Design of Wireless Communication System for CNC Machine Tools

Rui E(✉)

Heilongjiang Polytechnic, Harbin, Heilongjiang 150001, China
e_rui@l26.com

Abstract. This paper first introduces the development history and future development trends of computer numerical control (CNC) machine tools. In order to greatly improve the work efficiency, this paper proposes a new type of CNC machine tool system, the central control device and the machine tool are separated, which can carry out one-to-many centralized management. In addition, in order to achieve the goal of mobile management, this paper also proposes an embedded CNC handheld terminal program, which can assist the work of CNC machine tools and save labor costs.

Keywords: CNC machine tools · Zigbee star network · Embedded Linux

1 Introduction

The machine tool is an important element of the integration of advanced manufacturing technology and manufacturing information. It is an indispensable complex production tool for the development of the machine manufacturing industry and the entire industry. It is not only an element of productivity, but also an important commodity. To a certain extent, the development and innovation of machine tools reflect the main trends of processing technology. Modern CNC machine tools comprehensively apply the latest achievements in mechanical design and manufacturing process, computer automatic control technology, precision measurement and detection, information technology, artificial intelligence and other technical fields, and will develop toward the trend of high-speed, precision, compound, flexible, extreme and so on.

The world's first CNC machine tool was first developed by the Massachusetts Institute of Technology in 1952, and was immediately put into production of 100 units. Japan developed the first CNC machine tool in 1958. and China's CNC machine tool and technology also started in 1958. The development process of nearly 50 years can be divided into three stages. The first stage, from 1958 to 1979, is in a closed development stage. The second stage is in the "sixth five-year plan", "seventh Five-year Plan" and the early stage of "eighth Five-year Plan", that is, introducing technology, digesting and absorbing, and initially establishing a localization system. The third stage is in the late period of the eighth five-year Plan and the ninth five-year Plan period, that is, to carry out industrialization research and enter the stage of market competition.

Due to the rapid development of computer technology, the technology of CNC machine tools is promoted faster. Many CNC system manufacturers in the world use the

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rich software and hardware resources of PCs to develop a new generation of CNC systems with an open architecture. The open architecture enables the CNC system to have better versatility, flexibility, adaptability, and expandability, and it has developed greatly in the direction of intelligence and networking. In recent years, many countries have researched and developed this kind of system, such as the "Next Generation Workstation/Machine Controller Architecture" NGC jointly led by the United States Scientific Manufacturing Center (NCMS) and the Air Force, and the European Community's "Open Architecture in Automation System" "OSACA", Japan's OSEC plan, etc.

The development and research results have been applied. For example, A2100 system with open architecture has been adopted by Cincinnati Milacron since 1995 in its production of machining center, CNC milling machine, CNC lathe and other products. A new generation of open architecture CNC system, its hardware, software, and the bus specification are opening. Because there are sufficient software and hardware resources available, not only the system integration carried out by CNC system manufacturers and users is strongly supported, but it also brings great convenience to the user's secondary development, and promotes the multi-grade, multi-variety development and wide application.

The development of information technology makes machine tools develop towards the direction of digitization and intelligentization. Intelligent technology is adopted to realize the functions of reconstruction and optimization under multi-information fusion, such as intelligent decision making, process adaptive control, error compensation intelligent control, motion trajectory optimization control of complex surface machining, fault self-diagnosis, intelligent maintenance and information integration, which will greatly improve the forming and machining accuracy. The emergence of intelligent machine tools has created conditions for the future equipment manufacturing industry to realize complete automation of production. By automatically suppressing vibration, reducing thermal deformation, preventing interference, automatically adjusting the amount of lubricating oil, reducing noise, etc., the machining accuracy and efficiency of machine tools can be improved. The development and innovation of CNC system has played a significant role in the intelligence of machine tools. It can absorb a large amount of information and store, analyze, process, judge, adjust, optimize and control all kinds of information.

Product upgrading and people's demand for diversified and individualized products have made the market's demand for manufacturing systems with good flexibility and diverse processing capabilities exceed the demand for large-scale single manufacturing systems, which makes CNC machine tools move towards modularity. The development of reconfigurable and expandable flexibility also requires efficient production in a multi-variety, variable batch environment. Especially the development of automobile manufacturing industry and electronic communication equipment manufacturing industry has put forward higher requirements for production efficiency. As the automation of the manufacturing process increases, machine tools are required not only to complete the usual processing functions, but also to have functions such as automatic measurement, automatic loading and unloading, automatic tool change, automatic error compensation, automatic diagnosis, wire feeding and networking.

The intelligence of machine tool numerical control system is the general trend, and the proportion of software in the numerical control system is increasing day by day, so

that the numerical control system not only controls the machine tool movement, but also provides many possibilities for the optimized design and rational use of the machine tool. In recent years, in order to better meet the "high speed, high precision, compound, intelligence, and environmental protection" requirements of machine tool users for CNC machine tools, domestic and foreign CNC machine tool companies have continuously developed various types of CNC machine tools with intelligent functions. Especially with the development and application of machine tool design technology, Internet and information technology, and artificial intelligence technology, CNC machining has gradually shown a trend of networking and intelligence, and the intelligent functions of CNC machine tools have become more and more mature.

2 Design of Wireless Control System Based on ZigBee Star Network

2.1 Brief Introduction of ZigBee

CNC machine tool is the abbreviation of Computer numerical control machine tool. It is an automatic machine tool equipped with program control system. CNC machine tool makes it more convenient to process complex, precise, small batch and various kinds of parts. It has the advantages of good flexibility and high efficiency. In the direction of modern CNC machine tool control technology, it makes electro-mechanical integration. However, there are many problems in CNC machine tools. Firstly, the central control device is no longer connected with CNC machine tools, but wireless transmission information through ZigBee network can realize remote control. Secondly, a control device can control multiple CNC machine tools at the same time, saving resources and realizing centralized management. In addition, with the help of ZigBee network, the whole system can realize two-way communication, which can not only control the machine tool, but also monitor the working state of the CNC machine tool according to the feedback information at the control end. The above three characteristics well avoid the problems of traditional machine tools.

Zigbee Communication Protocol: ZigBee is a short distance, low power wireless communication technology based on IEEE802.15.4 standard. ZigBee represents the protocol based on Internet of things standard. It has the advantages of low power consumption, low cost, moderate transmission efficiency and distance, short delay and so on. The independence of each module in the network is relatively high. After connecting with the network, the data can be transmitted through the network, and each module is uploaded step by step. The characteristics of this technology can make industrial control, intelligent agriculture and intelligent buildings get a good development. When ZigBee establishes a network, it needs to judge whether the node is connected to other networks at the same time There can only be one coordinator in the network. When the network is established, the coordinator in the network node will enter the process router as a router. All this is because ZigBee network is distributed. As a wireless short-distance transmission technology, ZigBee has a wide range of applications in the field of Internet of things because its network can provide users with wireless transmission function conveniently.

Zigbee Network Node: ZigBee network node uses CC2530 board card. CC2530 is a real system on chip (SOC) solution for 2.4 GHz IEEE 802.15.4, ZigBee and RF4CE applications. It can build powerful network nodes with very low total material cost. ZigBee network topology mainly includes star network and network network. Different network topologies correspond to different application fields. In ZigBee wireless network, different network topologies have different configuration of network nodes. The types of network nodes are coordinator, router and terminal node. Mesh mesh network topology structure of the network has a strong function, the network can communicate through multi hop; the topology can also form a very complex network; the network also has the function of self-organization and self-healing.

2.2 Design Scheme

In this system, the CC2530 on the control side plays the role of coordinator, undertakes the task of establishing ZigBee network, and multiple CC2530 of multiple CNC machine tools play the role of convergence node, looking for and joining the ZigBee network established by the coordinator. If the memory occupied by the whole system is too large, some CC2530 nodes can be added as routers and relays to expand the communication distance of the whole network. The model of design scheme is shown in Fig. 1.

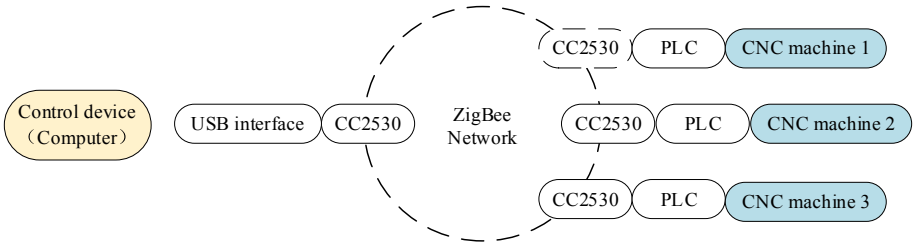

Fig. 1. Design scheme

In the control process, the command transmission process is as follows: the operator sends a command to the control device, that is, the ordinary computer. The command is written into the USB interface through the system special software or serial port assistant, and is transmitted to the CC2530 board card. The board card receives and analyzes the command, determines the controlled machine tool corresponding to the command, determines the connected CC2530 address, and calls the Z-stack protocol stack sending function The information is sent to the destination CC2530 in a wireless way. After receiving the information, the receiving board still needs to carry out some necessary processing, and then in the form of digital electrical signals sent to the CNC machine tool PLC, PLC to complete the processing task.

General Process of Zigbee Network: the initialization of ZigBee network can only be initiated by the network coordinator. Before establishing the network, it is necessary to

judge that this node has not been connected with other networks. If the node has been connected with other networks, this node can only be used as a sub node of the network. Therefore, the first step is to determine the network coordinator, the second step is to scan the channel, and the third step is to set the network ID. after that, each node can join the network through the ID. The process of node joining is to find network coordinator, send association request command, wait for coordinator to process, send data request command and wait for reply.

Based on the above process, the program in CC2530 can guarantee the reliability of ZigBee network. For example, the sender adds the serial number to each message sent, and adds one to each signal sent. In this way, the receiver can judge whether there is information loss according to the serial number. If the receiver receives the information correctly, it will send a confirmation message to the sender, otherwise the sending node will resend the message.

To sum up, the system realizes the separation of operators and machine tools, and ensures the personal safety of operators to a certain extent. Through the application of ZigBee protocol, the control end and the working end of the CNC system are isolated, and the control end is separated from the harsh production environment, which reduces the requirements for the central control instrument. Because of the join of ZigBee network, one to many control mode is realized, that is, a central control computer can control multiple CNC machine tools, which is convenient for unified management and overall coordination. The system provides two-way communication link. On the one hand, it can control CNC machine tools, on the other hand, it can monitor and view the working state of machine tools at the control end at any time. In short, the system provides a more secure, more convenient, more intelligent and easier solution for the field of CNC machine tool processing.

3 Hardware System Design for CNC Machine

The traditional CNC technology can not meet the need of modern manufacturing, a new generation CNC system is towards intelligent, open, flexible and diversified development. We must seize the opportunity, take advantage of talents, develop CNC systems that adapt to the situation of modern high-end CNC systems, and promote the development of CNC industrialization and manufacturing.

At present, the handheld terminals used in CNC equipment are still in the conceptual design stage and functional testing, most of which use the 816 microcontroller as the processor, and the physical keyboard can perform some simple control operations. The hardware and function expansion are difficult and friendly. The man-machine interface is not enough. With the development of manufacturing informatization, more sophisticated and powerful handheld terminal equipment will have broad application prospects in the machinery manufacturing industry.

3.1 System Design

In order to solve these problems, this paper proposes a development plan for embedded CNC handheld terminals for workshop CNC machine tools. The plan includes two

parts. The first part is the programming of the hardware development board; the second part is the programming of the mobile phone (Android terminal) For the development, the hardware development board uses a high-performance low-power 32-bit embedded microcontroller and a general-purpose operating system for embedded processors.

The hardware development board is connected to the CNC machine tool using a serial port or USB interface, and the operator sends instructions in real time (via Wi-Fi), and converts it into a format that can be recognized by the CNC machine tool. The CNC machine tool is sending work instructions.

After programming the kernel and the driver program, in terms of software design, read the user's instructions through Wi-Fi, query the commands corresponding to the semantic instructions stored in the internal storage, convert them into the format recognized by the CNC machine tool, and then pass the serial port Send to the CNC machine tool to complete the design of the hardware development board. If the scheme can be applied in practice, it can keep workers away from the machine tool, ensure safety, and repeatedly input instructions to improve work efficiency.

3.2 Hardware Selection

Based on the difficulty of system migration and further development and practical applicability, this article finally chooses OKMX6Q development board as the hardware platform.

The OKMX6Q development board uses Samsung's Cortex-A9 architecture and NXP quad-core i.MX6Q processor. It has strong internal resources and program processing capabilities, and integrates a variety of interfaces and peripherals, such as cameras, Ethernet interfaces, USB interface, LCD screen, SD card reader, etc. In addition, the OKMX6Q development board officially provides a wealth of technical information, which provides very convenient conditions for system configuration, cross-compilation environment construction, message and file transfer program writing, etc., which will lay a good foundation for further development. The OKMX6Q development board is shown in Fig. 2.

Fig. 2. The OKMX6Q development board

3.3 Uboot Startup Program

A bootloader program is required to start a Linux system, which means that a bootloader program is run after the chip is powered on. This bootloader program will first initialize DDR and other peripherals, then copy the Linux kernel from flash (NAND, NORFLASH, SD, MMC, etc.) to DDR, and finally start the Linux kernel. Of course, the actual work of the bootloader is much more complicated, but its main job is to start the Linux kernel. The relationship between the bootloader and the Linux kernel is the same as the relationship between the BIOS on the PC and Windows, and the bootloader is equivalent to the BIOS (Fig. 3).

```
/mx6ullevk/imximage-ddr512.cfg.cfgtmp board/freescale/mx6ullevk/imximage-ddr512.cfg
  ./tools/mkimage -n board/freescale/mx6ullevk/imximage-ddr512.cfg.cfgtmp -T imximage -e 0x87
800000 -d u-boot.bin u-boot.imx
Image Type:   Freescale IMX Boot Image
Image Ver:    2 (i.MX53/6/7 compatible)
Mode:         DCD
Data Size:    425984 Bytes = 416.00 kB = 0.41 MB
Load Address: 877ff420
Entry Point:  87800000
```

Fig. 3. Successfully compiled code

3.4 Operating System

Embedded Linux is an operating system that tailors the increasingly popular Linux operating system to make it run on embedded computer systems. Embedded Linux not only inherits the unlimited open source code resources on the Internet, but also has the characteristics of an embedded operating system. Embedded Linux is characterized by free copyright fees, excellent performance, easy software migration, open code, support for many application software, short application product development cycle, and rapid launch of new products because there are many open codes that can be referenced and transplanted.

3.5 Linux Kernel Tailoring and System Porting

Linux kernel tailoring. First copy the Linux3.0.35 source code compressed package to the Ubuntu home directory, and enter in the terminal:

```
# tar xjf linux-3.0.35.tar.bz3
# cd linux-3.0.35
# make distclean
#cp arch/arm/configs/imx6_s3_defconfig .config
# make imx6_defconfig
# make menuconfig
```

At the start of the graphical configuration interface, check the following parts:

Networking support → Networking options →
Networking packet filtering framework(Netfilter) → IP: Netfilter configuration →
<*> IP Userspace queueing via NETLINK(OBSOLETE),as shown in Fig. 4.

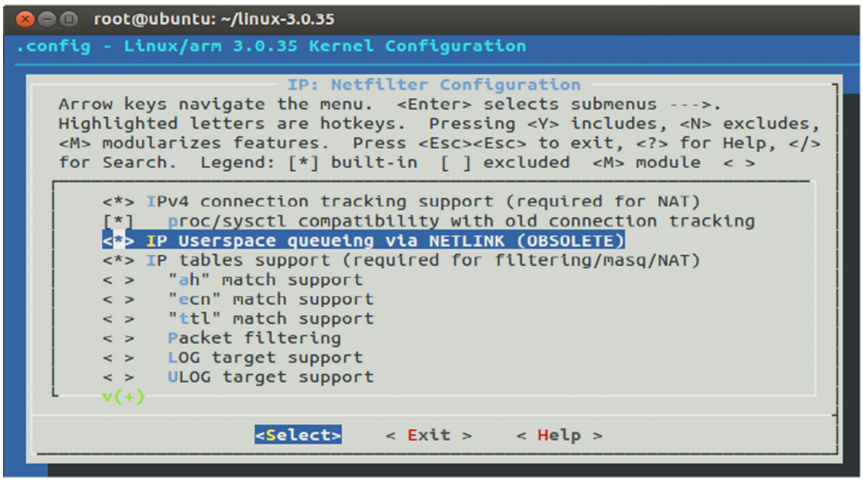

Fig. 4. Kernel module configuration

Finally, enter the following command:

make uImage

Complete the cross-compilation of the modified kernel and obtain the kernel file uImage.

Linux System Porting. Replace the modified and compiled kernel image uImage with the original file with the same name, together with the compiled uboot and rootfs file system, using the mfgtool3-qt-OKMX6-S-emmc.vbs system burning tool (as shown in Fig. 5), import the powered-on OKMX6Q platform together, and then reset or power on again to complete the Linux3.0.35 system migration.

Specific steps are as follows:

The first step is to install a cross compiler to build a development environment. The compiler uses arm-linux-gcc-4.5.1, which uses armv7 instructions when compiling and supports floating point operations. Unzip the compiler to the root directory of the Linux system of the computer virtual machine. Add the path of the compiler to the system environment variable.

The second step is to make the root file system. Use Busybox to make root file system with static compilation method (Fig. 6).

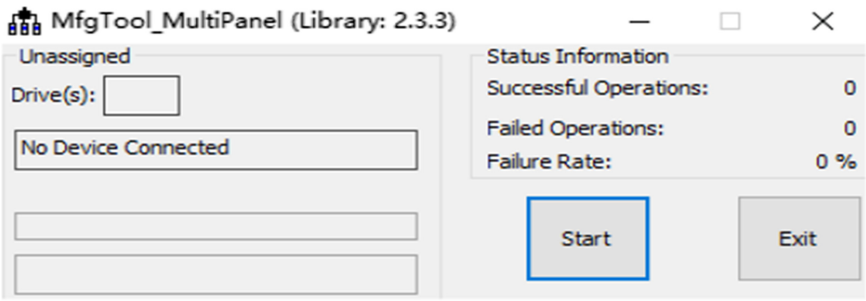

Fig. 5. OKMX6 system programming tool

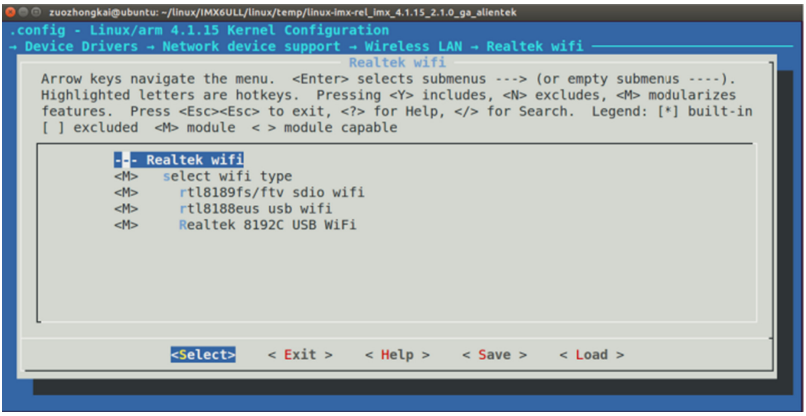

Fig. 6. WIFI configuration interface

The third step is to configure and compile the Linux kernel. Decompress the Linux kernel into the virtual machine Linux, use the make menuconfig (graphical kernel configuration interface) command, configure the root file system startup mode as nfs, use the cross compiler to compile the kernel, and output the Linux kernel image file zImage.

The fourth step is to use the dnw tool to download the Linux kernel image to the development board via USB.

3.6 Wireless Network Card Driver Transplantation and Configuration

The OKMX6Q development board currently supports two interfaces of WIFI: USB and SDIO. The chip used by USBWIFI is RTL8188EUS, and the chip used by SDIO interface is RTL8189FS, also called RTL8189FTV. Both are WIFI chips produced by Realtek. The WIFI driver does not need to be written by us, because Realtek company provides the WIFI driver source code, so we only need to add the WIFI driver source code to the Linux kernel, and then configure it through the graphical interface and choose to compile it into a module. Execute the “make menuconfig” command to open

the Linux kernel configuration interface, and then select the following path to compile the rtl81xx driver into a module:

The configuration interface is the WIFI configuration interface we added. Select "rtl8189 fs/ftv sdio wifi", "rtl8188eus usb wifi" and "Realtek 8193C USB WiFi" and compile them into modules. Execute the following command to compile the module:

make modules -j13//Compile the driver module.

8188eu.ko, 8189fs.ko and 8193cu.ko are the RTL8188EUS, RTL8189FS and RTL8188CUS/8193CU driver module files, copy these three files to the ootfs/lib/modules/4.1.15 directory.

3.7 Writing Application Software

The developed application software should be able to receive the data sent by Wi-Fi, and query the corresponding machine tool commands based on the data, such as tool change, set length, etc., and send the converted commands to the PCL machine tool CNC through the serial port or infrared interface Module. When the machine tool runs, it will return a success or failure command, which is received by the hardware development board to inform the user of the operation result. If necessary, the corresponding interface program can be developed. The machine tool can be directly controlled on the development board to ensure the instruction Can accurately enter the CNC machine tool.

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