Design of AGV human-machine interactive control system

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Abstract. The outdoor intelligent transportation of a pharmaceutical factory requires the workshop to put forward task requirements according to the situation and provide multiple AGVs that can meet both man-machine control and networked scheduling. On the basis of existing AGV, an AGV control method based on human-computer interaction is proposed. First, design the overall architecture of the control system, use the touch screen to design and develop the AGV mobile client and task request client to form an industrial wireless network. The establishment of a network enables the AGV mobile client, task request client and vehicle management system to achieve cross-platform communication. Based on this, the client system sets and controls the AGV, which effectively solves the AGV's man-machine control and networking scheduling problems. After functional testing and performance verification, the system works stably, with good flexibility and scalability.

1. Introduction
There are many types of automated guided vehicles (AGV), which are typical representatives of industrial mobile robots. Because of their flexible operation, high work efficiency, and easy upgrade, they have been widely used and promoted in modern industrial automation systems[1-2].

As an important part of logistics transportation, AGV's intelligence level determines its position in logistics transportation and its future application prospects. Now, manufacturing companies needs to conduct parallel customized production for a large number of different orders at the same time, and transport and process a large number of materials according to the requirements of these orders. The logistics management of the workshop has become a major difficulty [3-5]. According to the survey, the processing and manufacturing process took only 5% of the time for the whole production process of a product, and the remaining 95% spent on handling, transportation, storage and waiting for processing [6]. In the United States, experts count transportation and storage costs as 40% of total costs. Therefore, reducing costs and reconstructing more reasonable logistics structure has become a major measure for the development of logistics industry.

The rise and development of logistics industries such as JD.com uses automated operations, ranging from logistics sorting simulation systems to intelligent AGV operation scheduling systems, which can achieve orderly and efficient operations of vehicles, which can effectively reduce the work intensity of workshop workers [7].

The existing control systems often divide the control and human-computer interaction and fail to fully play the role of the two. For example, Jiang and others only use the touch screen as a monitoring interface for display. The AGV controls terminal basically adopts the fixed PC terminal, which is more mechanized and has poor expansibility. The AGV control is only started and stopped according to the established route, can not adapt to the more changeable and complex environment, and its function mode has some limitation [8].
The AGV is still mainly used in indoor, outdoor AGV technology application is still relatively small [9], but also has been a difficult point, heavy-duty AGV is of great significance to the transport industry, its control system also has more requirements, need more flexible, more stable a more secure protection mechanism, users need to provide a human-computer interface, so that people can choose different ways of use, can operate AGV single operation, but also can AGV more networks scheduling management, therefore, the research on AGV human-computer interaction and its control system is very important.

This paper proposes a man-machine interaction based control method for outdoor AGV control in pharmaceutical factory. first, the system architecture is introduced, then the AGV mobile client and task request client are developed from three aspects: hardware design, software design and communication message design, finally, the system function and performance are tested.

2. System architecture

2.1. Composition of the control system
The control system consists of task request client, AGV mobile client and industrial wireless AP, Client, switch. Client through the industrial wireless network, communication with the vehicle management system, through the serial port to the AGV and roller table control commands. The control system network topology is shown in figure 1.

![Figure 1 Network topology diagram of control system](image1)

2.2. The flow of system control
As the hub of the entire system control, the AGV mobile client can not only operate and control offline, but also connect to the vehicle management system network to perform scheduling tasks. According to the transportation needs, the task mode can be selected through the client man-machine interface: offline local mode can be used to operate the function buttons of the man-machine interface to issue control commands to the AGV; networking mode can be connected to the vehicle management system through the MOXA bridge, Receive scheduling instructions, parse the instructions, and issue control instructions to the AGV as required. The control flow diagram is shown in Figure 2.

![Figure 2 Control flow diagram](image2)

2.3. Control commands sending and uploading
Based on the Modbus protocol, AGV mobile client sends control and query commands to the AGV through the serial port, and receives status information from the car, disassembling and displaying according to the format requirements (see flow (3) in Figure 2).

Based on the TCP/IP protocol, the mobile client sends the AGV status information actively through the MOXA bridge; when receiving the vehicle tube instruction, it parses the status information and assembles it according to the format, and returns it to the vehicle tube system through the MOXA bridge (see (2) in figure 2).
Based on the TCP/IP protocol, the task request client sends the task request through the MOXA bridge, receives the information of the vehicle tube, packages the reply information according to the protocol, and uploads it to the vehicle tube system through the MOXA bridge. (See Figure 2, Process (1)).

3. The hardware design of control system
AGV the application of industrial site, we choose the stable brand touch screen, develop AGV mobile client and task to request client. And build industrial wireless network, based on TCP/IP to achieve client communication in the vehicle management system.

3.1. Building of industrial wireless networks
AGV is mobile, and often cannot be networked with other devices, and cannot be controlled in real time. In addition, the general wireless network cannot meet the needs of industrial applications, and its stability and reliability are poor, so choose industrial wireless AP: AWK-1131A, industrial wireless Client: AWK-1137C and industrial ring network switch: EDS-408A-MM-SC builds industrial network, industrial wireless AP: network base station, wireless network coverage in factory area. Use wired Ethernet cable to connect to the ring network switch, industrial wireless Client: installed on the AGV for access to network, industrial ring network switch: Fiber is used as the ring network in the factory area, and 100 megabit multimode fiber is used to connect each switch, so that the AGV can work on the network. As shown in Figure 3.

3.2. Client platform selection
The client needs to perform network communication and serial communication, and its communication is fast and large, and has high requirements for stability, so the touch screen of Weilun Tong brand is selected as the platform for client development. On the one hand, the AGV mobile client needs to communicate with the AGV with the AGV serial port, and also with the vehicle management system for network communication, in addition to controlling the loading and unloading of the roller conveyor. Therefore, it needs at least 3 communication ports. One RS232 port is connected to the AGV for real-time communication; one RS232 port is connected to the industrial wireless Client, which realizes network communication with the vehicle management system through the serial port to WIFI; one RS485 port is connected to the PLC of the roller conveyor to realize serial communication. The task request client only needs to use the RS232 port to connect to the industrial wireless client, and communicate with the vehicle management system network through the serial port to WIFI.

4. Control system software design
The control system software design is the design of AGV mobile client and task request client, so Easy Builder Pro software is used to develop the functions of the client.
AGV mobile client needs to connect three devices, so it needs to add three devices to the software, communicate Modbus with AGV and roller table, add Modbus device and define corresponding communication port number, baud rate and check bit; communicate TCP/IP network with vehicle management system, add Free protocol device and define corresponding port number, baud rate and check bit.

The task request client only needs to add a Free protocol device, define the corresponding RS232 port and baud rate, and communicate with the vehicle management system.

4.1 AGV status display module
The status display module is used to process the analysis of AGV trolley feedback information, as well as information update display, etc. This module is of great significance for functional operation feedback and information acquisition. There are a lot of status information that needs to be queried for AGVs, and there are also many query instructions. The real-time communication pressure is relatively large, which is easy to be blocked and delayed. Therefore, the storage location of the required query status information is designed to be continuous, and then, using the continuous query function of Modbus, the status information can be queried with only one instruction.

Use the macro instruction to edit a query instruction and execute it periodically. Then edit the receiving command, analyze the AGV feedback information, and write it into the local setting area. Complete the extraction and preservation of information. After the information is written locally, it needs to be displayed on the man-machine interface and intuitively fed back to the operator. Therefore, use the status indicator light, value box and picture in the software to query the local status bit information for real-time display and update status.

4.2 AGV monitoring interface
Monitoring interface has the function of observing and recording AGV parameter information and running state. According to the display box, the parameters and status information are queried and displayed on the interface. On this basis, the data sampling function will be saved to the local according to the period of one s, real-time parameters and status information, and form a history file. Users can not only monitor the current state, but also observe the history and analyze the AGV operation.

4.3 Path design module
AGV uses GPS navigation for outdoor driving, so its route design is aimed at latitude and longitude coordinates. This route design adopts the method of defining nodes. The coordinates of the points that need to be driven are read and stored, and then sent to the AGV node and its number, and the corresponding node is found to drive according to the number.

Set the display box on the interface to query GPS coordinates in real time, and edit the formula data table and the use functions of the formula table, such as saving, updating and deleting data. Read through the value box, input in the input box, and then use the formula table to save the coordinates and information of the node. When designing the route, the remote control vehicle arrives at the node position, and then writes parameters such as speed and safety level in the input box, and saves and updates the data by clicking the function button of the formula table. Stored in the recipe table according to the number.

After the path is edited, it needs to be sent to the AGV, so it is necessary to use the macro instruction to develop the function, query the formula table, extract the data by line, edit it into an instruction and send it to the AGV. The data is sent one line by one line, and one line after line is sent. After the sending and receiving are completed, the next sending command is executed. Figure 5 shows the path editing interface and operations.
4.4 Communication connection module

4.4.1 Design of Mobile Client and AGV Communication

Use Easy builder Pro software to develop the AGV mobile client, create Modbus device communication, and adopt the "question and answer" and "one question and one answer" approach with the AGV to design the connection between the client and the AGV device.

A CRC check and error code processing mechanism is set up to ensure the stability and accuracy of communication. If the communication has error code and error code, the mobile client can deal with the risk according to the corresponding processing library of error code and error code. In order to prevent the mobile client communication waiting time is too long, the communication timeout mechanism is designed. Communication does not receive a return value, more than the specified time, according to each interval of 50 ms retransmit instructions until the communication is completed; if in the communication ,10 consecutive instructions sent no reply, you can think of the communication disconnected. At this point, stop sending and disconnect at the HMI prompt.

4.4.2 Design of Communication between Mobile Client and Vehicle Management System

The client communicates with the vehicle management system in two ways, one is the main hair of the vehicle management, the other is that the mobile client sends the status information actively, and the vehicle management system confirms the reply.

Mobile client main transmission means that when the AGV reaches the designated landmark point, it will actively send operating information to the vehicle management system. After the vehicle management system receives the data transmitted by the client, it will return the received instruction to the client. The client stops the continuous sending function. If the AGV does not receive a response command from the vehicle management system to the AGV after sending the operating information to the vehicle management system, the AGV will continue to send data to the vehicle management system at a frequency of once per second until the response information is received.

The vehicle management system actively inquires and sends control commands. The vehicle management system determines the corresponding command according to the current operating state of the AGV. When sending data, it will also determine whether the AGV responds. If the corresponding AGV has not responded, it will be sent once per second. The frequency continues to be sent until the AGV reply is received.

5. Design of client communication protocol

In order to realize that the client can accept the command of the vehicle management system and realize the control of the AGV, two sets of protocols need to be designed according to the function. For the TCP/IP communication of the vehicle management system and the serial Modbus communication of the AGV, two sets of messages need to be designed according to its communication mechanism and functional characteristics.

The communication messages between the client and the vehicle management system are divided into frame header, frame end, serial number, command code and data code. The string length is defined as 12 bits, the 0-bit frame header is defined as 0xFF, and the frame end is defined as 0xFE to identify the message. According to the functions required by the AGV, the first digit is designed as a function code, which is used to distinguish functions, make the string length short, adapt to complex situations and multiple functions, and execute different commands. In order to meet the control of multiple AGVs and distinguish the AGV sending instructions, the second bit is defined as the AGV number, such as 01, 02, 03, etc. The 3rd to 9th bits are designed for AGV status information and commands, all in a two-digit format for receiving commands and uploading information. The 10th digit is used as the check digit, and the exclusive OR check method is used to ensure the accuracy of the data and ensure safety.

Table 1 shows part of the data in the custom format of the TCP/IP transmission message.
TABLE 1. TCP/IP protocol

| Header | Func-code | Number | AGV Information | Check Digit | End |
|--------|-----------|--------|-----------------|-------------|-----|
| FF     | 03        | 02 01 64 05 02 07 60 | FB | FE |
| FF     | 04        | 02 01 64 05 02 07 60 | FD | FE |

The communication message between the client and the AGV is divided into frame header, address, function bit and check bit. The character string adopts the method of variable length according to the function code. The frame header is defined as 01, and the first digit is the function code, which can correspond to multiple functions such as query, writing and continuous writing. The second and third bits correspond to the register address, and the fourth and fifth bits correspond to the number of data, followed by the data bit for writing instructions. The end of the frame is a check digit, and the CRC redundancy check method is used to ensure the accuracy of the data and ensure safety.

6. Experience verification object

Experimental verification object experiment takes Pengxiang heavy load AGV as the verification object, constructs the industrial wireless network, realizes the wireless coverage, realizes the network communication.

The experimental test is based on industrial wireless, and carried out the test verification of the AGV mobile client, including the data interaction between the AGV mobile client and the vehicle management system, and the serial communication between the AGV mobile client and the AGV. After experimental testing, the AGV mobile client can manually operate the AGV route sending, start, stop and other states to effectively control, and can view the status information of the AGV car in real time; the networking mode can also be stable with the vehicle management system Communicate, receive instructions, analyze and issue control instructions. The experimental results have reached the expected indicators, the client's functions are stable, and the AGV can be reliably controlled to achieve operational functions.

7. CONCLUSION

The experimental test is based on industrial wireless, and the test verification of AGV mobile client is carried out, including AGV data interaction between mobile client and vehicle management system, AGV serial communication between mobile client and AGV, etc. Through the experimental test, the AGV mobile client can not only manually control the various states such as route sending, starting and stopping of the AGV, but also view the status information of the AGV car in real time. The network mode can communicate stably with the vehicle tube system, receive the vehicle tube system instructions, and analyze the instructions sent to the AGV and roller table control. The experimental results reach the expected target, and the function of the client is stable and reliable. During this experiment, the AGV completed the whole transportation task through the control system, the control is sensitive and flexible.

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