Research on the Design of Medicine Storage Cabinet

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Abstract — The medicine storage cabinet uses intelligent technology to realize the efficient storage and sorting of drugs, and promotes the seamless connection between drugs and patients. Therefore, it has become a necessary facility in modern hospitals. On the basis of ensuring the accuracy of drug classification and the absence of tumbling, side-by-side overlapping, and horizontal rotation of the drug box in the drug storage tank, this paper solves the design problem of the medicine storage cabinet by establishing a reasonable mathematical model, which makes the drug storage cabinet as large as possible on the one hand, and as convenient as possible on the other hand. Thus, the optimal design of the medicine storage cabinet is realized with fewer kinds of medicine tanks, the type of spacing between horizontal and vertical partitions, and the maximum space utilization, which is of great practical significance for promoting centralized, accurate storage and distribution of medicine storage cabinets.

Keywords: medicine storage cabinet; optimization model; width redundancy; partition spacing

1 INTRODUCTION

With the rapid development of China's economy, the medical and health needs of the people have been gradually improved. The introduction of intelligent medicine storage cabinets into hospital pharmacies is a new direction of hospital reform. The realization of automation and digital management of hospital pharmacies is also an inevitable trend [1]. To realize the automatic management of the hospital pharmacy system and improve the efficiency of pharmacy dispensing, the intelligent medicine storage cabinet can play a very important role.

The application of intelligent medicine storage cabinets is gradually increasing, which not only reduces the dependence on labor but also improves the efficiency of drug storage and distribution, so it is favored by most hospitals [2]. However, given the complexity of the quantity and types of drugs, it puts forward new requirements and challenges for the efficient and accurate warehousing, storage, and delivery of drugs. At the same time, because of the different sizes of medicine boxes, if the design of the drug storage tank is unreasonable, it may cause problems such as rollover, side-by-side, overlap, and horizontal rotation, which will affect the efficiency of drug storage and space utilization [3]. Therefore, the optimization design of the storage cabinet has become an urgent need. This paper analyzes its optimization design objectives, puts forward feasible solutions, and establishes a mathematical model to promote the optimization and reasonable design of the medicine storage cabinet.

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Medical crowding is common in large hospitals, even in outpatients and pharmacies. During the peak period of drug collection, patients need to queue up and wait for the pharmacist to take the medicine from the drug rack according to the prescription issued by the doctor. Due to the scattered placement of drugs, patients often need to wait for a long time. In addition, since drugs are handed out by pharmacists by hand, mistakes are inevitable. However, the intelligent medicine storage cabinet can solve this problem well [4]. The structure of the medicine storage cabinet is similar to the bookcase, which is usually divided into several medicine storage tanks by several horizontal partitions and vertical partitions. To ensure the accuracy of drug sorting and prevent wrong drug distribution, only one drug can be placed in one drug storage tank, and the medicine box is put in from the back and taken out from the front [5].

Mathematical modeling problems often have a strong practical application background, and the design of a medicine cabinet was proposed in question D of the 2014 mathematical modeling contest for College Students [6]. To ensure the smooth entry and exit of drugs in the medicine storage tank, it is required to leave a 2mm gap between the cartridge and the vertical clapboards on both sides, and between the upper and lower horizontal clapboards. At the same time, it is also required that the cartridge will not appear side-by-side overlap, rollover, or horizontal rotation in the process of pushing in the drug storage tank. In the case of neglecting the thickness of the horizontal and vertical diaphragm, the mathematical model is established and the solutions to the following problems are given [7]. The problems to be solved are as follows:

1) According to the size of the medicine box, the minimum spacing category of the vertical partition and the suitable medicine box for the corresponding category is discussed;

2) To reduce the number of categories and the width redundancy as much as possible, the vertical partition spacing of the medicine storage cabinet is further discussed;

3) based on the previous discussion, this paper analyzes the spacing categories of the transverse partitions of the medicine storage cabinet, to minimize the number of categories and the total plane redundancy.

2 BASIC ASSUMPTIONS

(1) Setting the thickness of horizontal and vertical diaphragms is not considered;

(2) Set the distance between the medicine box and the upper and lower horizontal clapboards to be 2mm;

(3) set the drug demand as a constant value, and there is no fluctuation state.

3 CONSTRAINTS AND MODELING

3.1 Constraints

If the length, height, and width of the medicine box No. i isl_i, h_i and w_i respectively, and the distance between the two vertical partitions of the medicine storage tank is d_i, then the following constraint conditions must be satisfied:

(1) To ensure the smooth entry and exit of the drug in the medicine tank, a gap of 2mm should be left with the vertical diaphragms on both sides, that is: $d_i \geq w_i + 4$;

(2) To ensure that there is no side-by-side overlap of the medicine box in the medicine tank. In this case, the constraint condition is $d_i \leq 2w_i$:

(3) To prevent the medicine box from rollover as shown in Figure 1, and considering that the medicine box may roll over to the left or right, the constraint condition is $d_i < 2x$;

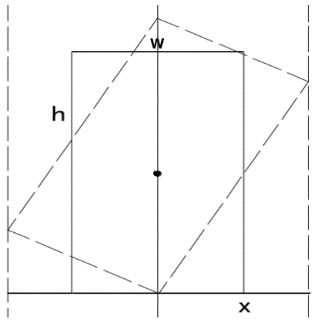

Figure 1. The rollover mode

(4) To prevent the medicine box from turning over horizontally, that is, the center of the rectangle on the bottom of the medicine box is taken as the center of the circle, as shown in Figure 2, In this case, the corresponding constraint condition is as follows:

$$d_i < \sqrt{l_i^2 + w_i^2} \tag{1}$$

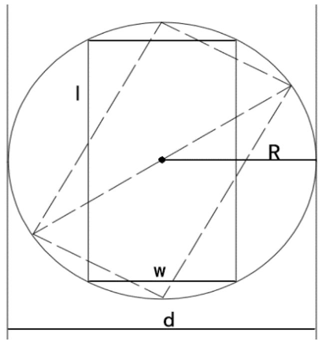

Figure 2. The flip mode

3.2 Model establishment

According to the analysis, the left endpoint of the allowed storage range of all 1919 kinds of medicine boxes is just 14 ~ 60mm. The model of this problem is simplified as in the 47 integers of 14 ~ 60, select the minimum number of combinations, so that the allowable interval of 1919 medicine boxes contains at least one value in this combination. Next, we establish a 0-1 programming model to solve the problem.

$$min \sum_{j=1}^{47} z_j$$

$$s.t.\quad z_j = \begin{cases} 1 & \sum_{i=1}^{1919} x_{ij} \geq 1 \\ 0 & \sum_{i=1}^{1919} x_{ij} = 0 \end{cases} \qquad j = 1,2,\cdots,47 \tag{2}$$

$$x_{ij} = \begin{cases} 1 & \text{The } i-\text{th medicine box can be put into the } j-\text{th medicine storage tank} \\ 0 & \text{otherwise} \end{cases}$$

We can get the design scheme of the vertical partition spacing of the medicine storage cabinet, and the specifications of the medicine boxes corresponding to each spacing category, as shown in Table 1.

Table 1 The design scheme of vertical partition spacing of medicine storage cabinet

Category of the distance between vertical diaphragms (mm)	The width range of the medicine box (mm)	Number of medicine box
19	10 -17	286
34	18-32	1096
46	33-44	342
58	45-56	195

The so-called width redundancy refers to the excessive gap between the medicine box and the left and right clapboard, that is, the part with a total gap of more than 4 mm. Obviously, the width redundancy decreases with the increase of the vertical partition spacing type, but if the partition spacing type is designed too much, it will not only increase the cost of the medicine cabinet but also reduce the adaptability of the medicine storage cabinet [8]. According to the previous discussion, at least five types of partition spacing should be used for the medicine boxes, however, the redundancy at this time is relatively large; at most forty-seven types of partition spacing can be used for the medicine boxes, and the total redundancy can reach 0.

Therefore, we expect to find a compromise design to minimize the number of partition spacing types and width redundancy [9]. The planning model is as follows:

$$min \sum_{j=1}^{47} \sum_{i=1}^{1919} x_{ij}(d_j - w_i - 4)$$

$$s.t.\quad \sum_{j=1}^{47} x_{ij} \geq 1 \quad (\mathrm{i} = 1,2,\cdots,1919) \tag{3}$$

$$x_{ij} = \begin{cases} 1 & \text{The } i-\text{th medicine box can be put into the } j-\text{th medicine storage tank} \\ 0 & \text{otherwise} \end{cases}$$

Here, d_j represents the interval distance of type j （$1,2,\cdots,47$）, and w_i represents the width of the i-th medicine box.

Using the above model, the optimal spacing selection scheme and minimum total redundancy width are obtained as shown in Table 2.

Table 2 Optimal total number of vertical partition spacing types

Number of spacing types	5	6	7	8	9	10
Minimum redundancy of total width (mm)	8379	5433	4515	3719	3090	2688

In the following, the total number of partition spacing types is taken as the abscissa, and the minimum redundant total width is taken as the ordinate. The relationship curve between the minimum redundant total width and the total number of partition spacing types is given, as shown in Figure 3.

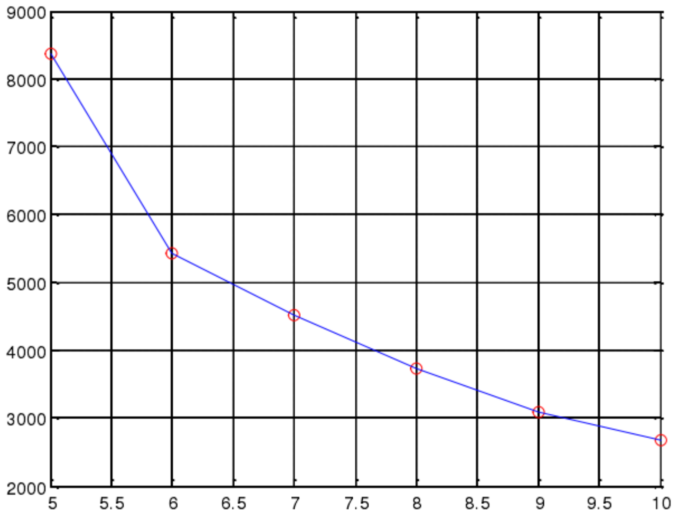

Figure 3 The relationship curve

It can be seen from the changing trend of the above figure that when the total spacing type increases from 5 to 6, the minimum total redundancy width decreases sharply, and after 7, the change slows down. Therefore, combined with the above results, when the total spacing type is 7, the minimum total redundancy width is 4515 mm, which is the most reasonable scheme, and the spacing sizes are 9mm, 25mm, 31mm, 37mm, 44mm, 51mm, and 60mm.

4 CONCLUSION

The structure of a medicine storage cabinet is usually composed of several horizontal partitions and vertical partitions. In real life, for different requirements, the design of a medicine storage cabinet is often different. According to the data in the appendix of the competition, combined with the concept of set cardinality, this paper gives the design scheme of the medicine storage cabinet with the least type of vertical partition. On this basis, a double objective mathematical programming model is established to minimize the total width redundancy and the type of spacing. This model has the following advantages:

(1) based on clear constraints, the model makes the results more accurate and reliable.

(2) When considering the constraint conditions, the medicine box can recover automatically when it deviates from the equilibrium state, and will never roll over.

(3) After reasonable assumptions, the results are in good agreement with reality.

According to the practical constraints faced by the traditional medicine storage cabinet, this paper proposes a solution to the problem and establishes a mathematical model, which has important practical significance for promoting the accurate storage and distribution of drugs.

The variety of drugs and the different packaging specifications have brought many problems to the accurate and efficient storage of drugs in drug storage cabinets and the improvement of space utilization. As the automatic medicine storage cabinet uses intelligent technology to realize the efficient storage and sorting of drugs, it will greatly promote the seamless connection between drugs and patients, so it will become the direction and focus of modern hospital preparation facilities research. In the future, we can continue to strengthen research on the following two aspects: the first is to realize the automatic management of hospital pharmacy system and improve the pharmacy dispensing efficiency; the second is to promote the design model of drug storage cabinet to other similar industries.

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