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Practical Visual Efficiency Management System for CNC Machine Tools Based on Embedded Microprocessor and Cloud Computing

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Abstract: The field monitoring devices were developed for Computer Numerical Control (CNC) machine tools based on embedded system, using STM32 series microprocessor, which can acquire the operating parameters of machine tools. The processed data were uploaded to the host computer integrated management system by Zigbee wireless communication network, making full use of the concept and architecture of cloud computing. According to the measured physical parameters of CNC manufacturing process, the corresponding mathematical models and soft-sensing algorithms can be constructed and utilized. At the same time, the actual operation situation of the manufacturing workshop and the efficiency of CNC machine tools were visual remote monitored, statistical analyzed and comprehensive managed based on LabVIEW software platform.

Key words: Computer numerical control machine tools, embedded system, cloud computing, labview, zigbee

INTRODUCTION

It is very important to improve the comprehensive efficiency of the manufacturing workshop or system based on Computer Numerical Control (CNC) machine tools. In fact, due to a series of unfavorable factors, such as improper operation and maintenance, parameters adjustment deviation, unreasonable process allocation, which can result in the adverse effect on the efficient operation and scientific management of production line or manufacturing workshop and also reduce the accuracy and economic benefits of the production enterprises. Therefore, real-time field monitoring of the manufacturing workshop and effectively management of CNC machine tools can achieve a satisfactory solution to reduce the cost and improve production efficiency.

Efficiency management platform can make full use of the embedded micro- processors and the concept of cloud computing. The communication between CNC system and Personal Computer (PC) or other peripheral controllers can be realized by network protocol. The PC or host computer can remotely visual monitor the internal parameters and working status of CNC machine tools, which can be applied to actual production workshop, used for the rational planning, task allocation and scheduling optimization, thereby improving the whole production efficiency.

Several world-famous companies of CNC system and machine tool have developed the conceptual production with the similar functions and features. Germany Siemens company has exhibited “Open Manufacturing Environment (OME)”. Japanese Mazak company has successfully developed “Cyber Production Center (CPC)” (Song *et al*., 2012). In China, researches on monitoring of CNC device have also made progress and Huazhong CNC Ltd. Company has developed "Huazhong Embedded CNC Machine Tool Management Platform", which can acquire operation parameters and transmit data to host computer through the corresponding communication network.

At present, the CNC machine tool monitoring techniques are especially designed based on its operating system, which the portability of its function and software is very poor (Deng *et al*., 2012). If the monitoring techniques are added into the existing CNC machine tools, the new CNC system must to be refurnished, which is clearly not suited to the actual demands. Based on the above background, this study has proposed a practical visual efficiency management system using the concept of cloud computing and embedded microprocessor. The system adopts the host monitor, which can collect real-time field data from the terminal modules in CNC machine tools. According to the statistics and detailed analysis, the enterprise managers can implement the integrated efficiency management for manufacturing workshop.

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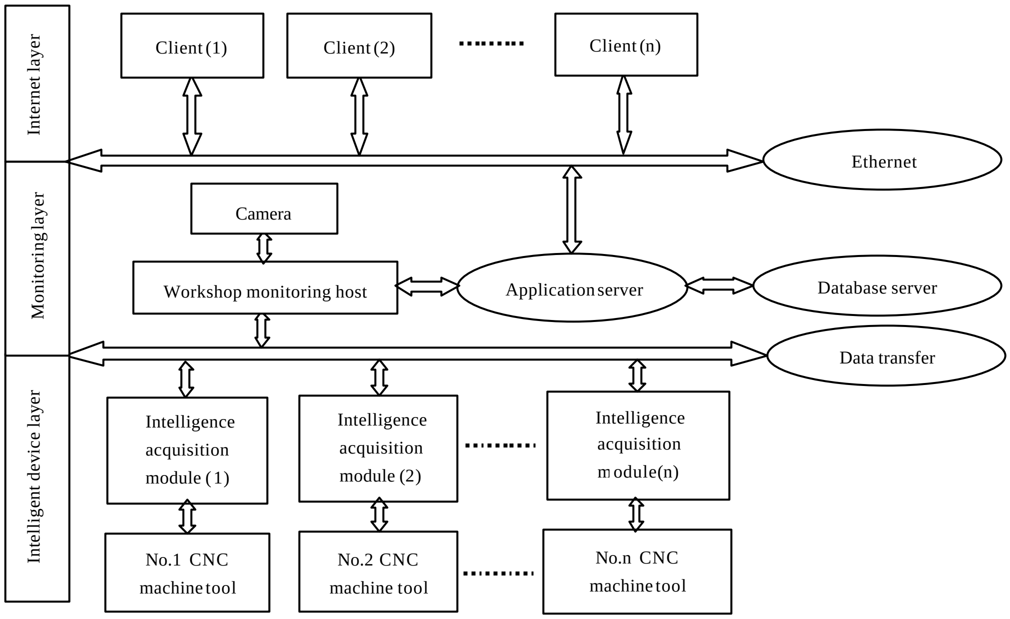

Fig. 1: Schematic diagram of the overall structure for visual efficiency management system

OVERALL ARCHITECTURE OF MANAGEMENT SYSTEM

The structure of practical visual efficiency management system for machine tools based on embedded microprocessor is shown in Fig. 1. The system is composed of intelligent device layer, monitoring layer and Internet layer. Three layers are constructed by the concept of "cloud computing platform", named "special clouds of cloud computing infrastructure". The "cloud computing platform" can integrate different hardware devices, such as PCs, the service terminals, memories and networks, which can balance the load of each device and support the application development (Wang, 2010).

Intelligent device layer belongs to the "infrastructure as a service" of the "cloud computing architecture". The devices are mainly composed of many intelligence acquisition modules mounting into CNC machine tools. The modules can collect switch signals, digital signals and analog signals, which can be used alone and can also operate by the way of multiple simultaneous acquisition data. The output signals and internal states of machine tools can be directly read from PLC I/O port, owing to the modules are installed in the electrical cabinet. Of course, the modules can also acquire the data from the sensors, such as vibration sensors, temperature sensors, machine vision sensors and so on. The collected data are transferred into the workshop monitoring host through Zigbee network. Thus, the state parameters of machine tools are visual monitored for the whole scope, which can realize the unified management.

Monitoring layer belongs to the "platform as a service" of the "cloud computing architecture". This layer is composed of a main monitoring computer, installing Zigbee communication units, network cameras and other components with the corresponding related software. The host computer can collect real-time information of the workshop together and realize information sharing through the network.

The Internet layer belongs to the "software as a service" of the "cloud computing architecture". The managers can access and acquire the real-time data in the host monitoring computer through the IP address and Ethernet, whenever and wherever possible, which has the function of visual remote monitoring and human-computer interaction. It is very important and useful that the comprehensive efficiency of production line can be accurately controlled based on the historical data.

HARDWARE CONSTRUCTION OF PRACTICAL VISUAL EFFICIENCY MANAGEMENT SYSTEM

The workshop monitor is mainly composed of a computer, a LCD touch screen, a video acquisition unit, USB interface unit, Zigbee communication module, RJ45 network interface, etc (Han and Wang, 2003; Wang *et al*., 2003). The touch screen is used to display the real-time monitoring data and many control commands. The video acquisition unit includes the cameras and USB video capture card. The card can convert the AV analog signals into digital signals and sent into the computer for processing and storage. Zigbee module works as a coordinator that is responsible for the creation and management of Zigbee network, also communicates with all intelligence acquisition modules in the workshop. The analyzed and processed data in the computer are shared into network through Ethernet interface, which can facilitate management and remote monitoring. The corresponding hardware structure is shown in Fig. 2.

Intelligent acquisition module is divided into host module and slave module. The host module is responsible for human-computer interface and the slave module is responsible for field data acquisition. The corresponding hardware structure is shown in Fig. 3.

The host module is installed onto the panel of machine tool, which is composed of LCD touch screen, keyboard, RFID unit, USB interface, etc. The operator can real-time monitor the machine information through the touch screen. RFID unit can recognize the personnel identity for operating and management. USB interface facilitates software upgrades in the future. The host module uses STM32 as the main control microprocessor with ARM Cortex- M3 kernel and has the characteristics of high performance, low power consumption and low cost (Wei *et al*., 2012).

The slave module is installed into the electrical cabinet and facilitates monitoring the signals and states. The module is composed of data acquisition single-microprocessor, I/O interface circuits and various sensors. The sensors can monitor vibration, power consumption, the remaining amount of lubricating oil and coolant, etc. The communication between host and slave modules adopts wireless Zigbee protocol.

The proposed Zigbee communication network employs the mode of a main Zigbee unit connecting with several embedded ARM boards (host acquisition modules). After the establishment of Zigbee network, the process parameters of machine tools are acquired and transmitted through the joint networking, based on the slave acquisition modules.

SOFTWARE DESIGN OF PRACTICAL VISUAL EFFICIENCY MANAGEMENT SYSTEM

The management system software of host monitoring computer is implemented based on the platform of LabVIEW (Laboratory Virtual Instrument Engineering Workbench), which is a graphical programming language

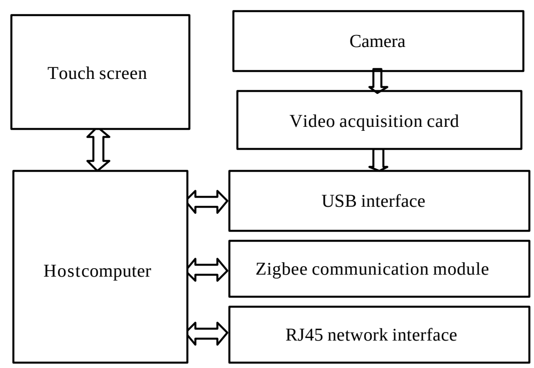

Fig. 2: Structure of host monitor computer system in the workshop

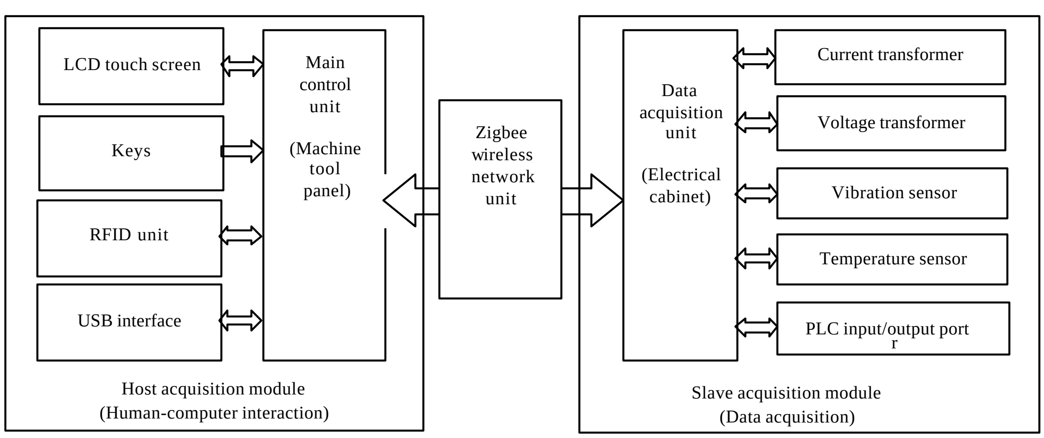

Fig. 3: Hardware structure diagram of intelligent acquisition module

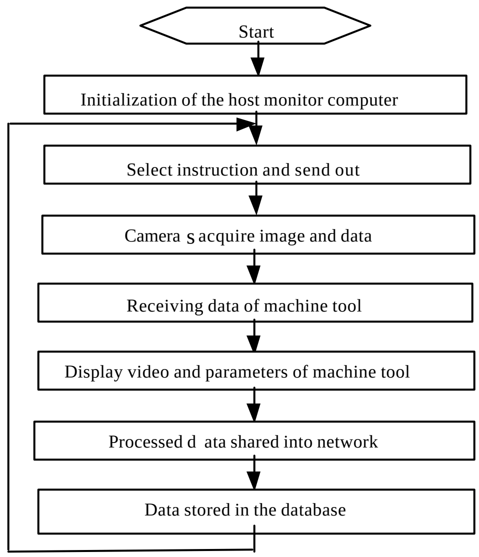

Fig. 4: Flow chart of host monitor computer in the workshop

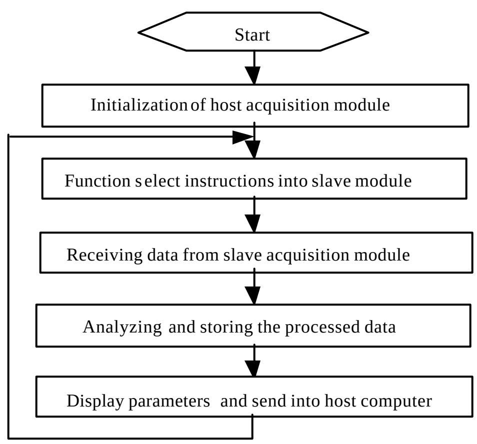

Fig. 5: Flow chart of the host acquisition module for machine tool

development environment. LabVIEW has abundant control and simulation functions, such as advanced digital signal processing, statistical process control, fuzzy control, PID control and other additional software packages. Program is made up of the front panel interface and the rear programming line frame, according to the functional requirements. At present, LabVIEW is widely selected by academic and industrial users, can be considered as an embedded field data acquisition and adaptive instrument control software (Ren, 2012).

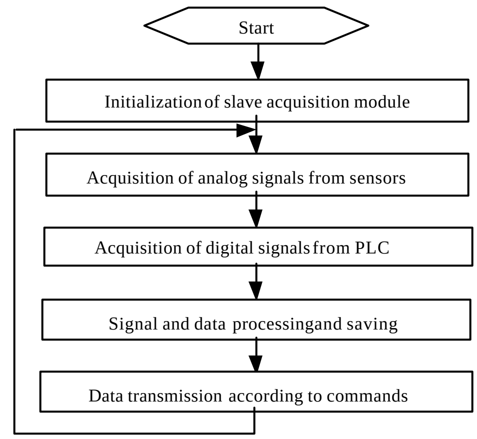

Fig. 6: Flow chart of the slave acquisition module for machine tool

Figure 4 shows the program flow chart of host monitor computer in the workshop. After the monitoring system starts, the hardware initializes and Zigbee wireless network sets up. According to the operator, the camera starts to capture video and process the sampling images. The corresponding parameters and pictures of overall workshop are chosen to display in time. When the commands are sent out, the data will be automatically statistically analyzed in details. The results will be saved into network database, which can be convenient for remote query through the IP address.

The slave embedded acquisition modules receive the sampling commands, various running parameters of machine tools are acquired through all kinds of sensors into the single-microprocessor. The signal processing and data analysis are carried out by the ARM development board and then the information is sent to the embedded STM32 microprocessor, which can be used for mathematical modeling and monitoring. Finally, the processed data are displayed on the panel interface of the host acquisition modules, which are convenient for the operator to observe. At the same time, the host acquisition modules will transmit the information into the host monitoring computer of the workshop. The program flow charts of the host acquisition module and the slave acquisition module are shown in the Fig. 5 and 6, respectively.

EXPERIMENTAL OPERATION OF MANAGEMENT SYSTEM

Figure 7 shows the overall view of the monitoring workshop, including 8 CNC machine tools and those working states.

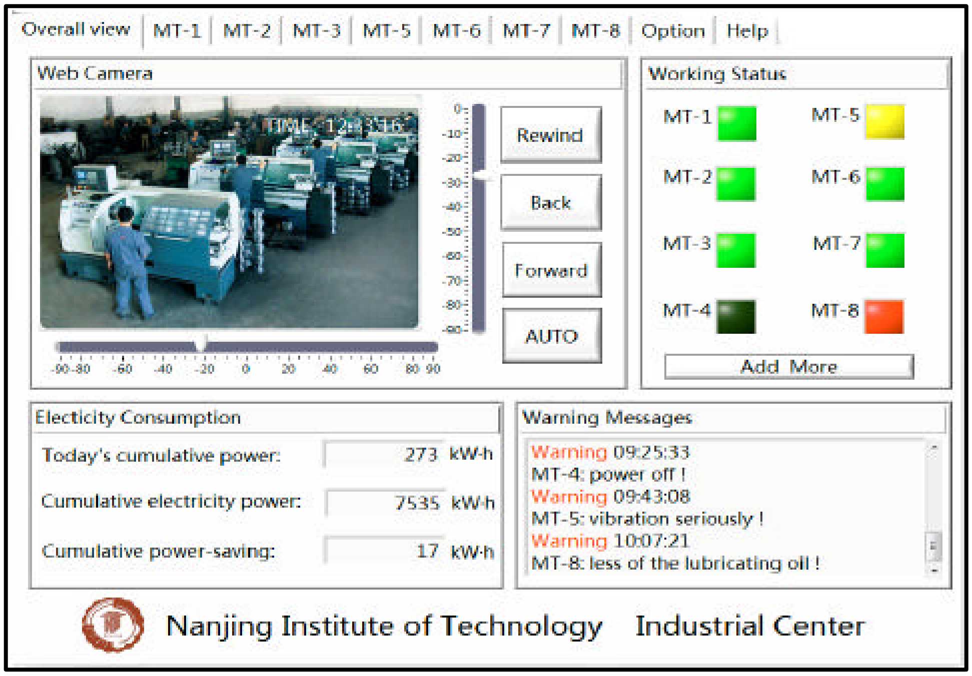

Fig. 7: Main monitoring interface based on LabVIEW software

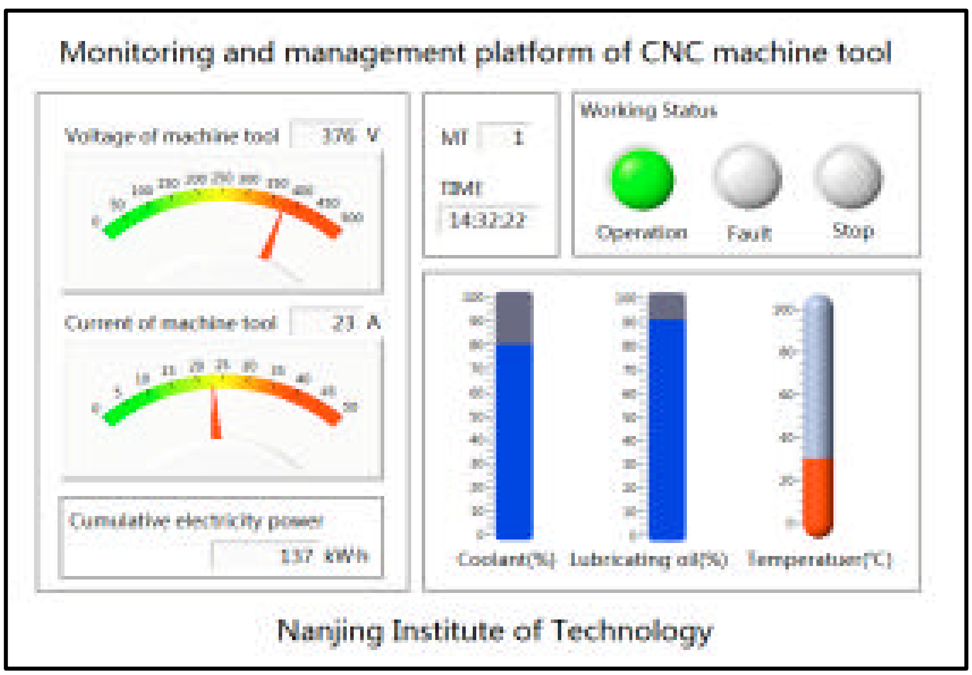

Fig. 8: Visual interface of operation parameters for machine tool

Figure 8 continues to show the operating state of No. 1 CNC machine tool. Of course, there are many other parameters and data to inquiry in time according to the receiving commands from the managers.

CONCLUSION

According to the existing machinery and workshop, the corresponding management system for CNC machine tool manufacturing process data acquisition and machine status monitoring is developed, which is benifit for real-time scheduling and optimization to improve the production efficiency and promote the development of modern enterprise informationization and automation. Using the concept of "frame of cloud computing", the remote monitoring and control system is constructed based on the embedded ARM development board, which is very economical and practical. Adopting wireless Zigbee network communication protocol, data acquisition is great convenient. The hardware resources are saved and without large-scale reformation for manufacturing workshop and CNC machine tools. The topology structure of visual efficiency management system for CNC machine tools can be applied to other objects and situations. The proposed platform can also continue to carry out mathematical modeling, soft-sensing algorithm, a series of virtual digital simulation, optimization scheduling, remote fault diagnosis and other advanced functions, which are to be studied and implemented in the future (Zhao *et al*., 2010).

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