Research on AGV Scheduling System Based on Internet of Things

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Abstract. In this paper, in order to solve the needs of a pharmaceutical factory's logistics system for multiple automated guided vehicles (AGV), a set of AGV scheduling system architecture was developed on the basis of the outdoor heavy-duty AGV that has been developed. Firstly, a WiFi wireless network communication environment is established in the factory area. The AGV side establishes a TCP/IP connection with the dispatching system through the MOXA bridge. The communication application layer uses the MQTT protocol widely used in the Internet of Things, and combines the production beats, considering the task distribution and path Planning and other possible realistic factors, developing scheduling software, and establishing a factory environment scheduling model. Through function test and performance test, the feasibility of the system is verified. This solution is conducive to improving the scheduling system's ability to handle high concurrent tasks and increasing the cargo transportation throughput of the logistics system.

1. Introduction
In industrial production, the logistics system plays an important role. Since raw materials and final products are constantly flowing between the factory's warehouse and production workshop, any bottleneck will reduce the production efficiency of the entire factory. Traditional industrial logistics uses a combination of conveyor belts and manpower, which is costly and does not adapt to future development trends. With the development of flexible manufacturing systems and the adoption of industrial automation by small and medium-sized enterprises, automated guided vehicles (AGV), as a flexible and efficient transportation equipment, have been widely used in new unmanned factories in recent years. The multi-AGV system can work uninterrupted 24 hours a day, and is flexible and efficient. Under the condition of ensuring safety, it is a practical and reliable solution to improve industrial handling efficiency.

In terms of system design, Lu [1] developed an intelligent warehouse management system based on VB language and Access database. AGV and the host computer transmit data through a long-distance 433MHZ transparent transmission module to realize intelligent management of storage materials and intelligent scheduling of production materials. The AGV smart parking system developed by Zhang [2] uses UDP protocol for message transmission between the server and the human-computer interaction integrated machine, which allows packet loss on the network. The database module is based on the SQL Server platform, and the COM and object-oriented The ADO interface can realize the stable operation of 3 AGVs, 8 pallets, and 30 parking spaces. Xinsong Robot Company [3] obtains the ERP weighing work order from MES and performs relevant pre-processing. After determining the production demand according to the actual production progress of the current MES production module, the relevant weighing demand is sent to the AGV dispatch center in time, AGV The dispatch center only needs to
be responsible for the arrangement of the AGV and the parking location, which gives full play to the effectiveness of the MES system, thereby increasing the degree of production automation and production efficiency. Wang [4] developed WMS and sent it to the AGV scheduling system in the form of database and datagram through Ethernet. After parsing the message, it generates AGV job and dispatches AGV to perform corresponding handling tasks. AGV needs to perform data with AS/RS at the pick-up location. Interactively complete the pickup and unloading operations. Ye [5] developed a set of dynamic scheduling system architecture on the basis of OpenTCS. The information transmission format of the communication system adopts JSON format. Redis server is used as the carrier of data exchange. The lower computer develops the driver to complete the data communication and control the response to ROS. The node realizes the control of the sensor.

In terms of environmental modeling, Qian [6] took the actual factory environment as a reference, adopted the two-dimensional code navigation method to navigate the landmark index, designed the corresponding grid electronic map, and conducted partition management on it, so as to reduce the number of failures. The interlacing of responsibilities between AGVs. José A. Ventura [7] developed a dynamic programming algorithm to solve the problem of idling vehicle positioning in a one-way single-loop system to minimize the response time, while considering the time required for driving and loading/unloading. Limit, when all requests are processed by a single AGV, this polynomial time algorithm will find the best stop point. Qiu[8] aimed at problems such as collision, deadlock, and inefficiency caused by the operation of multiple AGVs in smart warehousing, explored the design from two aspects of map construction and scheduling algorithm, and rationally allocated system resources to prevent possible deadlocks. Then, through optimized scheduling and resource lock control, collisions between AGVs are avoided, and multiple AGVs can run to their respective target points without collisions and deadlocks, thereby completing large-scale orders. Waldemar Malopolski [9] proposed a square grid method. The motion of the AGV is regarded as a movement from square to square at a fixed average speed, combined with the method of AGV collision and deadlock prevention based on the retention chain, which is suitable for square structures and a large number of AGV transportation systems.

The multi-AGV scheduling system is a complex dynamic multi-target discrete system. As the map density increases and the number of AGVs increases, the probability of waiting for AGVs increases greatly. At present, a lot of research has been conducted mainly on theories such as dispatch routing algorithms at home and abroad, and most of them consider the operation of AGV in an ideal environment. This paper will take the AGV system of a pharmaceutical factory as the research object, combined with the actual factory environment, and apply the latest technology of the Internet of Things to the development of the AGV dispatch system.

2. System design

2.1. Demand analysis

According to the actual needs of the factory and the principle of adapting to the current production cycle, the overall plan of the system is designed.

The task of the AGV scheduling system consists of five stages, namely (1) task order distribution (2) dispatching the AGV to the loading station (3) controlling the AGV to collect the goods (4) arranging the AGV to the corresponding unloading station (5) for unloading. Normally, AGVs do not need to return to the base after unloading, so they can directly start the next mission.

Specific workflow: In the task allocation stage, the AGV scheduling system receives the orders dispatched by the MES/ERP system, then interacts with the WMS system to obtain the storage status of the goods, and dispatches the idle AGV to the work platform to interact with the roller conveyor system, and from the warehouse Take out the raw materials of medicines; in the cargo transportation stage, the AGV scheduling system will plan the route according to the destination site of the goods, and generate a sequence of access to the target site. The AGV will gradually execute according to the route access instructions, and carry out a reasonable dynamic scheduling strategy, so that multiple AGVs can
collaborate in parallel. Carry out autonomous navigation and positioning and automatic transportation; the AGV arrives at the final target site, enters the work platform of the production workshop, interacts with the roller conveyor system and unloads the goods to complete the cargo transportation task; during the charging phase, when the system detects that the AGV power is lower than the predetermined threshold, when the time, the AGV is dispatched into the charging area and the charging is automatically completed. In addition, the AGV needs to transport the processing waste from the production workshop to the solid waste warehouse, and return the pallets left after unloading to the hardware warehouse.

2.2. Introduction of outdoor heavy load AGV
This system is based on the developed outdoor heavy-duty AGV. The AGV adopts differential GPS navigation mode and connects the vehicle controller and MOXA bridge through a serial server. The MOXA bridge establishes a WiFi connection with the factory wireless network to receive scheduling system tasks, upload AGV status data, such as current power, location, load status and other information.

2.3. Build a wireless network environment
First, a WiFi wireless network communication environment was established in the factory area. The WiFi base station uses MOXA industrial wireless AP-AWK-1131A, which is connected to the ring network switch with an Ethernet cable. The AP and the switch are installed in the protective box together, and the wireless signal is exported to the outside of the box through the feeder. Each AP is equipped with 2 sets of antennas. Use vertical polarization installation. Each switch passes through 100M multimode optical fiber to form a redundant ring network, as shown in Figure 1. WiFi is 802.11a/b/g/n protocol, the highest rate is 300Mbps. As there are many APs, a completely non-interfering frequency band should be used in three adjacent areas, and AP channels should be planned reasonably.

Figure 1 Network connection topology diagram
The AGV establishes a WiFi connection with the factory’s wireless network through the MOXA bridge. In order to ensure that the AGV terminal is switched from one access point to another, the communication can be seamlessly connected. Turbo Roaming technology is used to integrate with WAC-1001 AWK series bridges can complete 50 milliseconds roaming between access points while providing security support in harsh environments.
2.4. Communication system design

The current multi-AGV system mostly adopts centralized scheduling mode. Motion planning and task distribution are completed by the central controller independently. The advantages are high precision and easy control. However, when the number of AGVs and working platforms increases, the control difficulty increases significantly.

Message Queuing Telemetry Transport (MQTT) is a message protocol based on the publish/subscribe paradigm under the ISO standard (ISO/IEC PRF 20922). It works on the TCP/IP protocol family and is a message protocol designed for remote devices with low hardware performance and poor network conditions. Compared with traditional HTTP query, MQTT has the following advantages [10]:

① Use the publish/subscribe message model to provide one-to-many message publishing to decouple the application.

② There are three types of message publishing QoS: "At most once". Message publishing is completely dependent on the underlying TCP/IP network, and message loss or duplication will occur. This level can be used in the following situations. It does not matter if the environmental sensor data loses one reading record, because there will be a second transmission in the near future; "At least once", to ensure that the message arrives, but message repetition may occur; "Only once", To ensure that the message arrives once, this level can be used in the following situations. In the billing system, duplicate or missing messages will cause incorrect results.

③ Use the Last Will and Testament features to notify the relevant parties of the client's abnormal interruption mechanism

④ Small transmission, low overhead (fixed length header is 2 bytes), and protocol exchange is minimized to reduce network traffic.

EMQ X Broker is developed based on the highly concurrent Erlang/OTP language platform, supports millions of connections and distributed cluster architecture, and adopts an open-source MQTT message server with a publish-subscribe model. At the same time, EMQ X Broker is widely used in the global IoT market. It is suitable for building various 5G, Internet of Things, and Internet of Vehicles platforms and applications from the edge to the cloud, and can easily support millions of TCP connections.

First, use the Socket method to establish a TCP connection between the server and the AGV side and the roller side. The transport layer uses the TCP/IP protocol. On this basis, the application layer uses the MQTT protocol. Use EMQ X Broker to build MQTT server. All AGVs, roller conveyors, AGV scheduling systems, and station material systems are used as clients of the server (as shown in Figure 2). The specific implementation is as follows:

① Release: AGV releases the topic of status information; roller conveyor releases the topic of operation; the work point material system releases the demand information topic; the AGV dispatch system releases the order topic.

② Subscription: AGV subscribes to the topic of roller conveyor operation, subscribes to the AGV scheduling system order topic; roller subscribes to the AGV status information topic, subscribes to the AGV scheduling system order topic; AGV scheduling system subscribes to all topics.

In this way, the functional modules of the system are decoupled, which improves the system's ability to handle high concurrent tasks, which is beneficial to increase the cargo transportation throughput of the AGV system.
2.5. Scheduling software design

OpenTCS is an open source, supplier-independent and flexible and usable control system software developed by the Fraunhofer Institute for Material Flow and Logistics (IML) in Dortmund, Germany. It is used for the dispatch control of the Automatic Guided Vehicle System (AGVS). Provides a set of API interfaces for external calls. This research uses OpenTCS as the core and develops scheduling middleware at the top level. It is responsible for routing orders generated by users or warehouse management systems (WMS) and production management systems (MES), order fusion optimization, AGV distribution, and then generating specific Kernels. The internal data is transmitted to the Kernel through HTTP reports; the user interface is developed on the client, and the RMI remote scheduling method is used to exchange data with the Kernel to realize the separation and communication between the HMI and the main process of the server; the communication driver for the lower computer is developed in the Kernel, The scheduling data is preprocessed in the driver, and MQTT communication is established with the AGV; the AGV end develops a driver that connects with the driver in the kernel to complete the data communication, and the control response AGV end and the work platform realize the control of the sensor, as shown in Figure 3.

![Figure 2 Communication system](image)

Figure 2 Communication system

![Figure 3 Software architecture](image)

Figure 3 Software architecture

The AGV scheduling system supports two order generation methods, including manual addition and automatic addition. The manual addition method requires inputting information based on the deadline, loading point, and unloading point of the task order; the automatic addition method is to receive orders...
from the factory production management system (including MES, ERP), combine with the WMS system, and automatically assign tasks to generate orders.

The monitoring module allows the operator to remotely view and monitor the real-time operation and process of the entire warehouse system, display the location and status information of each AGV (including power, speed, load weight, etc.), the completion of the tasks being performed, and the estimated completion time. It is convenient for staff to supervise and manage. This system is based on Java.Swing to develop an AGV dispatching human-computer interaction system, which displays AGV status information in real time, and realizes interactive functions by using remote method invocation (RMI) and Kernel data exchange.

2.6. Database
Redis database can be used to cache messages, set the expiration time according to the key, and it will be automatically deleted after expiration. Using Redis mainly provides buffering for MQTT messages. At the same time, it also decouples the TCS system and MQTT function modules to improve independent performance. The information stored in the database specifically includes
① task list
② communication information
③ roller docking information
④ login information
⑤ material type
⑥ log information
⑦ AGV registration information.

3. Factory environment modeling
Combining the actual factory environment, establishing an appropriate environmental model is a key issue. There are many ways to model the warehouse environment, and the most commonly used method is topology theory to realize the visual number representation of the environment. This method realizes collision-free path planning of multiple AGVs by modeling nodes (ie roller platforms) and routes (ie structured roads in the factory).

In order to avoid conflict and deadlock, the structured path in the factory is abstracted as a one-way topology path, and the road direction of the whole factory is in a circular layout. The factory environment is divided into four areas as a whole: storage area, production area, waste area, parking and charging area. All work stations adopt recessed platform design. If AGV needs to enter this station to load and unload goods, it needs to drive into the platform area. When it is in place, it will control the AGV vehicle-mounted roller table to rotate, handover with the roller system placed there, and design safety inspections System to ensure the stable work of handover tasks. When the AGV power is lower than the set threshold, it will automatically enter the charging area for charging, as shown in Figure 4 and 5.

![Figure 4 Dispatching system model](image-url)
4. Conclusion
In this paper, the research is carried out from two aspects of dispatching system design and factory environment modeling. Based on the developed outdoor heavy-duty AGV, a set of AGV dispatching system architecture is developed. Firstly, a WiFi wireless network communication environment is established in the factory area. The AGV side establishes a TCP/IP connection with the dispatching system through the MOXA bridge. The communication application layer uses the MQTT protocol widely used in the Internet of Things, and combines the production beats, considering the task distribution and path Planning and other possible realistic factors, developing scheduling software, and establishing a factory environment scheduling model. Through function test and performance test, the feasibility of the system is verified. It proves that the AGV dispatch system scheme based on the Internet of Things is beneficial to improve the dispatch system's ability to handle high concurrent tasks and increase the cargo transportation throughput of the logistics system.

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