Distributed Machinery Arms Control System Design Based on CAN Bus

Mu Weiwei

Zhonghuan Information College Tianjin University of Technology, Tianjin, 300380, China

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Abstract: The architecture of distributed machinery arms control system based on CAN bus was introduced in this study. The main controller received the operator control information and controlled six joint controllers to achieve the motion task. The real-time communication between the main controller and the joint controller was realized by CAN. The joint controller realized the DC motor PID servo control by controlling LM 629. TheμC/OS-II embedded real-time operating system was transplanted in the main controller, which allocated each management task module. Each joint controller completed the PID servo control of joint motor and monitored feedback error messages. The software design system and flow chart of main controller and joint controller were given. Finally, the experiment proved that good results were achieved.

1. Introduction

China is the largest coal-producing country in the world. Coal is the main energy in our country. In the future, China will still be a coal-based energy structure. With the transformation of economic growth mode of coal mining industry and the expansion of coal use, the strategic position of coal is still very important. However, coal safety incidents continue to appear in the newspapers, endangering the lives of every miner, increasing the production costs of coal mining enterprises, and seriously affecting the construction of a harmonious society. If robotic mining is used, this problem will be solved thoroughly. Robot mining has high efficiency, high horsepower and strong transportation capacity. It can work continuously for 24 hours. Its efficiency is more than ten times that of manual mining, which greatly improves the output. The remote control robot can realize remote automatic coal mining, and can clearly observe the position and progress of the mining surface and the mining robot. Although the use of robots in coal mining is a big investment, there will be no casualties. Efficiency, science and technology, security, will be the development direction in the future. On this basis, this paper presents a control system of coal mining manipulator based on CAN general field to realize remote control.

2. Hardware System of Distributed Manipulator Control Based on CAN Bus

In this system, CAN bus is used to realize distributed control of joint controller. Each joint of the manipulator is driven by a DC motor. The position detection device detects the position and speed of the motor motion with feed backs of them to form a closed-loop system of the joint controller [1]. The joint controllers and main controllers are connected to CAN bus, which can realize the point-to-point and point-to-multipoint distributed control mode. The remarkable characteristics of CA N bus are strong anti-jamming ability and low data error rate. It is known that it is very suiTable for coal mine field use. Especially, its message distance can reach 10 km, so it can fully realize the underground operation of coal mine. Operators can avoid safety problems of miners by operating on the well. The hardware system structure realizes the CAN bus communication with the msCAN module in the controller HCS12DG128B [2]. The control of the joint controller is realized by choosing the microcontroller HCS12DG128B and the precise motion controller LM 629. The position information of the motor is detected by a 500-line rotary encoder, and the joint controller is closed with the respective joint motors [3]. The main controller also chooses the MCU of HCS12 series with its own tusCAN module, which can realize the communication between the main controller and the joint controllers based on CAN bus for distributed control. Its structure is shown in figure 1.

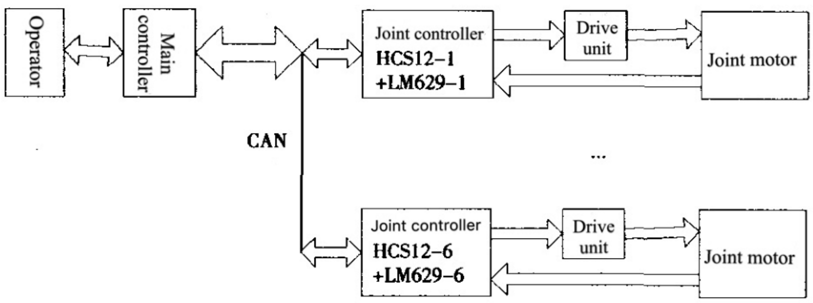

Fig.1. Scheme block diagram of single-joint controller for DC motor

Figure 2 shows the single-joint controller circuit of the manipulator. The PORTA port of MCU is connected to the bi-directional data port of LM629 precise motion controller through 74LS245 chip. 74LS245 chip is an eight-bus transceiver. E port is the chip enabler, which is low-efficient and controlled by the single-chip processor's PTT1 terminal; DIR port is the directional terminal, which is connected with the single-chip processor's PTT2 port to control the direction of data flow [4]. The use of 74LS245 8-bus transceiver is due to the HCS12 single. The chip computer and LM629 precise motion controller use different crystal oscillators to provide the clock. The inconsistent frequency will make the data transmission unsTable, so the bus transceiver is indispensable here.

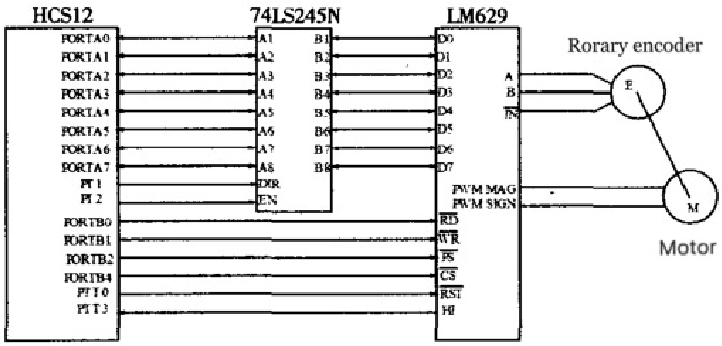

Fig.2. Joint control circuit diagram

The PORTB4 of MCU connects the selected port of motion controller. PTT0, PORTBO, PORTB1 and PORTB 2 control reset, command selection, read and write data ports respectively. LM 629 has an interrupt port H1, which connects the PTT3 port of HCS12. Once the interruption of LM629 occurs, the MCU will be notified to deal with it according to the actual situation [5]. The output signals C, A and B of the incremental rotary encoding disk connected with IN, A and B of LM629 can detect the position information of the motor at any time.

3. Control System Design

3.1. Precision motion controller

The system uses precise motion controller LM629 to realize PID control of DC motor. LM629 contains trapezoidal speed generator and digital PID regulator, which can be easily used in the PID control of DC, BLDC motor and other servo mechanisms that can provide incremental position feedback signals [6]. As long as the acceleration, speed and position information are provided for LM629, and the proportional, integral and differential parameters of digital PID control are provided, the DC motor can be controlled to run according to the given trajectory.

The use of LM629 effectively simplifies the hardware and software of the system, and improves the speed and reliability of the system. LM629 has 22 instructions, which can be used for MCU to control, transmit data or read status information, so as to complete the servo control of DC motor.

3.2. Node distribution of CAN bus

The main controller and the lower joint controllers interact with each other in real time through the CAN bus. CAN technical specification 2.0 includes two parts: A and B. The 2.0A gives the standard format of CAN message, while 2.0B gives the standard format and the extended format [7]. The system adopts standard message format of 2.0B specification and 11-bit identifier.

Messages are divided into different priorities by identifiers, so each controller is assigned a unique identifier. The higher the real-time requirement is, the higher the priority of the identifier allocated is, which can meet different real-time requirements.

In order to simplify the design, the whole identifier can be used for message filtering, and the part of identifier masking can also be used for message filtering [8]. If the function processing command is represented by several bits in the identifier, the data frame length can be reduced and the communication efficiency can be increased. The latter filtering method is adopted in this system. The first five bits of the 11-bit identifier are used as identifiers to distinguish the controllers, and the last six bits are used as instruction codes to distinguish the functional modules.

3.3. Design of control system program

Controller software is divided into two parts: main controller software and joint controller software. The main controller software is mainly used to receive operator control information, manage task allocation, and deal with faults. The joint controller software is an independent servo digital controller system for each joint. It is mainly used to complete the joint motion task under the control of the main controller.

(1) Design of main controller system. The main controller has many tasks, heavy workload and high real-time requirement, so it needs embedded operating system to manage and deploy various tasks. Considering reliability, real-time, ease of use, difficulty of transplantation, cost and so on, after analyzing and comparing the embedded real-time operating system, the system adopts a lightweight and widely used μC/OS-II real-time operating system to manage each task module. Its main feature is that it uses a preemptive real-time multi-task kernel. The preemptive real-time kernel runs the highest priority task in ready tasks at any time.

After analyzing the functions of the main controller, its tasks are divided into four task modules: communication receiving task, communication sending task, computing task and process control task. The main information received in the communication and receiving task of the master controller is the position and posture information of the master hand and the state information of the joint controllers. The task of communication transmission includes sending the required position information to the joint controllers, or feeding back the actual trajectory information or fault information to the operators [9]. The main task of calculation is to obtain the position and attitude information of the manipulator end effector transmitted by the operator, and then to obtain the motion parameters of each joint by inverse kinematics equation. Process control task refers to the real-time processing of peripheral information in the working process, which includes real-time processing of force sensor information and fault processing.

These four tasks are complementary and interrelated. For example, to run the calculation task, it is necessary to wait for the master hand to transmit the position and posture information before processing, and the communication sending task also needs to wait for the completion of the calculation task before sending the position and posture information of each joint to the joint controller. Therefore, the system establishes corresponding semaphores or message queues for each task. When there is a corresponding semaphore or message queue, that is, when each waiting condition is satisfied, the corresponding task will become ready. Once this task becomes the highest priority task among all ready tasks, it can be run with CPU usage rights.

A semaphore is used to denote access to a shared resource or to denote the occurrence of an event, which is used here to denote the occurrence of an event. Message queuing is another communication mechanism that allows a task or interrupt service subroutine to send pointer-defined variables or other tasks to another task. In this master controller system, a message queue and gas semaphores need to be established, which are: process control message queue: when there is external information to be processed, the information is put into the message queue, and the message type is judged in the process control task for processing separately; data processing semaphore: the data received in the communication receiving task is the signal sent by the master hand position information; signal of data processing ending: when the computing task is completed, send this signal to inform the communication sending task to send the computing result; signal of communication reception: when there is an interruption of communication reception, read out the data and store it in a global variable, and send this signal to inform the communication receiving task of this data [10].

(2) Design of joint controller system. The main task of the joint controller is to exchange information with the main controller, control the LM629 precise motion controller, and receive the interruption of LM629 for processing.

When the receiving buffer of the joint controller receives the data from the main controller, the interruption will be triggered. In the receiving data interrupt processing function, the received position and attitude information is stored in the global variable POSITION, and the received data is marked as 1 for the detection and processing of the main function.

The speed, acceleration and displacement of LM629 are provided by the joint controller (PID parameters have been fixed for each joint according to the characteristics of the joint motor). Therefore, only displacement is transmitted by the main controller. So, the acceleration and maximum speed should be calculated according to the displacement and movement time (the interval time between the parameters from the main controller), and then controlled.

4. Conclusion

A distributed control system based on CAN bus communication from hardware to software which has good real-time performance and high performance was constructed, the hardware structure diagram was presented and the software system of the controller was designed, then the system structure of the main controller and the joint control were introduced respectively. The main controller software system choosesμC/OS-II embedded real-time operating system with excellent performance and open code, which adopted the idea of hierarchical development while taking into account the system characteristics. Finally, good experimental results were achieved through communication experiments and motion control of joint controller.

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