Research and design of multi-robot wireless control system based on ZigBee

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Abstract

Combining wireless communication technology and the multi-robot technology, this paper designed a multi-robot wireless control system based on wireless sensing ZigBee network technology. ZigBee node is introduced in the hardware system of the robots, multiple robots depend on ZigBee to form a star network, each robot can keep communication with each other through the center node, so as to achieve simple wiring, the collaborative communication between the multi-robots, and improve the work efficiency of the robots.

Keywords: wireless communication technology, ZigBee technology, multi-robot

1 Introduction

As the development of wireless communication technology, robotics and embedded system, the wireless communication between multi-robots become today's research focus, and initiate a new movement to study wireless communication technology. ZigBee wireless network technology is a wireless communication technology of short distance and low power consumption based on IEEE802.15.4 standard. Its characteristic is close range, low complexity, self-organization, low power consumption, low data rate and low cost, and support the network topology structure of star, tree, and mesh. It is mainly suitable for automatic control and remote control, and can be embedded into all sorts of equipment. For multi-robot cooperation, they only need to transmit limited information for each other intermittently, and save energy as much as possible. So ZigBee is very suitable for the application of this occasion.

This paper establishes a MRWCS based on ZigBee technology by using ZigBee wireless module, and provides an experimental platform for the study of multi-robot cooperative control.

2 The necessity of system development

As the typical representative and main technical means of information technology and advanced manufacturing technology, robotics develops rapidly in a short few decades. From the automatic production line to the exploration of Marine resources, and even the space operation, etc., the robot is ubiquitous. However, in terms of the robot's current technology level of robot, a single one is limited in the ability of information acquisition, processing and control. For complex tasks and changeful work environment, the ability of the single robot more shows some insufficient. With the rapid development of modern industry and science technology, especially the development of computer technology and automation technology, people's requirement of control in the field of control and coordination is higher and higher. So form the different robot to a group system, each one takes on different roles in the task group, and the group completes the work that single robot unable or difficult to do through the coordination and cooperation. That will be a trend in the development of robots. At present, the multi-robot communication generally adopt the way of wire communication, with mature technology and high reliability, but the cable limits the robots' moving range and flexibility, with complicated wiring, difficulty of fault diagnosis and monitoring, and lack of flexibility.

3 Wireless communication network based on the ZigBee

3.1 THE ZIGBEE TECHNOLOGY INTRODUCTION

Zigbee is a kind of wireless network protocol of low speed, low power consumption and short distance transmission based on IEEE802.15.4 standard. The main characteristic of ZigBee network is low power consumption, low complexity, low cost, low rate, reliable, safe, and support a large number of nodes and a variety of network topology. It is mainly used for wireless connection in close range. In general, with the increase of communication distance, the complexity, the power consumption of the equipment, and even the cost of the system are increasing. Compared with the existing various wireless communication technology, ZigBee technology is the one of lowest power consumption and low cost. At the same time, the characteristics of the low data rate and small communication range determine the ZigBee technology suitable for carrying business of smaller data flow.

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There are three types of ZigBee network nodes: coordinator, router, end device. The coordinator is responsible for the launch and maintenance of the normal work in the network; the router has the function of forwarding data message; the end device is simple, no forwarding function, and can only send and receive data. Each coordinator can be connected to as many as 255 nodes, and the resulting ZigBee network right has no limit to the number of the transmission. An actual Zigbee network only supports two kinds of wireless devices: full function device (FFD) and reduced function device (RFD). FFD can provide all the IEEE802.15.4 protocol service, not only can send and receive data, also has the routing function. RFD can only act as an end-node, responsible for collecting data, and then sends it to coordinator or router for processing.

The three types of nodes can make ZigBee supports three types of network topologies: star structure, tree structure and mesh structure, as shown in Figure 1. Star network is a kind of spread network topology, centered on the coordinator, responsible for establishing network and forwarding data. It is simple, but the network structure is single and lack of flexibility, that makes the coordinator easy to become the network transmission bottleneck. Tree structure is the extension of the star network, and makes the networking method more flexible way and the network coverage greater. But this structure is still relatively fixed, and the key nodes of damage will seriously affect the performance of the network. Network structure is the most complex, can provide multiple routing for any two nodes in the network, so the reliability of the network is greatly improved. The disadvantage is that along with the expanding of network size, the routing overhead also increases, and the network delay is more serious.

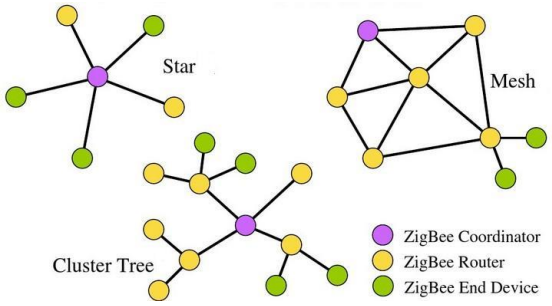

FIGURE 1 The network topology of the Zigbee

3.2 THE COMMONLY USED WIRELESS MODULES INTRODUCTION

Besides the Zigbee technology, short distance wireless communication technology includes Bluetooth, Wi-Fi technology and so on, their comparisons of the main performance parameters are shown in Table 1.

TABLE 1 Comparison of short-range wireless communication parameters

Category	Zigbee	Bluetooth	Wi-Fi
Single point coverage distance	50~300m	10m	50m
Power consumption	low	middle	high
Time for networking	30ms	10s	3s
Transmission rate (bit/s)	250Kbps	1Mbps	1 to 11Mbps
The number of nodes	65535	8	50
Terminal equipment cost	low	low	high
Complexity	Simple	complex	very complex
Network expansibility	auto	no	no
Security	128bitAES	64bit, 128bit	SSID
Integration and reliability	high	high	middle
Cost	low	middle	high

From Table 1, Zigbee technology in the field of low network transmission rate has a great advantage.

3.3 THE WIRELESS COMMUNICATION NETWORK ESTABLISHMENT

In KEIL, create a source file after building a new project. Besides the call to the header file reg51.h, there must be the call to header file RTX51TNY.h which contains the required functions for RTX51. Then compile a basic drive function for each hardware modules and put it in each TASK, finally call them throughout the main function by the RTX51 programming format.

Zigbee network was established based on the Zigbee protocol stack, as shown in Figure 2. ZigBee protocol from bottom to top respectively is the Physical Layer (PHY), Medium Access Control Layer (MAC), Network Layer (NWK), Application Layer (APL), etc. IEEE only processes the PHY and MAC, the ZigBee alliance standardizes the NWK and APL, and user custom the upper protocol. It has low power consumption and low speed, high reliability, powerful function of network routing, excellent self-recovery and redundancy. It can realize point-to-point, radio communications and other communication way.

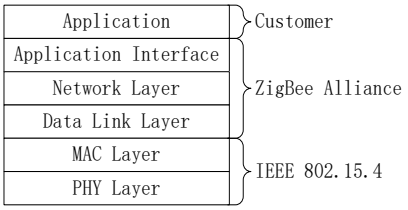

FIGURE 2 The protocol stack of the ZigBee

4 The System design

4.1 THE SYSTEM DESIGN PRINCIPLE

With the rapid development of modern industry and science and technology, especially the development of computer technology and automation technology, people's

requirement of control in the field of control and coordination is higher and higher. Many complex tasks are difficult to be finished only by a single robot, need multiple robot coordination and cooperation jointly. To make the robots mutual cooperation to accomplish the complex tasks that single robot cannot complete, communication and consultation cooperation is the key to the robot dynamic operation. For each robot, the self-intelligence features make it able to independently solve local problems; at the same time, cooperating with other robots is likely to affect the solution of global problem because of the information limitation, therefore, it is particularly important to communication and consultation. The robots can communicate through the ZigBee wireless network, follow the communication protocol of prior agreement, and communicate with each other, so as to achieve the communication control of the multi-robot. Intelligent robot system uses ZigBee technology, installs ZigBee nodes in the robot key parts, and takes the robot as a wireless sensor area. These nodes constitute the wireless network by self-organization way, collect and process the needed information in network coverage area in the form of collaboration, and realize the acquisition, processing and analysis for any node information at any time. At the same time, this also needs a computer for monitoring and coordination control, and completes complex tasks based on the complexity and unpredictability of the current environment.

In this paper, the MRWCS uses the star structure, and the communication system design diagram is shown in Figure 3. In the figure, the coordinator is responsible for establishing the wireless network, receives end-node status information and display or alarm, and sends command to control node status. End-node is responsible for data acquisition, alarm or display, and sends status information to the coordinator.

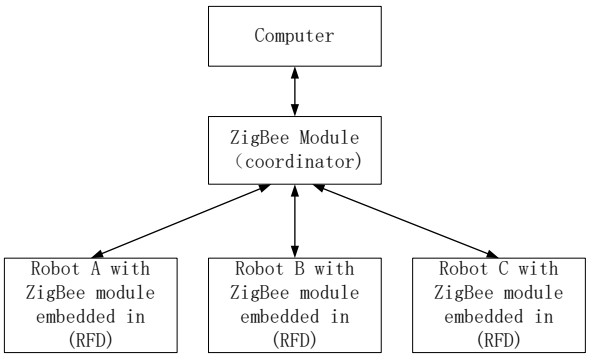

FIGURE 3 The design diagram of multi-robot communication system

ZigBee module has a 16 bit address and each ZigBee module has its own unique address, values from 1 to 65535. By the address, ZigBee module can implement the communication between each other. However, address 65535 (0xFFFF) is reserved for broadcasting mode.

When system running, the coordinator starts the initialization firstly and then establishes the network, after the robots also start and join the network. The master node and the numbered child nodes constitute the wireless network by self-organization way, collect and process the needed information in network coverage area in the form of collaboration in, and realize the acquisition, processing and analysis for any node information at any time. The master node sends control commands to the robot child nodes, the robot terminal nodes send measured data and equipment state to the master node after receive the control commands. The coordinator uploads the data to PC via the serial port, PC processes the data after receives it, and sends the control commands. Robot child node communication module receives the instruction, the micro controller processes and analyzes it and then control the motor drive system. All kinds of action of the robot are complete by the motor drive system.

4.2 THE ROBOT HARDWARE MODULE DESIGN

In the MEWCS, the robot hardware is generally contains the core controller module, the data acquisition module, drive module, actuators, and ZigBee wireless communication module. The ZIG-100 module used in this system is shown in Figure 4.

FIGURE 4 The ZIG-100 module circuit

ZIG-100 is a small module that has a built-in MCU and Zigbee IC, allowing UART communication using 2.4GHz frequency. Utilized as a PAN (Personal Area Network) Module, it replaces wired serial communication with more modern wireless characteristics. ZIG-100 is installed on the robot controller module.

The robot terminals connect to computer through ZigBee wireless communication, and receive the motion control commands sent from the computer or upload the movement status information. When receiving the command or data, the robot carries on the corresponding processing, and then transmits the command to the high-speed processor, robot motor parts will be driven by high-speed processor, realize the corresponding operation. When the robots need to send command or data to other robots or PC, the high-speed processor will send organized data to the ZigBee node, so as to realize the transmission and communication of information. The system uses PC to monitor and control the robots, shifts the work which requires time and computation to PC, thus improves the operation efficiency of the network.

4.3 THE COMPUTER-CONTROLLED PROGRAM FLOW CHART

The MRWCS controls the robot motion according to the process shown in Figure 5. The computer sends off collection packages, after receives the multiple locomotion

status information upload by robots, then sends control packets, realize the robots control.

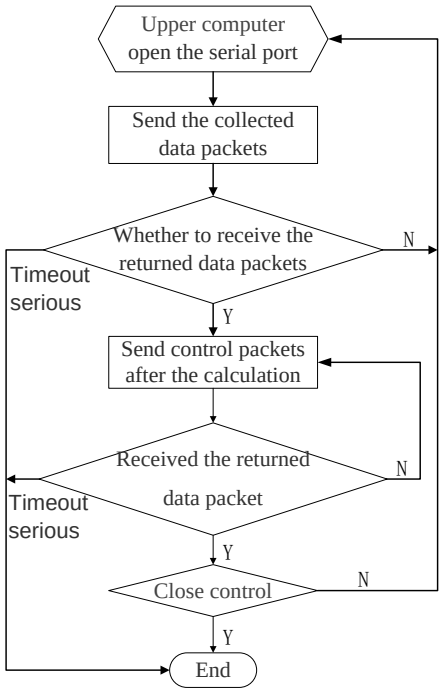

FIGURE 5 The computer-controlled program chart

5 Conclusions

This paper analyzes the robot communication characteristics, combines with ZigBee communication characteristics and development status, and designs the MRWCS. By using the ZigBee technology, the multiple robots and the computer become nodes in the wireless communication network. According to the communication protocol, the computer obtains the real-time movement state information of multiple robots, after analysis and processing, sends off the motion control commands. Realize the communication between robots, computer and a single robot, and the control of the group robots. Provide a good experimental platform to research the more complex multi-robot coordination control in the future.

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