The Design of Automatic Carton Packing System of Tobacco Based on STM32

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Abstract. This article is aimed at the requirements of a cigarette factory's off-site technical transformation task, and it needs to transfer part of the stem and expanded silk produced by the new factory to the old factory. Therefore, it is necessary to construct a set of fully automatic carton packing system for shredded tobacco to improve production efficiency and reduce labor intensity. The system is divided into mechanical equipment layer, equipment control layer and production monitoring layer. The mechanical equipment layer is the design of the process flow between the various machinery and equipment of the tobacco packing production line; the equipment control layer is based on the STMicroelectronics32 (STM32) single-chip microcomputer as the control core, through Modbus The protocol controls each device and performs data transmission, and communicates with the upper computer through the industrial Ethernet and Modbus Transmission Control Protocol (Modbus TCP) protocol; the production monitoring layer is based on the Qt programming tool for interface design and data transmission with the lower computer, and the relevant data is stored in My Structured Query Language (MySQL) in the database. This solution realizes the automation, networking and intelligence of industrial production lines, liberating manpower and improving efficiency.

1. Introduction

With the introduction of the German Industry 4.0 concept, the wave of intelligent manufacturing has swept the world. The Internet unites processes, systems and intelligent machinery to form a complex network [1]. As a result, internet hot words such as "Internet of Things" and "Service Network" appeared. Among them, the Internet of Things technology is a very hot topic nowadays, and the application of the Internet of Things in the industrial field has become the Industrial Internet of Things. Industrial systems need to connect many different types of sensor equipment and industrial equipment arranged on the industrial site through a network according to different production requirements to form a data transmission network [2]. This is the Industrial Internet. Countries such as Germany and the United States regard smart factories as the core of Industry 4.0. The research of smart factory focuses on the deep integration of new-generation information technologies such as blockchain and Internet of Things with industrial systems, to realize the interconnection of production equipment with the Internet or terminal equipment, and make the manufacturing industry digitalized and networked [3]. Based on the current structure of the digital factory, it is very necessary to build a smart factory to upgrade the manufacturing industry [4].

China's manufacturing industry not only started later than Western countries, but also faced the dual pressure of industrial structure adjustment and the increasingly tense international economic situation, and the low-end development model at the bottom of the industrial chain was impacted [5]. With the
rapid development of China's tobacco industry, the intelligent transformation of tobacco factories is an urgent problem for tobacco companies to solve. However, due to the late start of China's manufacturing industry and a large gap with Western developed countries, it is imperative to carry out a new round of industrial upgrading for my country's equipment manufacturing industry with automation, digitization, intelligence, and greenization as the core[6]. In tobacco factories, the traditional boxing and outbound transportation of shredded tobacco mainly relies on manual boxing, which is characterized by poor operating environment, greater labor intensity, higher cost, and lower degree of automation. Therefore, it is necessary to carry out research on the automatic carton packing process of shredded tobacco out of the country and develop corresponding equipment to improve the work intensity of workers and increase the level of automation in production and processing.

2. Overall scheme design

2.1. Production requirements

The existing transfer mode of the cigarette factory, except that some expanded silks are transferred in turnover boxes, the others are still transferred in cartons after packing. At this stage, carton packing adopts a manual packing mode, that is, manual unpacking, manual bagging, manual packing, manual weighing, and manual sealing. This mode has high labor intensity, low packing efficiency, and workers. The working environment is bad and other phenomena. Therefore, an automatic carton packing system for shredded tobacco is urgently needed to improve factory automation capabilities and work efficiency. The technical requirements and design parameters to be met by the system are shown in Table 1.

| Item                  | Technical specifications             |
|-----------------------|--------------------------------------|
| Carton size           | 690mm*400mm*630mm                    |
| Packing weight of expanded wire | 14kg (bulk weight ≥ 65kg/m3)        |
| Stem packing weight   | 14.5kg (bulk weight ≥80kg/m3)        |
| Packing accuracy      | ±0.5kg                               |
| Packing qualification rate | ≥98%                             |
| Environment humidity  | relative humidity ≤80%               |
| Environment temperature | 5~50°C                             |

2.2. Overall layout of the production line

The functions completed by this production line are as follows: First, the flat carton will be formed in the carton forming machine and taped to the bottom. The action of the carton molding machine is to integrate the box taking, forming, folding and bottom sealing; then the carton follows the roller table. The conveyor moves to the fully automatic bag-feeding packaging machine, which integrates bagging, filling, and sealing. It has the following functions: complete feeding, automatic bag removal, bag opening, quantitative filling, and output of hot products. This fully automatic bag-to-bag packaging machine is equipped with an electronic weighing device to detect the weight of the cut tobacco in real time. When the cut tobacco reaches the predetermined weight, the feeding is finished; then the carton filled with the cut tobacco will move to the one-word seal along the roller conveyor. At the box machine, this machine integrates automatic lid folding and one-word sealing, and uses instant tape to seal the carton; next is the I-shaped carton sealing machine, which can tape the four corners of the carton at one time. To complete the I-shaped box; the last is a smart inkjet and labeling machine, the machine will spray an information code on the carton, and affix an electronic label based on Radio Frequency Identification(RFID) technology, the label is used to identify the carton and the relevant information of the tobacco, Such as the weight of the shredded tobacco, the date of packaging, etc. The process flow of the automatic cartoning system for shredded tobacco is roughly as follows (Figure 1):
2.3. Device control layer design

A large number of production line control systems are based on Programmable Logic Controllers (PLC) as the main control core. PLC is well-known for its anti-interference ability, reliability and stability, and was specially created for industry. The current STM32 single-chip microcomputer has sufficiently powerful performance and low cost, which can be used as the control core of the production line control system. The production line uses the STM32F407IGT6 chip, which mainly relies on Advanced RISC Machine's (ARM) Cortex-M4 core [7]. In the Cortex series, Cortex_A, Cortex_R and Cortex_M cores are used to meet various markets and services. Cortex_M is suitable for low performance, low power consumption and high performance microcontroller market [8]. The entire control system uses industrial Ethernet and Modbus industrial fieldbus protocols. The control system block diagram is shown in Figure 2, and the system flow chart is shown in Figure 3.

Since there are many production line equipment, each machine may have its own dedicated PLC, or it may directly control the equipment by controlling the motor, and there are many sensors, so the control system chooses the Modbus protocol to realize the communication between the automation equipment. Since Modbus is an industrial master-slave communication protocol between several devices, the physical communication mode is usually interface and RS485/RS232 protocol. Each master node can support up to 247 slave communication requests [9]. The master device in the control system is our STM32F4 series single-chip microcomputer, and the slave device is the PLC, motor and various sensors of each machine. The Modbus protocol has two modes: Remote Terminal Unit (RTU) and American Standard Code for Information Interchange (ASCII) for serial data transmission. This control system uses RTU transmission. The protocol used for the communication between the STM32 microcontroller and our computer is Modbus TCP. The microcontroller uses an Ethernet interface to connect to the router and is in the same local area network as the computer. The communication in the local area network is based on the Modbus TCP protocol.
We use the Keil development kit to develop the program of the lower computer. The Keil μVision development tool of Microcontroller Development Kit (MDK) integrates many advanced technologies. It is one of the most authoritative single-chip development tools at present. Compared with the general development tools, it has more For a stable development environment and simpler operation, single-chip microcomputers can be developed more efficiently and quickly.

2.4. Design of production monitoring layer

Combining the latest control and control concepts with the latest computer technology, a comprehensive central monitoring system is designed to integrate top equipment and production control layers to ensure efficient and reliable operation and accuracy, produce. Timely data transmission decision-making, management and production departments are completely organic, forming a complete system [10]. Thanks to the software platform for data collection and monitoring, the central monitoring system can collect, transmit and process data in the main field control via industrial Ethernet to perform inspection and monitoring tasks [11].

There are many programming tools for the host computer, such as Qt, Microsoft Foundation Classes (MFC), etc. We choose Qt as our host computer interface production tool. The upper computer system is designed and implemented according to four sub-function modules, which are production management module, process monitoring module, data management module and system management module. The production management module is mainly about production line operation planning and production control; the process monitoring module is mainly to monitor the operation process of the production line, so as to check whether the production line is operating normally or what failures occur; the data management module is mainly to manage various process data in the production line and Device data, such as device operating speed, sensor data, fault information, etc., and this module is also responsible for establishing a connection with the database, and synchronizing the data to the database; the system management module is mainly related to user management settings and viewing and operating logs. storage. The system block diagram of the production monitoring layer is shown in Figure 4.

3. Function test

3.1. RFID radio frequency module function test

After the shredded tobacco is packed and sealed, an electronic label based on RFID technology will be affixed to the carton, which stores relevant information about the shredded tobacco, such as the weight of the shredded tobacco, and the type of the shredded tobacco. The test uses RFID wireless radio module
based on MFRC522 chip, and the electronic tag uses IC coin card based on FM11RF08. MFRC522 is an integrated non-linear chip for reading and writing (13.56 MHz). This module uses modulation and demodulation principles and integrates them into various protocols and non-communication (13.56 MHz). The internal transmitter of MFRC522 provides powerful and efficient decoding and decoding circuit, which can process the signal from ISO 14443A/MIFARE card and transmitter. It can create various host interfaces such as Serial Peripheral Interface(SPI), serial Universal Asynchronous Receiver/Transmitter(UART) and Inter—Integrated Circuit(I2C).

The test first carries out the connection between the various devices, the STM32 single-chip microcomputer is connected with the MFRC522 module, and then the single-chip microcomputer is connected with the upper computer through the serial port, and the ST-Link debugger connection is also required. After connecting the cable, download the program to the lower computer through ST-Link, and then debug it. The result is shown in Figure 5. It can be seen from the interface that the program runs successfully, and the information in the electronic label is successfully received, which contains the Identity document (ID) of the electronic tag, tobacco weight, and tobacco packaging date.

3.2. Communication test of upper and lower computer
The communication between the upper computer and the lower computer is based on the industrial Ethernet and Modbus TCP protocol. The test first performs the connection between each device. The lower computer is connected to the router through the Ethernet interface, so that the computer and the lower computer are in the same local area network. The communication between the upper and lower computers is realized through static Internet Protocol (IP) and ports, and then the serial port of the lower computer is debugged. Both the ST-Link debugger and the ST-Link debugger must be connected to the computer. After the line is connected, the program is burned to the lower computer through ST-Link, and then debugged, you can see the static IP assigned by the router to the lower computer from the serial debugging assistant, and then set the IP and port of the slave in the network debugging assistant. Try to connect, after experiments, it is found that the upper and lower computers can communicate normally, and the communication effect is shown in Figure 6 and Figure 7. The communication data in the figure below is the standard data message structure of the Modbus TCP protocol. For example, read data request: 00 01 00 00 06 18 03 00 02 00 02. 00 01 in the message indicates the instruction of this communication transaction. Usually, After each communication, you will need to add 1 to distinguish different communication messages; 00 00 represents the protocol identifier, 00 00 represents the Modbus protocol; 00 06 represents the length of the data, used to display the length of the following data; 18 is used for Identifying the address of the device. These seven-byte bytes are also called Modbus headers. 03 means reading the holding register data, which is a function code; 00 02 means the default starting address; 00 02 means the number of registers.

Figure 6 Lower computer communication effect diagram

Figure 7 Host computer communication effect diagram
4. In conclusion

Based on STM32, this paper developed an automatic cartoning system for shredded tobacco. This system can not only meet the production needs of tobacco factories, but also improve the problems of tobacco factories with low levels of automation, networking and intelligence. The system is based on the Modbus field bus protocol to realize the communication and control between the STM32 as the main device and the various sensors, motors and the PLC of each device as the slave devices; based on the industrial Ethernet and Modbus TCP protocol to realize the communication and control between the computer and the STM32 Communications. The created system verifies the correctness of the design method and provides a reliable reference method for the development of intelligent production line control systems.

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