{W},\mathbf{H}) + \alpha z_2(\mathbf{p}) + \beta z_3(\mathbf{p}) + \gamma z_4(\mathbf{p})$$

$$z_4(\mathbf{p}) = \sum_{k=1}^{N} g\left(\sum_{i=1}^{m}\sum_{j=1}^{n} p_{ijk}\right) * penalty \qquad (10)$$

where γ is balance parameter. $penalty$ is constant, which represents the penalty factor. $g(\cdot)$ also an illustrative function, which is defined as follows,

$$g(x) = \begin{cases} 1, & if \quad x = 0 \\ 0, & else \end{cases} \qquad (11)$$

According to the definition of function (10), $z_4(\mathbf{p})$ is the penalty iterm. $z_4(\mathbf{p})$ is defined by the product of the number of medicine boxes that cannot be loaded into the medicine cabinet and the penalty factor.

In addition, in the process of solving the genetic algorithm, we adopt the "elite selection" strategy. In each iteration, the first *n* individuals with the highest fitness function values are retained.

5. Optimal Number of Medicine Grooves

As pointed out above, the optimal design of medicine cabinet in this paper is divided into two steps. The first step is to solve the selection of types of medicine grooves comprehensively consider the space redundancy and specification quantity. The second step is to calculate the number of medicine groove of each specification according to the size of the medicine cabinet, the types of medicine grooves and the sales volume of medicines. The calculation method is as follows:

First, calculate the number of drug storage tanks of each width, as shown in formula (12):

$$f(x'_a) = 1 + round\left(W - \sum_{i=1}^{m'} x'_i \Big/ \sum_{i=1}^{m'} x'_i \frac{\sum_{j=1}^{n'} p_{ajk} \frac{s_k}{\sum_{k=1}^{N} s_k}}{\sum_{j=1}^{n'} p_{ijk} \frac{s_k}{\sum_{k=1}^{N} s_k}} \right) \qquad (12)$$

where $f(x'_a)$ donotes the number of groove with width equal to x'_a. W is the width of the medicine cabinet. m' represents the number of types of grooves' widths. x'_i is the *i*th width of medicine cabinet in the optimized set of width of medicine grooves.

Similarly, calculate the number of medicine groove of each height, as shown in formula (13):

$$f(y'_b) = 1 + round\left(H - \sum_{j=1}^{n'} y'_j \Big/ \sum_{j=1}^{n'} y'_j \frac{\sum_{i=1}^{m'} p_{ibk} \frac{s_k}{\sum_{k=1}^{N} s_k}}{\sum_{i=1}^{m'} p_{ijk} \frac{s_k}{\sum_{k=1}^{N} s_k}} \right) \qquad (13)$$

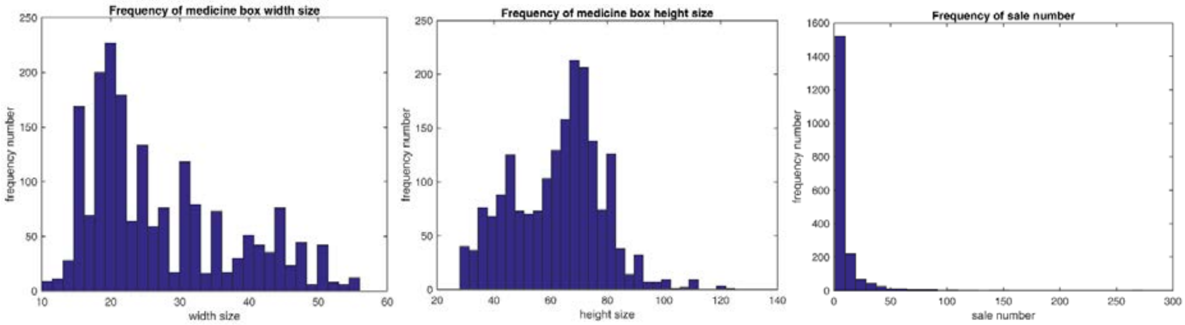
where $f(y'_b)$ is the number of groove with height y'_b. H denotes the height of the medicine cabinet. n' represents the number of types of height of medicine groove. y'_j is the height of the *j*th medicine groove in the optimized set of width of medicine

6. Experimental Results

6.1 Dataset and Settings

In order to verify the effectiveness of the proposed method, a reasonable scheme of medicine storage cabinet is designed for a dataset of medicine box of different specifications. The dataset contains 1919 kinds of medicine boxes. We have made statistics on the width, height and sales data of medicine boxes respectively, and their distribution is shown in the Figure 3.

In this paper, for the optimal design of medicine storage cabinet, the width and height of medicine box are mainly considered. The statistical data of width and height in the specification data of medicine box are given as follows:



(a) width distribution (b) height distribution (c) sale number distribution

Fig.3 Statistical Histograms of Width, Height and Sale Number of All Medicine Boxes

As shown in Figure 3, the histograms of width, height and sale number of the test dataset are given. It can be seen from this figure that although the size of the medicine boxes is diverse, the number of width and height are distributed in a limited range. The width ranges from 10 to 56 and the height ranges from 28 to 125. Therefore, we take the integer value on $[12,58]$ for the width of vertical baffle. we take the integer value on $[30,127]$ for the height of vertical baffle. That is to say that $x_i \in \{10,11,12,\cdots,56\}$ and $y_j \in \{28,29,30,\cdots,125\}$. The sale numbers of the medicines range from 1 to 273.

The width of medicine cabinet is 2.5m. The height of the medicine cabinet is 2m (the effective height is 1.5m and the bottom is a conveyor). The length of the medicine cabinet is 1.5m. In this paper, we set $\alpha = 0.05$, β=1, γ=0.5, and *penalty*=100.

6.2 Results

The design scheme of medicine cabinet is solved by genetic algorithm. The convergence curve of genetic algorithm is shown in Figure 3. The horizontal axis represents the number of iterations, and the vertical axis represents the value of the objective function. As can be seen from this figure, after about 250 iterations, the model obtains a convergent result.

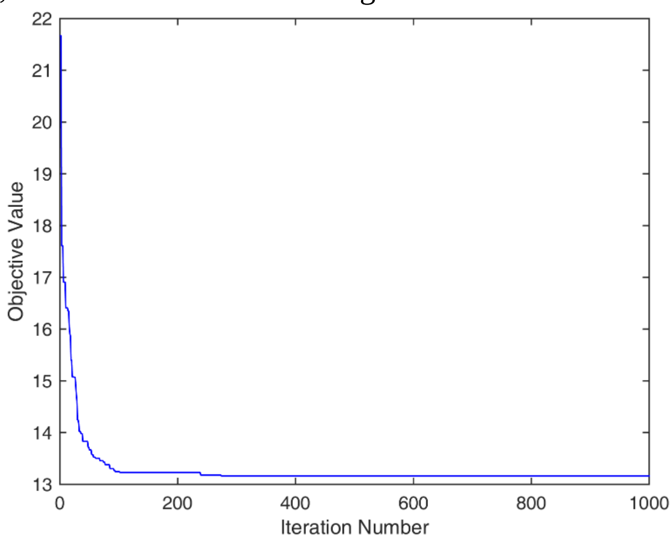


Fig. 4 convergence curve

Through calculation, the design scheme of medicine cabinet is as shown in the Table 1. The set of width types, the set of height types, and the numbers of corresponding numbers of grooves are given in this table.

Table 1 Design Scheme Of Medicine Cabinet

Width (mm)	Number	Height(mm)	Number
18	9	40	3
21	11	46	1
22	10	48	2
26	13	52	2
31	8	60	2
36	9	65	2
44	9	69	2
58	10	72	2
		74	2
		78	2
		82	1
		87	1
		127	1

According to the design scheme in Table 1, the total space redundancy is 18026 mm^2. The area proportion of redundant space is 0.5%. The standard deviation of the usage of all specifications of medicine grooves is 15.19, and the utilization rate is relatively balanced. It can be seen that the optimization model proposed in this paper can make full use of the space of drug storage cabinet.

7. Conclusion

In this paper, the optimization problem of medicine cabinet design is studied based on 0-1 integer programming. In this paper, the optimal design model is divided into two steps to solve the problem. In the first step, firstly, the specifications and types of medicine grooves are optimized. A multi-objective optimization model based on 0-1 integer programming is proposed to minimize the space redundancy, the types of medicine grooves and the difference of utilization rate of different medicine grooves. In addition, during the calculation of spatial redundancy, different weights are given to each medicine box according to the actual sales volume of each medicine box. Then, based on genetic algorithm, the solution method of the optimization model is designed. The second step is to calculate the number of grooves of each width and height according to the types of grooves selected in the first step. An effective method is established based on the sales volume of each drug box and the size of the medicine cabinet. Finally, the effectiveness of the model is fully verified by testing on a dataset of 1919 medicines. The method in this paper successfully realizes the optimal design of the medicine cabinet, and realizes the efficient storage of all test medicine boxes through a small number of specifications of medicine grooves. The space redundancy rate is only 0.5%, and the utilization rate of the medicine storage tank of each groove is relatively balanced.

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