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Application on Automated Warehouse Simulation System in Location Optimization

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***Abstract*-Enterprise warehousing management level is the core link of logistics companies. The level of warehousing management plays a crucial role in improving the efficiency of the entire logistics. The efficiency of the warehouse is mainly determined by the allocation strategy of the warehouse location. The use of a good location optimization strategy can greatly improve the efficiency of the warehousing and reduce the cost of the warehousing system. In order to improve the overall operating efficiency of the automated warehouse, company requires optimization of the location, coupling the chain of goods and the chain of storage, reducing storage and handling time. It can reduce overall logistics costs and increase economic returns. Based on the previous researches on the problem of automated warehouse, the paper further studies the optimization of warehouse storage and proposes corresponding solutions.**

Keywords-Automated warehouse; Warehousing Location Optimization; Genetic algorithm; Simulation System

I. INTRODUCTION

With the rapid development of modern logistics system technology, automated warehouses play an important role based on their advantages [1]. The advantages of all aspects of automated warehouses are significant: such as rational space utilization, intelligent cargo access, reducing labor, improving production efficiency and production management level, reducing inventory backlog, reducing storage loss, achieving rational use of liquid funds and so on [2]. As a typical representative of modern logistics technology, automated warehouse is a combination of machinery, electronics, computer, communication, automatic control and sensors. It has gradually become a main logistics facility for modern distribution, production, storage.

With the development of automated warehouse, its application has become an important factor in the rapid development of modern enterprises. The operating efficiency and management efficiency of the automated warehouse are directly affected by the efficiency of order picking, which is an important indicator of the level of automated warehouse services. It is an important content to study the three-dimensional warehouse system by using reasonable allocation control strategies for the warehouse area and location of the three-dimensional warehouse to improve the efficiency of the three-dimensional warehouse [3]. Rational allocation control strategy for the warehouse location and improving the efficiency of the three-dimensional warehouse is an important part of the research. Optimize the allocation of the inbound warehouse of the three-dimensional warehouse, which is conducive to improving access efficiency and reduce the loss of goods during access and handling. Therefore, it is of great practical significance to study the optimization of the warehouse location [4][5].

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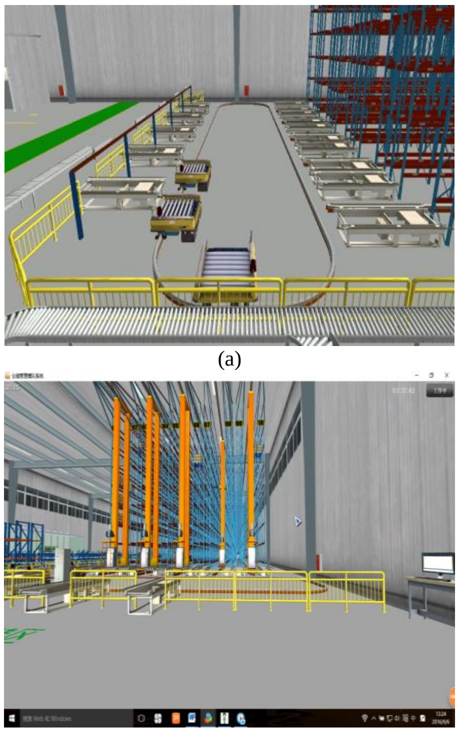
II. AUTOMATED WAREHOUSE WAREHOUSING PROCESS AND DISTRIBUTION PRINCIPLE

A. Automated Warehouse Structure



(a)

(b)

Fig 1. SCHEMATIC DIAGRAM OF AN AUTOMATED THREE-DIMENSIONAL WAREHOUSE

Automated warehouse is mainly composed of warehouse, high-rise shelves, roadway stacking machine, peripheral conveying equipment (conveyor belt, guiding trolley), automatic control device, etc. [6].

B. Automated Warehouse Warehousing Process

The warehousing process starts from the warehousing platform and stores the goods in the specified location. When the warehousing company forms an order with the customer, the goods will be delivered to the correct location (the platform) by the exclusive driver at the specified time. Then, the warehousing administrator takes the order from the warehousing room for task analysis, and waits for the manual bar code scanning to confirm the pallet item attribute category and the warehousing channel port according to the scanned information [7][8]. The administrator assigns the porter to manually store the pallet into the inbound storage area by manually placing the pallet truck and the pallet in the warehouse. The tally handler picks up the goods, scans the bar code on the pallet to be invented and displays the specified inbound area. The porter delivers the goods to the three-dimensional warehouse. The conveyor automatically transports the pallets to the starting point of the stacker (the end of the rack). The roadway stacker performs a storage operation to take the pallet fork to a designated location pre-allocated by the host PC. The warehousing information will be fed back to the warehousing information system to complete the entire warehousing operation [9].

C. Storage Location Division Principle and Distribution Principle

The principle of automated three-dimensional warehouse partitioning is to logically divide an overall warehouse into multiple different areas according to the characteristics of the goods, the way of operation and the way of picking warehouse. It can improve the storage and storage efficiency of items while better meeting the storage requirements of different goods [10]. Reasonable location allocation can improve workflow, shorten work cycle, and improve the efficiency of goods entering and leaving the warehouse. The general basic criteria for the allocation of warehousing locations are: proximity to the export principle, the principle of relevance of goods, the principle of turnover rate, and the principle of uniform distribution [11]. The problem of location allocation in warehousing is a multi-objective combination decision problem, and its solution is generally more complicated, and there are many solving methods used, such as particle swarm optimization algorithm, ant colony algorithm, and simulated annealing fusion algorithm.

III. METHODOLOGY AND PROPOSED CRITERIA

TABLE I. ENTITY RELATED KEY ATTRIBUTES

Research object	Key attributes of goods
Goods	Length, width and height of the goods, the weight of the location, the turnover rate of the goods
Roadway stacker	Maximum rising speed in the vertical direction, maximum moving speed in the longitudinal direction, starting position of the stacker
Location	The length, width and height of the cargo, the maximum load-bearing capacity of the shelf, the number of locations

The establishment of the model requires abstracting the objective properties of the research object. The research considers the relationship between goods, warehouses and roadway stackers, and finds the relevant attributes between entities. It also through the research and analysis of the cargo information in the warehouse stereo warehouse, which can get the relevant key attributes of each research object [12].

A. Model Hypothesis

In order to establish an easy-to-solve and realistic location optimization model, the study needs to make the following assumptions [13]：

(1) The access method of the automated three-dimensional warehouse system is a unit cargo format, that is, one lane stacker in each channel of the warehouse. There is one shelf on each side of each channel. The roadway stacker can access the shelf pallets on both sides. Because the operation on both sides is the same, only the operation of one shelf is considered in the solution.

(2) Assume that the pallet size specifications on all shelves are the same. The pallet size is long, wide and high, and is 1000mm X 1200mm X 150mm. The length, width and height of the pallet are 2600mm X 1400mm X 1500mm.

(3) The demand for each item in the three-dimensional warehouse is fixed and known, and there is no correlation between the various items.

(4) The roadway stacker can move simultaneously in the horizontal direction and the vertical direction. It is assumed that the acceleration and deceleration of the roadway stacker in the horizontal and vertical directions is linear. And its acceleration and maximum speed in the horizontal and vertical directions are known [14]. In order to simplify the process, in the solution, the speed of the roadway stacker is constant at the maximum speed.

(5) It is assumed that the loading and unloading time of the roadway stacker from the cargo space is independent of the running speed of the stacker and the shape of the shelf.

B. Model Building

Assume that the automated warehouse has a total of m rows and n columns per row [15]. The layer closest to the ground is the first layer, and the column closest to the entrance is the first column. The vertical running speed of the roadway stacker is v_y, the horizontal running speed is v_x, and the length of the cargo is L and the width is H

According to the principle that the shelf load is uniform and the upper part is heavier than the lower part, the sum of the mass of the goods on each tray and the product of the layer is minimized, thereby establishing a mathematical model：

$$\min f_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} W_{ij} * (i-1) \qquad (1)$$

In the formula： f_1——the sum of the mass of the goods on each pallet and the product of the layer on which it is placed

W_{ij}——the weight of the goods in row i and column j on the shelf

According to the principle of improving efficiency and warehousing, the sum of the frequency of accessing all goods and the stacking machine running time when picking this cargo is minimized, thereby establishing a mathematical model:

$$\min f_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij} * p_{ij} \tag{2}$$

$$t_{ij} = [\mathrm{L}*\mathrm{i}/\mathrm{v}_x, H*(\mathrm{j}\text{-}1)/v_y]$$

In the formula： f_2 -the sum of the frequency of access to the goods and the stacking time of the stacking machine

t_{ij} -the time required moving the goods in the warehouse level to the exit

p_{ij} -the access frequency of the goods in the inventory level

L -length of the cargo

H-width of the cargo

According to the above, this study can get the optimization model of the warehouse allocation of automated warehouses as follows:

$$\begin{cases} \min f_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} W_{ij} * (\mathrm{i}\text{-}1) \\ \min f_2 = \sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij} * p_{ij} \end{cases} \quad 1 \le i \le m; 1 \le j \le n。 \tag{3}$$

In the formula：

This is a multi-objective optimization problem that needs to be addressed with multi-objective decisions. The solution process is complicated. Here, by assigning weights to the two objective functions, the two-objective problem can be turned into a single-objective problem. Different stereo warehouses have different requirements for the importance of the two objectives. In order to study the need to achieve simplification, this study assigns weights equal to 0.5.Multi-objective function becomes：

$$\min h = 0.5f_1 + 0.5f_2 = 0.5\sum_{i=1}^{m}\sum_{j=1}^{n} W_{ij} * (\mathrm{i}\text{-}1) + 0.5\sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij} * p_{ij} \tag{4}$$

Multiply each side by two. The result is that the final inbound location optimization function is：

$$\min f = \sum_{i=1}^{m}\sum_{j=1}^{n} w_{ij} * (i-1) + \sum_{i=1}^{m}\sum_{j=1}^{n} t_{ij} * p_{ij}$$

$$t_{ij} = [\mathrm{L} * \mathrm{i}/\mathrm{V}_x, H \times (J-1)/V_y]$$

$$1 \le \mathrm{i} \le m; 1 \le j \le n。 \tag{5}$$

In the formula：

IV. Case Analysis

A. Analysis process

This paper takes the BD distribution center three-dimensional warehouse as an example to optimize the location adjustment. In order to facilitate the calculation of this example, 10 representative goods are selected from the warehouse storage goods. Assume that the automated warehouse has 10 rows and 20 columns per row. The layer closest to the ground is the first floor, and the column closest to the entrance is the first column. The vertical running speed of the roadway stacking machine is 600mm/s and the horizontal running speed is 520mm/s. The length of the cargo is 2600mm and the width is 1400mm.

A total of 200 locations in 10 rows and 20 columns of a row were selected as research objects. At the same time, there are 200 pallets that need to be stored. According to the actual situation, the parameters of the 200 pallets are shown in Table 2.

Objective function：

$$\min f_1 = \sum_{i=1}^{10}\sum_{j=1}^{20} w_{ij} * (i-1) \tag{6}$$

$$\min f_2 = \sum_{i=1}^{10}\sum_{j=1}^{20} t_{ij} * p_{ij} \tag{7}$$

$$\min h = 0.5f_1 + 0.5f_2 = 0.5\sum_{i=1}^{10}\sum_{j=1}^{20} w_{ij} * (i-1) + 0.5\sum_{i=1}^{10}\sum_{j=1}^{20} t_{ij} * p_{ij} \tag{8}$$

TABLE II. PRODUCT PARAMETERS

product name	Outbound frequency	Weight (KG/ tray)	Number of bits occupied
mineral water	0.03	150	20
vinegar	0.04	200	10
Citrus	0.05	230	15
washing powder	0.1	240	65
Xylitol	0.16	100	20
toffee	0.2	120	30
soy sauce	0.24	200	40

Restrictions：

(1) $t_{ij} = [2600 * i / 520, 1400 * (j-1) / 600]$

(2) $1 \le i \le 10; 1 \le j \le 20$

B. Case analysis result

The inbound location optimization model is programmed in Matlab software. The corresponding conclusion can be drawn by the f function value curve. The objective f function value decreases as the number of iterations increases. After the number of iterations reaches 170, the objective f function value tends to be almost flat. When the objective f function value starts at the iteration of $1.98*10^5$, the objective f function value is $1.45*10^5$ after the optimization is completed.

TABLE III. SCHEMATIC DIAGRAM OF ALLOCATED GOODS IN COLUMN 1 TO 10 AFTER OPTIMIZATION

Row \ Column	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
R1	5	4	4	4	4	4	4	4	4	4
R2	5	4	4	4	4	4	4	4	4	4
R3	5	4	4	4	4	4	4	4	4	4
R4	5	4	4	4	4	4	4	4	4	3
R5	5	3	3	3	7	7	7	7	7	7
R6	7	7	7	7	7	7	7	7	7	7
R7	7	7	7	7	7	2	2	2	2	2
R8	1	1	1	1	1	1	1	1	1	1
R9	6	6	6	6	6	6	6	6	6	6
R10	5	5	5	5	5	5	5	5	5	5

TABLE IV. SCHEMATIC DIAGRAM OF ALLOCATED GOODS IN COLUMN 11 TO 20 AFTER OPTIMIZATION

Row \ Column	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
R1	4	4	4	4	4	4	4	4	4	4
R2	4	4	4	4	4	4	4	4	4	4
R3	4	4	4	4	4	4	4	4	4	4
R4	3	3	3	3	3	3	3	3	3	3
R5	7	7	7	7	7	7	7	7	7	3
R6	7	7	7	7	7	7	7	7	7	7
R7	2	2	2	2	2	1	1	1	1	1
R8	1	1	1	1	1	6	6	6	6	6
R9	6	6	6	6	6	6	6	6	6	6
R10	5	5	5	5	5	6	6	6	6	6

Finally, through the optimization of the inbound and outbound frequency of the goods and the weight of the storage space, the final distribution plan of the goods is obtained.

For the convenience of observation, the author replaced the mineral water, balsamic vinegar, citrus, washing powder, xylitol, toffee and soy sauce with the numbers 1, 2, 3, 4, 5, 6, and 7 respectively.

C. Optimization suggestion

1) Pay attention to the initial planning and construction of automated warehouse.

Enterprises and major scientific research units must pay full attention to the basic parts of automated warehouses; continuously improve existing facilities in China, and gradually master scientific and efficient management methods.

2) Establish a standard inbound and outbound operational process

The Warehouse Operations Guide is a code of conduct that guides warehouse personnel in their work in warehouse management. Enterprises must set up different warehouse staff for different links to ensure clear division of labor and clear responsibility. Enterprises must standardize warehouse operation guidelines and strictly enforce them to ensure the effectiveness of warehouse location optimization.

3) Strengthen on-job training for warehouse staff

On-job training for warehouse staff can not only improve the professional skills of employees, but also improve the efficiency of personal work. At the same time, this training can also prevent employees from operating the storage equipment in violation of regulations, reducing unnecessary personal injury and death. Strengthening the training of in-service personnel in the warehouse not only enhances the individual skills of the employees, but also plays a significant supporting role in improving the efficiency of storage and ensuring the effective implementation of the inventory optimization program [16].

V. CONCLUSIONS AND PROSPECTS

This paper mainly studies the optimization of the storage location of the automated warehouse in the process of warehousing. At the same time, this paper introduces the automated warehouse and storage management. The AS/RS warehousing operation is one of the important functions of the three-dimensional warehouse. The genetic algorithm is applied to the storage scheduling optimization problem of AS/RS, which can improve the efficiency of warehousing. Automated warehouse systems and technologies are increasingly valued and favored by all walks of life. Different types of stereo library design are required for different enterprises. According to different warehouse functions and storage forms, more research content should emerge. Automated warehouse inventory research will remain a hot topic in the field of automatic control [17].

There are still many shortcomings in the research work of this paper. Follow-up work can also be carried out from the following aspects:

1) Further enrich the content of mathematical models and constraints, consider more practical issues.

2) In the optimization of AS/RS storage location, it is difficult to consider the overall optimization.

3) Path optimization of intelligent AGV, coordination and distribution optimization between conveying equipment and handling equipment, etc., can be further optimized in subsequent research.

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