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Exploration of Soft Motion Control Platform for Real-time Linux System and Ethernet Fieldbus

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Abstract:

At present, the world's major economic powers have introduced the development strategy of "revitalizing the manufacturing industry," which has promoted a new wave of industrial and technological revolution. China has also introduced the "Made in China 2025" plan to promote the development of high-end manufacturing. As a core part of industrial production, high-quality control systems play a very important role in improving the level of industrial production in China. To adapt to the increasingly complex processing requirements, the operation requirements of the robot are getting higher, requiring it to have a strong openness and easy operability and be able to integrate various types of sensors. At present, the action controller produced by many manufacturers in China lack openness, low-cost performance, not easily integrate all kinds of sensors and other problems, and many core technologies rely on foreign manufacturers lack a certain independent research and development ability, which greatly restricts the development of China's industrial manufacturing industry. Because of the above problems, this paper proposes a soft motion control platform based on a real-time Linux system, designs a soft motion control platform, and gives a solution for building a motion control system, hoping to be a certain reference [1].

Keywords:

Real-time Linux system
Ethernet fieldbus
Soft motion control platform
Exploration

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1. Research background analysis

The traditional motion controller is mostly realized by way of a hardware board, the openness and expansibility are poor, and cannot adapt to the current requirements. In order to improve the performance of the controller, network technology has been introduced into the motion control system in recent years, and Ethernet technology has also developed. With the continuous progress of computer technology and real-time operating system technology, the motion control system with an Ethernet bus as the core of PC has become a general trend [2]. Different from the traditional control mode, this project is based on a PC and real-time system, the important functions of the controller are realized in the way of software, which has the characteristics of high openness, flexible topology, high communication rate, and low cost. In recent years, domestic motion control technology has been greatly developed, but high-end motion control is still relatively backward. Domestic manufacturing enterprises mainly rely on foreign commercial solutions in the key links and have not fully mastered the core technology. Therefore, this paper proposes a flexible motion control platform based on an embedded real-time operating system and Ethernet fieldbus technology, which has high openness and cost performance [3].

2. Functional requirement analysis of soft motion control platform

2.1. Support real-time Ethernet fieldbus

The system takes motion control as the basic function, and its core is to control each device such as servo motor, IO, etc., to achieve the pre-set goals. On this basis, a new control mode is proposed, that is, a new type of bus with high reliability is adopted. There are many types of real-time Ethernet buses, such as Ethernet, Profinet, etc. Power Link, Ethical VIP, etc. [4] Among these buses, Ethernet bus is famous for its high communication speed, high data utilization efficiency and good synchronization performance. Because of its flexible topology and other characteristics, it has become the first choice of many automation manufacturers at home and abroad. To enhance the openness and flexibility of the system, it is necessary to monitor the whole system in real-time, especially the EtherCAT bus.

2.2. Provide motion control library and support algorithm expansion

To ensure the stable operation of the robot, it is necessary to design a complete set of multiple complete robot systems. PLCopen action control technology has been widely used in the world, so it is necessary to design a matching action control for it to reduce the operating difficulties of developers, which has a certain guiding effect on the use of crane control systems. In addition, the flexible action control system has a higher degree of openness, so it is necessary to design a basic control interface for it so that users can design the corresponding action control strategy according to the actual situation, and carry out the corresponding algorithm expansion [5].

2.3. Support all kinds of sensors

In the modern manufacturing industry, due to the continuous improvement of processing technology and technological level, making its processing technology increasingly complex, not only the motion control ability of the system and the intelligence of the system also put forward higher requirements. To adapt to the increasingly complex control requirements, industrial cameras are usually used in the control system, and more control is completed with the aid of computer vision. In addition, other types of sensing devices have also been widely used in actual production. Therefore, support for industrial cameras and various types of sensors is also a key feature of a high-end motion control platform [6].

2.4. Easy networking

At present, the world is setting off a new scientific, technological and industrial revolution, accelerating the upgrading of manufacturing, Germany took the lead in launching the "Industry 4.0," and many countries around the world have also launched their manufacturing development strategies. The country has formulated the "Made in China 2025" plan to promote the interconnection of industrial equipment and information sharing through the Internet and improve the wisdom of manufacturing. In multiple factories, the mobile control platform, as the main carrier to collect various industrial site information, has put forward higher requirements for its operation mode. Therefore, the action controller that realizes network connection has also become a key technology of modern control systems [7].

2.5. Good man-machine interface

In order to enable the user to carry out the initial debugging of the controlled device, the system parameters and related parameters are set, so there must be a good man-machine interface. In addition, most automatic systems are equipped with a man-machine interface for the user to operate [8]. This requires the system to have a better human-machine interface but also requires it to be convenient for man-machine interaction.

3. The construction of a real-time Linux system

A real-time operating system (RTOS) is an operating environment that can perform a certain job in a certain amount of time. It is divided into "hard execution" and "soft execution" two parts, in which "hard execution" refers to within a certain time limit, to complete a specific task, otherwise, it will produce unforeseeable results [9]. In addition, finish the work as early as possible, where if you exceed the prescribed time limit, there will be no danger to your life. In the current situation, it is usually used to extend the general operating system in real-time, and the Windows, Linux and other operating systems in real-time extension is a more common method. Compared with Windows, Linux has the advantages of high stability, free open filtering, etc. The paper chooses the parallel extension technology on the Linux platform and builds the Xenomai real-time operating system.

3.1. The factors that affect the real-time performance of Linux system

The concept of universal operating system design is to shorten the average response time of the whole system as far as possible, improve the total number of tasks handled by the system per unit time, pay attention to the overall functional requirements of the system, and achieve better average performance. However, these design concepts run counter to the requirements of a real-time operating system. The factors that affect the real-time performance of Linux systems are mainly as follows:

(1) The scheduling method of process

There are two scheduling methods based on priority and fairness in Linux. The scheduling by priority mechanism allows processes to be arranged according to priority, while the process preemption policy only applies to a process in the user state, and a process in the core state does not guarantee that it will be occupied, so the phenomenon of priority reversal occurs. It does not meet the requirement of real-time. A fair allocation strategy, which ensures that each processing can reasonably use hardware resources such as CPU, makes high real-time processing, which has a great limit on running speed, cannot be prioritized.

(2) Core preemption

Linux's default core preemption means that a process cannot be occupied by high-priority processing while the CPU is occupied, which violates the need for real-time. Linux 2.6, although also has priority, but in the critical area or cannot be preempted, in principle, such a mechanism can only achieve "soft real-time" [10].

(3) Intermittent mask

Linux's default interrupt is the largest, and when it executes half of an interrupt, it will shut down the interrupt, so that higher interrupts cannot be answered, resulting in increased system failure delays and scheduled delays.

(4) Rough clock granularity

Clock granularity refers to the minimum time interval that the system can achieve, and is the minimum cycle of task scheduling in the operating system. The larger the clock granularity, the slower the response, the higher the network cost, and the lower the network transmission rate. Linux has a minimum clock accuracy of 0. In the actual production process, the requirement of 8 ms is a millisecond level, which cannot meet the real-time requirement.

(5) Virtual memory technology

The operating system generally adopts the way of virtual memory to manage memory and generally adopts the way of paging fragments. If the CPU wants to get the data that is not in the cache, then it will swap the memory pages, which will increase the work delay, so that it cannot complete the task in the specified time.

3.2. Linux system real-time transformation scheme

To solve the problem of poor real-time performance of Linux systems, there are two existing real-time improvement methods:

(1) Internal reconstruction

In this scheme in the case of no great changes, the Linux core source code is directly changed, so as to achieve a complete CPU can be occupied [11]. However, such a control strategy can only ensure that all kinds of unpredictable effects exist in the actual process without affecting the actual process, so the control strategy proposed in this project has the characteristics of "soft real-time."

(2) Method of dual kernel

That is to build a real-time kernel in parallel with the Linux core. The kernel is responsible for all the real-time execution, which ensures the real-time of the system. In the middle of the two operating systems, a just-in-time kernel was built to replace Linux and check-kernel. Using the dual-core method, it can achieve both high real-time and strong real-time, and ensure the stable operation of the Linux system itself. After comparing and comparing the above two ways of implementation, we put forward a solution using a dual-core way, using Xenomai real-time processing technology [12].

3.3. Xenomai real-time system construction

Xenomai adopts ADEOS (OS Adaptive Domain Environment) to complete the processing and control of hardware-level interruptions. ADEOS adopts the idea of "domain" to realize the control of multiple OS cores, multiple OS cores run in the fields supported by ADEOS, and ensure the priority of work in each field by setting the priority of each field.

Xenomai in the development process uses ADEOS programming language so that it can adapt to a variety of different real-time operating systems [13]. Each of the functional modules in Xenomai is called Xenomai "skin," which supports the interface with real-time applications such as vxorks so that software compatibility can be achieved at the source code level, and improve the portability of software. Xenomai company's RTL (Real-Driver Programming Model) provides an embedded system based on Linux kernel for the core software.

When developing Xenomai, a core with an instant patch must first compiled, the Linux core code used here is 3.18.20, and Linux Xenomai is 2.6.5, and Ubuntu 4.04.6 is its operating system. First of all, to download the Linux core code and Xenomai source code, there are some instant patches, because the workload of this program is relatively large, so to run in an efficient development machine, the specific workflow is like this:

(1) The development machine installs an assembly link and a dependency library with the machine that is running. In Ubuntu 4.04.6, gcc-4.8 is used to edit the compilation link of the limix kernel, which is done on a developer's terminal.

(2) The core settings in operation were set up, and it was immediately patched. Before start writing Linux code, the functions of your system have to be set up first, and then you have to run a compiled core on a running machine, so the settings are the same as the running machine, the purpose of this is to copy the conflg file in the running/root directory into the Linux source code to be edited, and then name it conflg. Next, enter the source code for Linux on the command line, and then patch the Linux source code with this script.

(3) Instant settings on the core were performed. Features that negatively affect real-time performance were turned off, such as power-saving management of the Linux core processor, and setting maximum stack memory for real-time systems. Once the configuration is complete, compiling started.

(4) Install the core image on the running machine and install the Xenomai user-space library. On the running machine, the source code of Xenomai-2.6.5 was downloaded, compiled and installed.

The delay time in Xenomai software was detected and its performance was analyzed. The machine adopts an Intel J1900 series chip to play back the high-definition image to improve the system load, and delays the positive and negative delay in the test after 6 hours. The system has a high delay time, and can well meet the requirements of a flexible action control system in real time.

4. Soft motion control platform software architecture

Based on the established embedded real-time operating system, a set of flexible motion controllers is built using two Ethernet buses as drivers [14]. Its ultimate form consists of two aspects: one is the management tool of the platform, and the other is a functional component. Each module of the system is composed of two levels: the lower communication thread and the user interface library.

On this basis, a new bus network model based on the network is proposed. The corresponding information is generated in the system. The software provides some settings for the host and slave stations, such as the host and slave stations, which can set parameters and produce a synopsis for recording parameters. When the user is designing the application program, the user can get the relevant information through the interface provided by the platform to achieve the purpose of simplifying the program development. In addition, the software also realizes the monitoring of the software in the process of performance indicators, convenient for users to analyze.

The functional component of the platform is a software ontology of the control platform, which includes its communication thread library and a user interface library for users to use, and the EtherCAT and EtherMAC bus call protocol stack to realize the real-time thread of data exchange between the slave station as the basis. Threads assign individual data to thread II's process variable resources. In a Linux environment, users can use this interface to create their applications. The user interface library mainly includes the control interface, management interface, action control interface and so on. The function of the interface management module of the system is: start stop, stop, stop and so on. The motion control interface realizes the control of the servo system and 10 devices. The number of its adjustment will eventually affect the variable resources allocated by the lower flow plan to the slave program, and then realize the control of the slave program.

The system is designed into two levels, namely the real-time level and the non-real-time level. In the real-time level, it is mainly for some algorithms that require real-time processing. First of all, through the operation of the system, it can realize the operation of the system according to its operating ability. At the same time, the system also provides a lower axis control interface and PDO interface, which can allow users to expand different algorithms according to different applications [15].

5. Conclusion

To sum up, the motion controller is the "brain" of industrial equipment and one of the most important components in the manufacturing field. The development of advanced motion controllers is the key to improving the level of manufacturing. Nowadays, the manufacturing of all kinds of products is more complex, and the motion controller must constantly meet the current advanced manufacturing process to meet the ever-changing manufacturing needs of the advanced manufacturing industry.

Disclosure statement

The authors declare no conflict of interest.

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