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Design and Implementation of Warehouse Automation System based on AGV Control

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Abstract

After entering the 21st century, especially in recent years, the domestic logistics industry has shown an unprecedented development trend. The traditional logistics industry is undergoing tremendous changes. The status of logistics warehouses in the logistics supply chain is becoming more and more important. Upgrade to intelligence and automation. Therefore, warehousing automation came into being in logistics warehouses. As an important part of warehouse automation, automatic guided vehicles (AGVs) are also playing an increasingly important role. The overall operational performance of the multi-AGV system has a significant impact on the efficiency of the warehousing automation system, which further affects the work efficiency of the logistics warehouse, and the AGV will inevitably have collision and conflict problems during the work process, so the effective and fast AGV scheduling problem has become a problem. A problem that needs to be studied and needs to be continuously broken through. Aiming at the problem of less research on multi-AGV scheduling in warehousing automation at present, this paper mainly carries out the following work on the basis of the existing shortest path search algorithm, task allocation theoretical algorithm and scheduling theoretical algorithm: First, by consulting network materials and papers Literature research, analysis and summary of the current composition elements and development status of warehousing automation multi-AGV system. Secondly, under the premise of applying breadth-first search to solve the shortest path, the traveling salesman problem model is used to solve the shortest selection path problem in the multi-loading and multi-AGV system. At the same time, the shortest selection path is input into the Fuzzy system as a parameter to realize the task allocation optimization. . Then, a dynamic locking/unlocking scheduling algorithm based on lock mechanism is proposed, which makes reasonable use of map resources and prevents path conflicts and deadlocks from occurring. At the same time, combined with the actual situation of the project requirements, the theory of the shortest path search and scheduling algorithm is comprehensively used, and the AGV control is realized in the C# .Net Framework environment. Finally, the relevant implementation details and program display interface of the AGV control system are introduced, and the simulation experiments are used to measure the performance of the improved Fuzzy System task allocation algorithm and scheduling algorithm proposed in this paper, and related analysis and further prospects are given.

Keywords

AGV; Real-time; Scheduling; Path; Planning.

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1. Introduction

1.1 Research Background and Meaning

Logistics system refers to a number of mutual influences and constraints, such as loading machinery, unloading machinery, cargo, cargo handling equipment, communication systems, basic storage facilities, and related staff, in a specific space location and time[1]. A complex organic whole with specific functions composed of dynamic elements. As a complex discrete event system, modern logistics system not only promotes the development of manufacturing industry, but also improves the flow rate of goods and people's quality of life. In this context, the executive meeting of the State Council of my country issued the "Mid- and Long-Term Planning for the Development of the Logistics Industry" in mid-June 2014, also known as the "Mid- and Long-Term Planning"[2]. This is another important document that guides the development direction of the logistics industry after the State Council promulgated the "Plan for Adjustment and Revitalization of the Logistics Industry" in 2009. The "Medium and Long-Term Planning" document promulgated this time is a key symbol for the further improvement of the strategic position of the logistics industry in the domestic development. It locks the logistics industry as a strategic and basic industry that supports the development of the national economy[3]. The "Medium and Long-Term Plan" clearly points out that by 2020, a modern logistics service system that is convenient, efficient, technologically advanced, safe and orderly, and green and environmentally friendly has been basically established, so as to further realize the target strategic pattern of medium and long-term development of the logistics industry. The "Medium and Long-Term Planning" grasps the core essentials of realizing the long-term and stable development of the logistics industry, and clearly gives the development direction of the future industry[4]. It is the top-level design blueprint to guide the healthy, stable and long-term development of my country's logistics industry under the "new normal"[5].

Automatic guided vehicle (AGV), as an automatic guided transportation device, is widely used in warehousing automation logistics scheduling system. The first AGV was born in the 1950s and was mainly used as transportation equipment. And with the vigorous development of technology in the field of electronics and machinery manufacturing, and the continuous improvement of AGV hardware performance and appearance design, AGVs are widely used in the logistics industry, tobacco manufacturing industry, post office express sorting industry, pharmaceutical industry, port and terminal cargo transportation industry, dangerous places, special industries, etc. In general, AGVs are widely used in flexible manufacturing systems, automated material handling systems[6].

1.2 Development Status of AGV Intelligent Cars at Home and Abroad

From a global perspective, the first AGV car was developed by the American Barret Electronics Company. In the 1960s and early 1970s, Webb and Clark also began to develop AGVs, and achieved good results. By the mid-to-late 1970s, about 520 AGV systems were manufactured and equipped in Europe, including a total of 4,800 AGV hardware devices, and the industry's applications were mainly in the automotive industry. AGV equipment manufacturing and production in Europe began in the early 1980s[7]. In 1984, General Motors of the United States became the largest customer of AGV trolley equipment. In 1986, the company's AGV car usage reached 1,409 units, and in 1987, 1,662 units were added. And American companies have developed AGV technology to a more advanced level on the basis of existing European AGV technology. They embedded a computer control system in the AGV trolley, which expanded the functions of the AGV, increased the transportation volume, and reduced the carrying time. At the same time, it has the function of real-time online charging, so that the AGV can work continuously and uninterruptedly. The first AGV factory in Japan was opened in 2019[8]. By the end of 1986, the country had assembled a total of 2,312 AGV systems available for use, and 5,032 AGV devices were running on various production lines. By 1988, there were more than 20 AGV manufacturers in Japan. So far, with the continuous development of the AGV industry, the development of the AGV industry has become more mature. Today, the more typical and implemented AGV companies in the world include Kiva System, which was acquired by Amazon in 2012 at a price of up to 780 million US dollars. , specifically for Amazon's warehousing system[9].

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From the perspective of domestic development, my country has independently developed AGV equipment since the 1960s. In 1976, the Beijing Institute of Hoisting and Transportation Machinery developed the ZDB-1 automatic transport vehicle, which is the earliest practical AGV. In 1988, the institute developed the postal hub AGV; in 1992, it specially developed optics suitable for nuclear power plants. Guided AGV; As of 1998, the laser-guided AGV car was born in the institute. At the same time, in the introduction of foreign AGV products and technologies: the first AGV system was introduced in 1980[10]. In early 1990, electromagnetic guided AGV trolley was introduced from Japan. In 1995, AGV system began to be widely used in port transportation industry, automobile manufacturing industry, special industry and so on. In 19%, the introduction of vision-guided AGV and related technologies from WEBB company in the United States means that my country's AGV has reached the international advanced level. So far, a large number of AGV equipment research and development and AGV software system research and development companies have emerged in China, such as SIASUN, Kunchuan, Geek+, Kuicang, Jiateng AGV Kromat, Shenzhen Okai, etc. The development of domestic AGVs is unprecedented. Vibrant scene. In general, AGV smart cars at home and abroad have developed to a fairly mature level[11].

1.3 Research Status of AGV Scheduling Algorithms

From the birth of the first AGV to the present, the theoretical research on AGV has been uninterrupted. The literature gives a more detailed description of the development of AGV scheduling algorithms before 2003. It can be seen from the literature that the multi-AGV control system mainly solves problems such as path guidance system design, AGV quantity evaluation, AGV scheduling, AGV software control system engineering implementation, AGV power management, AGV task path planning, and task allocation. In summary, these questions touch on different levels of the decision-making process. The design of the path guidance system can be regarded as the basic decision-making level, because the decision-making results and effects at this level will have a significant impact on the decisions at other levels. The design effect of the path guidance system will directly affect the optimal number of AGVs under the current system and the computational complexity of the scheduling system. In other words, if the path guidance system is well designed, it is conducive to the rapid implementation of other levels, such as AGV scheduling and path planning[12]. If there are bad defects in the design of the path guidance system, it will not be conducive to the further realization of subsequent decisions. Above the basic decision-making layer, that is, the advanced decision-making layer, the problems that need to be solved are AGV quantity evaluation and power management. Finally, at the operational decision-making level, the problems that need to be solved are the path planning, scheduling, path conflict and code realization of the warehouse management system for the trolley. In summary, the more basic the decision-making level, the greater the impact on the automation system.

Since the design and implementation of the pipeline scheduling mode has become mature, this article will not introduce it in detail, and the contents of the later chapters of this article are all described in the free scheduling mode. For the AGV free scheduling mode, due to its flexible and free characteristics, it has a huge practical application value and a lot of theoretical research value. The efficiency of the AGV free scheduling mode depends on the implementation of the path guidance system, path planning algorithm, scheduling algorithm, and scheduling system software architecture. The design of the path guidance system has a huge impact on the number of AGVs under the current system. The number of AGVs will play a decisive role in the realization of the software architecture of the upper-level scheduling system. A reasonable number of AGVs will make the scheduling system run more safely and efficiently. On the contrary, the huge number of AGVs will make the upper-level scheduling system face a huge performance burden, and even make the scheduling system architecture difficult to design or even impossible to achieve. The path planning algorithm and scheduling algorithm need to rely on the path guidance system.

2. Elements of Warehousing Automation Multi-AGV System

A well-designed modern warehouse automation system can not only save a lot of labor and material costs, but also greatly improve the work efficiency and throughput of the system. But to establish a relatively complete warehousing automation system, in addition to requiring a lot of manpower, it also needs to invest a lot of money. In addition to the AGV software control system, AGV intelligent hardware, AGV path planning algorithm, task allocation algorithm, scheduling algorithm, and path guidance system, the elements that make up the warehouse automation system also include some mechanical auxiliary systems, such as loading/pickup machinery. Equipment (manipulators), conveying equipment (conveyor belts, rolling steel bars, etc.), storage shelves, etc. Implementing a warehouse automation system is a huge project. In addition to software development, hardware coordination is very important and strict. Without the cooperation of related peripheral equipment, a complete warehouse automation system cannot be realized, let alone a complete solution[13]. Due to space limitations, it is impossible to introduce each component of the entire warehouse automation system in detail. This chapter mainly introduces the software control system part, the path planning and scheduling algorithm part, the AGV intelligent hardware part, The path guidance system and mechanical assistance system will be briefly introduced.

2.1 AGV Software Control System and AGV Communication Realization

For a modern large warehouse, the upper-level AGV software control system must use the network to communicate with the AGV in the actual environment. If the wired mode is adopted, the AGV must communicate with the upper-layer software control system through the transmission line during the scheduling process, but this will introduce a large number of limited cables into the AGV operating environment, thus hindering the normal AGV scheduling. Therefore, the communication method of this system Use wireless communication. At present, the popular wireless communication method adopts IGBEE or WIFY. However, there are still problems with wireless communication. During the implementation of this system, there is a problem that the radiation area of a wireless network device is smaller than that of a large warehouse due to the limited signal radiation range of a wireless network device, as shown in Figure 1[14].

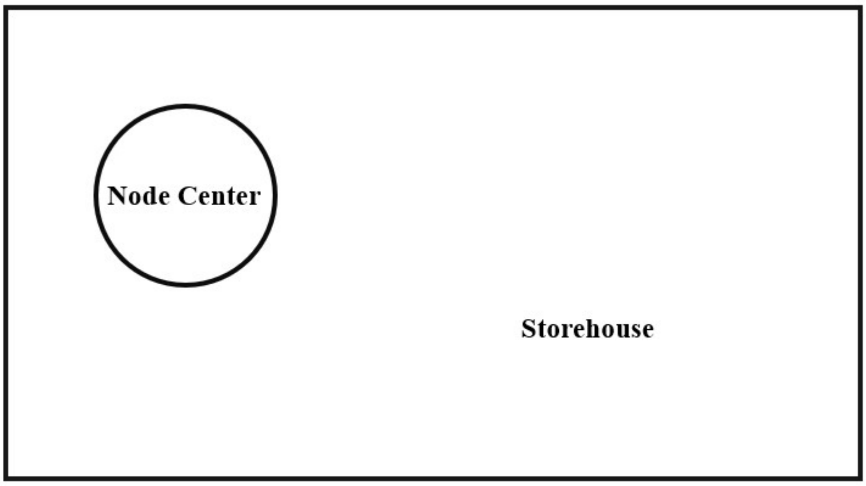

Figure 1. Wireless Signal Range

Assuming that the length of the warehouse is L, the width is W, and the signal radiation radius of a single network device is R, for this case:

$$L * W > \pi * R * R$$

Obviously, a single wireless network device cannot cover the entire warehouse area. At this time, if the AGV position is not within the signal radiation range of no network device, then the AGV will inevitably be lost, which means that the software control system will not be able to control the AGV. Therefore, to make the wireless signal cover most of the warehouse area, multiple wireless network devices must be added[15].

2.2 The Underlying AGV Intelligent Hardware Part

The hardware composition architecture of the AGV car used in this paper is shown in Figure 2.

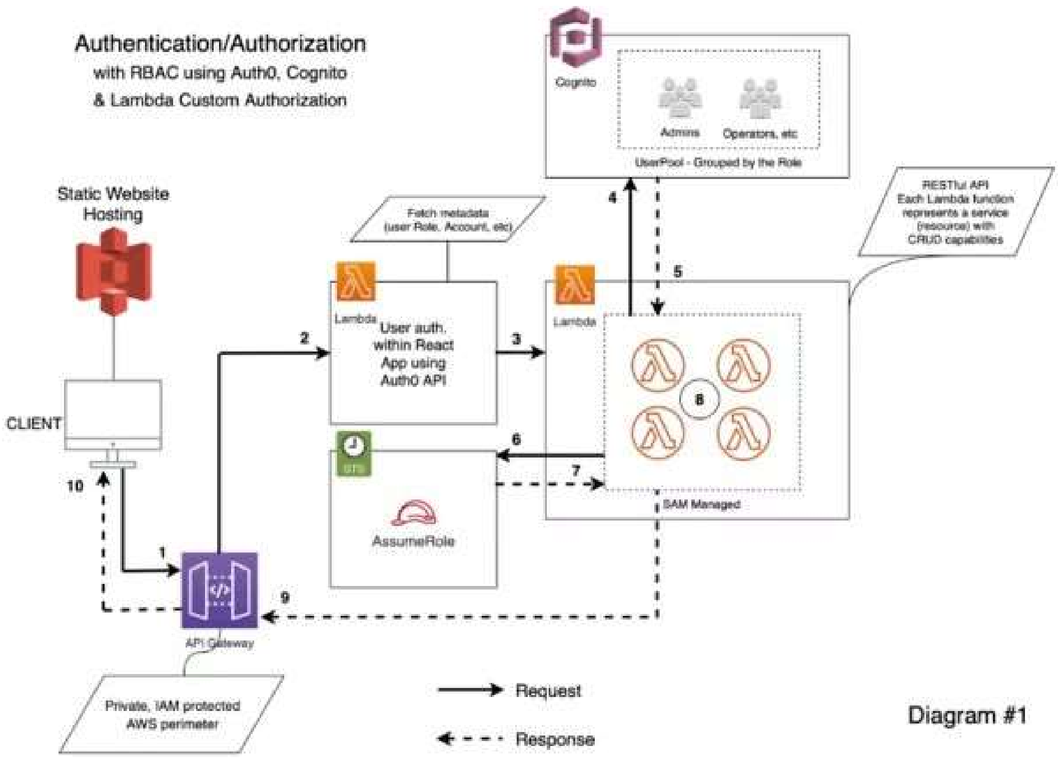

Figure 2. The underlying AGV hardware architecture diagram

This AGV is a hardware architecture based on camera vision navigation type. For the specific implementation of the visual navigation type AGV hardware architecture, please refer to the literature. These documents provide a detailed description of the architectural implementation of the visual navigation AGV. The system is equipped with the Ubuntu operating system. The reason for using the Ubuntu system is that it supports a large number of drivers and has powerful driver expandability. The principle of the car's visual recognition path is: first, the road surface information is continuously captured by the camera, and the road data is transmitted to the OpenCV graphics processing program through the string p. After the program is processed, the AGV's walking direction information is output, so as to control the car through the driver program. steering wheel. Other hardware parts mainly include driving wheel, site identification device, wireless communication device, obstacle avoidance radar device, power supply device, speed controller, motor, etc. The driving wheel is used to realize the walking of the AGV, the site identification device is used to identify the RFI radio frequency card laid on the ground, and the wireless communication device is used for the wireless data exchange between the AGV and the system. The obstacle avoidance radar device is used for the AGV to realize an emergency stop when it encounters an unknown obstacle during the walking process. When the unknown obstacle is cleared, it can continue to travel. The power supply device is

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used to provide electrical energy to the AGV, so that the car can run continuously. The speed controller is used to control the speed of the trolley. The motor is used to control the motion state of the AGV. This article uses visual navigation AGV. Of course, the more popular navigation methods in the market include magnetic navigation, laser navigation, etc. The hardware system architecture is similar to the visual navigation AGV system architecture, but the navigation type is different[16].

2.3 Path Guidance System

The path guidance system is used to provide a path for the AGV to walk. In the design process of this system, the first thing to consider is the design of the path guidance system. After actual debugging and verification, it is learned that the excellent design of the path guidance system will have a huge impact on the subsequent development. First of all, the path planning algorithm and scheduling algorithm need to adopt different methods according to the design of the path guidance system, and different path planning algorithms and scheduling algorithms will have different effects on the throughput and efficiency of the system. Secondly, the design of the Road King guidance system relies heavily on factors such as the layout and space size of the warehouse in the storage system. In most cases, the location of the warehouse is fixed, which imposes macro-space constraints on the path guidance system. The path guidance system mainly includes intersection points, loading/unloading points, and arc edges, which represent the path that the AGV can take from one node to another. The directed arc between the two nodes represents the direction in which the AGV can walk. The length of the arc edge represents the distance between two nodes. Therefore, the route guidance system can also be abstracted into a network-based system. According to the flow topology, the path guidance system can be divided into traditional structure, single-ring structure, and Tandem structure. The traditionally structured route guidance system is a network that connects all the workstations of the entire system together. This network may contain intersections, arc edges[17]. The path guidance system can be unidirectional (directed graph) or bidirectional (undirected graph). In the unidirectional guidance system, the AGV can only form in one direction along the arc edge. In a bidirectional guidance system, AGV can drive in both directions along the arc edge.

3. Multi-AGV System Modeling and Related Theory Introduction

This chapter will use mathematical tools to analyze and represent the multi-AGV system proposed in this paper. Since the work efficiency of the multi-AGV system determines the throughput of the warehouse automation system, in order to effectively analyze the performance of the multi-AGV system, it is necessary to quantify it and express the system data through a mathematical model. In a multi-AGV system, the path planning algorithm, task allocation algorithm, and scheduling algorithm have an important impact on its throughput. Abstracting the path planning algorithm and the scheduling system algorithm into a mathematical model is conducive to analyzing them through mathematical expressions, so as to continuously optimize the path planning module and the scheduling system module and improve the throughput of the system.

3.1 Mathematical Modeling of Multi-AGV System

The modeling of a multi-AGV system is essentially an abstract representation of the path guidance system and AGV. The design and implementation of the path planning algorithm, task allocation algorithm, and scheduling algorithm are inseparable from the operating environment of the AGV, that is, the path guidance system. The path guidance system consists of lines, tracks and stations. By analogy with the arc edges and vertices in graph theory, the path guidance system can be abstracted into a graph data structure, that is, the path planning module and the scheduling algorithm module are analyzed with the help of graph theory. relevant definitions.

For any graph data structure G, it consists of vertex set NODE and edge set into ARC, namely:

$$G = (NODE, ARC),$$
$$NODE = \{n_1, n_2, \dots, n_k, k \in N^*\},$$
$$ARC = \{a_i, a_2, \dots, a_{k'}, i \in N^*\},$$

For any ARC, the set of path lengths of all edges in the set is claw:

$$W = \{|w_1|, |w_2|, \dots, |w_k|, k \in N^*\}$$

Under the multi-AGV single-loading problem, for any task assigned to the AGV system, if the starting point is S and the end point is E, then after calculating by the shortest path search algorithm in the graph data structure constructed by the formula, there is a non-empty The shortest path sequence Path:

$$\text{Path } = \left\{S \to P_1, P_1 \to P_2, \dots, P_j \to P_k, P_k \to E, k \in N^*\right\}$$

If it is calculated from the point of view of node set, the formula can be combined to get:

$$L = \left|m_{1i} \to m_{1j}\right| + \left|m_{2i} \to m_{2j}\right| + \cdots + \left|m_{ki} \to m_{kj}\right|, k \in N,$$

Therefore, no matter from the node angle or the arc edge angle, the task shortest path sequence path and the shortest path sequence length L can be obtained. In the above description, the graph theory is used to abstract the AGV system into a graph data structure, and the shortest path solution of the AGV task is converted into the shortest path search based on the graph data structure by introducing graph theory[18]. In the subsequent analysis process, the graph data structure will be used for analysis.

3.2 Basic Theory of Path Planning

Path planning algorithms are used to solve graph-based shortest path search and path sequence generation problems. Path search algorithms used in graph theory include breadth-first search, depth-first search, and Dijkstr search algorithm. In the application of this paper, BFS is mainly used to solve the shortest path. The BFS algorithm was invented by Dr. Knorad Zuse in 1945. Its key idea is to track an expanding ring called a boundary, and continuously explore the untraversed vertices around the expanding ring until all vertices are traversed. The process of breadth-first search can be regarded as "flood filling", as shown in Figure 3. Taking the center as the basic point, it continues to expand outward until all vertices are traversed.

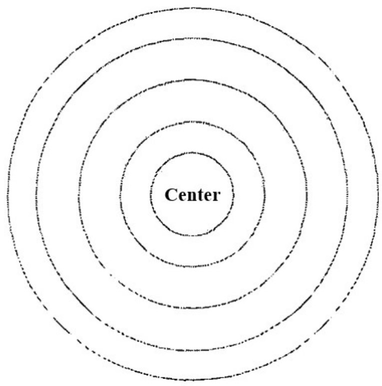

Figure 3. Breadth-first search process

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3.3 Task Assignment Theory

In a multi-AGV system, before performing scheduling tasks, task allocation needs to be performed first. The theory of task allocation algorithm mainly studies how to reasonably select tasks and allocate AGVs to perform specified tasks through task allocation algorithm when there are a large number of tasks in a multi-AGV system/or when tasks are not continuously arrived in a continuous system, so as to maximize the throughput of the automation system , Minimize loading wait time, and minimize task queue length[19].

3.3.1 Allocation Method based on FCFS/CNET/Fuzzy

For task allocation methods, usually mainly include FCFS first-come, first-served method and contract network method. According to the time series, task sets can be divided into discontinuous (discrete) task sets and continuous task sets. For tasks that arrive discontinuously, the FCFS task assignment method can be used directly. FSFS can guarantee that tasks are processed according to the chronological size of arrival.

The Contract Networking (CNET) approach uses a single attribute-based protocol function for task assignment. For example, for a task, the shortest distance of each AGV relative to the target point of the current task is used as the protocol function, and the task with the optimal function value is assigned to the corresponding AGV.

3.3.2 Multiple Load Shortest Path Selection (SSP)

This section first presents the application simulation scenario of a modern logistics storage warehouse with multiple loading and multiple AGV systems, as shown in Figure 4. In this scenario, the following three main elements are included:

(1) Task target point (Goods Point). Different cargoes are stored at different cargo points, for example a cargo named "A' is stored in a location named "A".

(2) AGV Parking Point (AGV Point). In this article, considering if the AGV parking is not designed in this area, the system will have a deadlock problem, so when the AGV car completes the task, it must return to its parking point.

(3) Truck parking point: the location where the truck is loaded/unloaded, the AGV needs to transport the goods from Goods Point to the truck point, and then the truck can load and remove the goods.

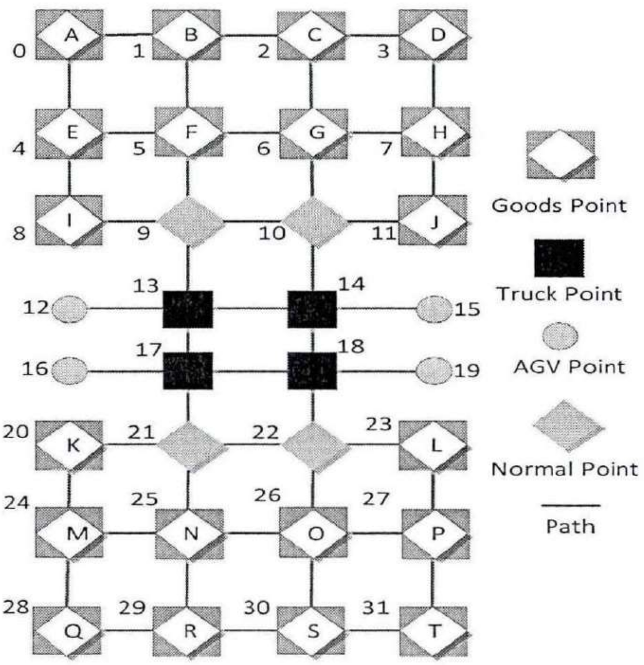

Figure 4. Multi-loading and multi-AGV simulation environment diagram

In modern warehouses, loading/unloading operations can be done either by manual loading or unloading, or by loading/unloading palletizers, so the loading and unloading process is not considered in this paper. So many loading problems can be described as follows: the cargo collection of the service is A, and the loading point number is P. The current location of the AGV performing this task is S, and it is assumed that any truck AGV starts from S to load goods at four target points (the traversal order of the four target points is uncertain), and finally delivers to point P. In this process, because it must pass through each point of A, B, C, D if and only once, it is very important to determine the most reasonable order of {A, B, C, D} to obtain the shortest distance of the scheduling process. Important and unavoidable, namely the shortest path selection problem. In order to describe the selection path selection problem in more detail, the example shown in FIG. 5 is used for description.

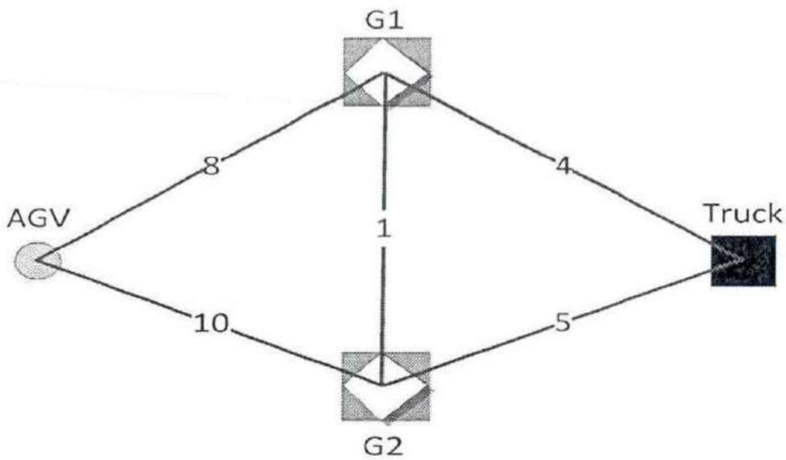

Figure 5. Example of the shortest selection path

Under the multi-AGV system multi-loading problem!15], for any task, the task target loading point set is:

$$EC = \{E_1, E_2, \dots, E_{k-1}, E_k, k \in N^*\}$$

All parameters in the figure are represented as follows:

$$|S \to E_1| = |E_1 \to S| = 1$$
$$|S \to E_2| = |E_2 \to S| = 2$$
$$|S \to E_3| = |E_3 \to S| = 3$$
$$|E_1 \to E_2| = |E_2 \to E_1| = 2$$
$$|E_1 \to E_3| = |E_3 \to E_1| = 3$$
$$|E_2 \to E_3| = |E_3 \to E_2| = 2$$

Then the shortest path sequence has a shortest path length of 5. Further analysis found that the solution to the multi-AGV multi-loading problem can also be regarded as the solution process of the traveling salesman problem model.

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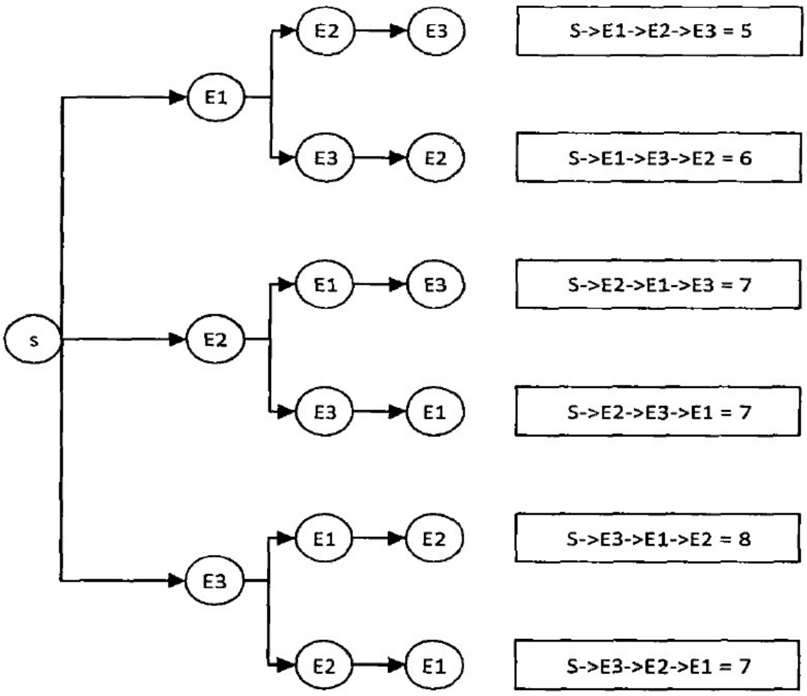

Figure 6. Shortest selection path solution diagram

4. AGV Scheduling Algorithm

After the task is allocated to the AGV through the task allocation algorithm, the scheduling algorithm needs to be used to control the AGV to execute and complete the task. The essence of the scheduling algorithm is to solve the path conflict and deadlock problems that occur when multiple AGVs execute scheduling. Assume that the number of AGVs in the multi-AGV system is m. In the case of m=1, when the AGV path is planned, the path deadlock problem will not occur, and the task can be completed directly without waiting. However, when the warehousing automation system contains multiple (m>1) AGVs, due to the limited number of track paths on the map, the AGV path planning will result in repeated paths, which will lead to path conflicts in the scheduling process of multiple AGVs. and deadlock collisions. Therefore, the research of scheduling algorithm is an unavoidable and even urgent problem[20].

4.1 Analysis of Path Conflict and Deadlock

Through the mathematical modeling analysis of the multi-AGV system in the previous chapter, it can be seen that the essential reason for the deadlock is due to resource competition. When multiple AGVs work at the same time in the same environment, it is inevitable that map resources will compete with each other. In this case, this is similar to the process resource competition of the operating system. If there is no better strategy, it will inevitably cause conflicts or deadlocks in the entire system, which will directly cause the AGV to wait and cannot continue to schedule work. Therefore, it is unavoidable to analyze the deadlock situation of the multi-AGV system. Only by solving all possible deadlock situations, can the multi-AGV process smoothly in the scheduling process. By combining the literature, this paper lists all the conflict deadlock situations that may occur during the operation of multiple AGVs.

4.1.1 Multi-AGY Interrogation Driving

In order to construct the situation of AGV driving in opposite directions, we give the following assumptions: Suppose that the path sequence searched by the shortest path search algorithm when AGV1 performs task i is:

$$\text{path}_{\,i} = \left\{P_1 \to P_2, P_2 \to P_3, \dots, P_j \to P_k, k \in N^*\right\}$$

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Then in this case, the AGV will inevitably have conflicting driving paths in the opposite direction during the scheduling process. As shown in Figure 7.

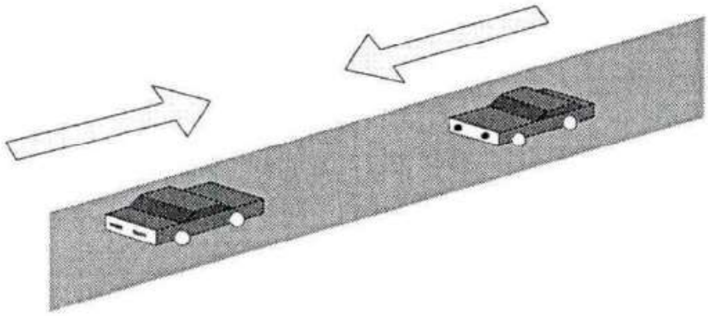

Figure 7. Schematic diagram of opposite driving

For a multi-AGV system with a bidirectional path guidance system, that is, when multiple AGVs are connected in an undirected graph, there will inevitably be opposite driving conflicts between AGVs. In the absence of rescheduling, this conflict will directly cause the AGV to fail to work. A more reasonable solution is to temporarily stop one AGV, while another AGV re-plans the scheduling path.

4.1.2 Multi-AGV Intersection Collision

Similarly, in order to construct the collision of multiple intersections, it is assumed that when AG executes task a, the path sequence searched by the shortest path search algorithm is:

$$\text{path}_a = \{P_1 \rightarrow P_2, P_2 \rightarrow P_3, \dots, P_j \rightarrow P_k, k \in N^*\}$$

By comparison, it can be seen that the end points of the four paths are all Pk, which means that the four AGVs will compete for site resources in C, that is, collisions will occur, as shown in Figure 8.

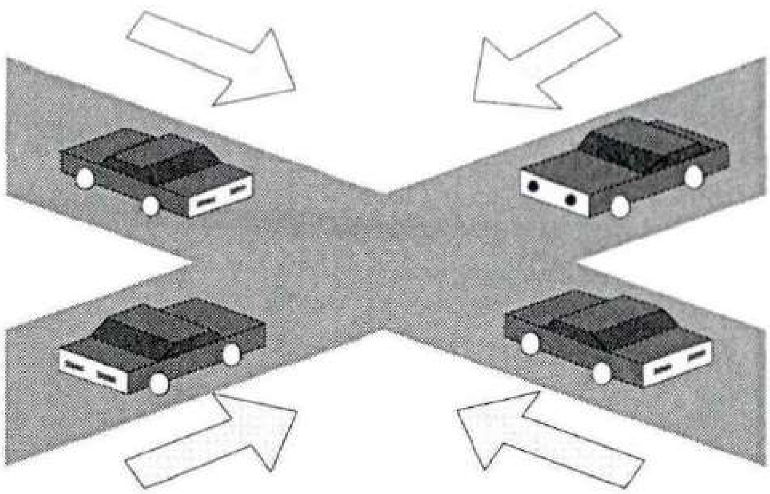

Figure 8. Schematic diagram of intersection collision

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4.2 Dynamic Unlock Algorithm of One-way Strongly Connected Graph

Compared with the two-way connected graph, according to property 1, when the free scheduling task is performed in the one-way strong connected graph, due to the influence of the directed attribute of the one-way strong connected graph itself, the driving directions of all AGVs will follow a strict order. . This will result in no path-to-overlap problem described in the previous section. At the same time, in terms of path crossing problem, there will be no opposite path crossing problem, but only forward path crossing problem, so there is no need to lock sequentially. Now the definition of scheduling matrix Ma based on one-way strongly connected graph is given.

For a unidirectional strongly connected graph with x AGVs and k vertices, the scheduling matrix Ma represents the description of the sequence AGV occupies in the graph G site during the scheduling process, namely:

$$Ma = (M_{1,1} \quad \cdots \quad M_{1,k})$$

For ease of understanding, it is assumed that there are three AGVs performing scheduling tasks in the map shown in FIG. 9.

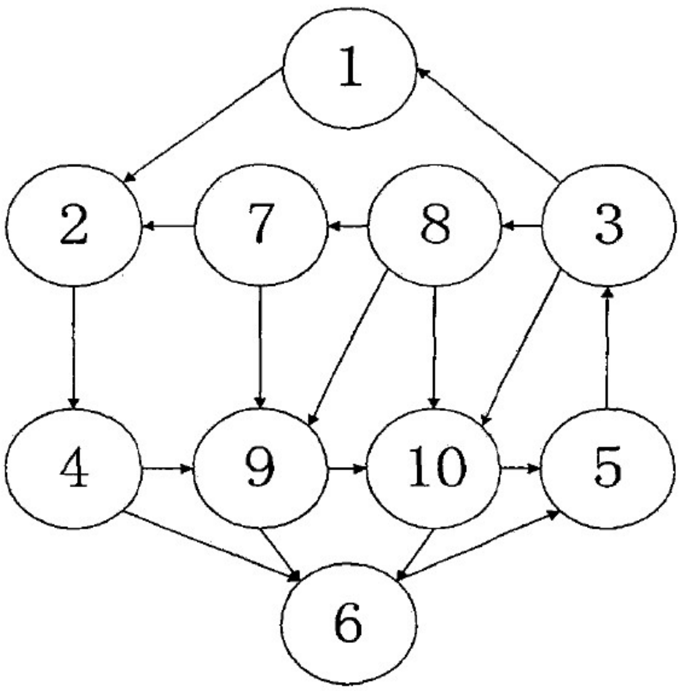

Figure 9. Example diagram of one-way strongly connected graph scheduling

4.3 AGV Scheduling State Transition

In the actual application process, in addition to the path planning and scheduling algorithm, the working state of the AGV also needs to be considered. Starting from the processing logic level of the scheduling system, in the process of AGV performing task scheduling, its operating state is constantly changing, and the various states are closely related. In general, the scheduling status of an AGV can be summarized as: offline, idle, busy, charging, blocked by unknown obstacles, and fault. The state change of the AGV can be expressed as follows: First, when the AGV is not in the power-on state, that is, before logging into the multi-AGV scheduling system, it can be regarded as a stop working state.

The above gives the states in which the AGV may undergo further transitions when the system changes in all states. Except for the ABORT state, if the logout operation is triggered, all of them will be converted into the ABORT state. At the implementation level of the software control system, the realization of AGV state transition can facilitate the system to manage the working state of the AGV. For example, when the AGV performing the task is in the BUSY state, when a new task arrives, the system cannot designate the AGV to execute the task. When the AGV enters the CHARGING charging model, the system cannot retrieve the AGV to perform other tasks.

5. Conclusion

The development of modern warehouse automation systems has become an inevitable trend, and AGVs play an irreplaceable role in warehouse automation systems. Therefore, the research on the multi-AGV control system and scheduling algorithm of warehouse automation has great practical significance. From the perspective of practical application, this paper summarizes the composition of the multi-AGV system, and studies the system management, status monitoring, system UI design, database information storage, task allocation, path planning, AGV scheduling, etc. involved in the AGV control system. As follows: The breadth-first search algorithm is used to realize the shortest path search of system tasks. Under the multi-loading and multi-AGV system, the shortest path selection problem is solved through the traveling salesman problem model, and a task allocation method based on the improved Fuzzy system is proposed. The experimental simulation verifies that the task assignment method can indeed improve the work efficiency of the system. The multi-AGV scheduling algorithm is studied. At the same time, a dynamic locking/unlocking scheduling algorithm based on the lock mechanism is proposed, and the algorithm is embedded in the actual project to solve the path conflict and deadlock problems in the multi-AGV scheduling process.

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