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Research on PDA-based Predictive Maintenance System of CNC Machine Tools

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Abstract: The research on the predictive maintenance system of CNC machine tools based on PDA is of great theoretical significance and practical application value. This paper studied PDA-based predictive maintenance system of CNC machine tools using predictive maintenance theory as a guide to obtain the work state of CNC machine tools in machining process. The corresponding acoustic emission sensors, acceleration sensors and speed sensors are installed on CNC machine tools, by which PDA collected the information of tool machining process. If collected data is found abnormal, the warning module sends the alarm information to the staff via email or SMS and monitors the work state of CNC machine tools. Based on HP iPAQ hx2490 with data acquisition card, the sensor and other hardware equipment, the structure of hardware platform is completed. Employing LabVIEW, the system modules including data acquisition, email warning, SMS warning, login, and report generation are developed. This paper carried out positive exploration on the design of PDA-based portable data acquisition platform, data communication, the early warning maintenance.

Keywords: PDA, Predictive maintenance, CNC machine tools, Data communication, Ubiquitous manufacturing.

1. Introduction

The development of network communication technology and the improvement of the cost-effective of PDA make PDA-based monitoring of CNC machine tools in ubiquitous manufacturing network environment become possible [1-3]. With the hardware platform of PDA, the staff can obtain the work status information of CNC machine tools through the network platform anytime and anywhere to achieve the ubiquitous monitoring and diagnosis of CNC machine tools [4, 5]. Data detection and remote network traffic based on PDA can get rid of the space constraints and has the significance to the building of ubiquitous network.

Based on ubiquitous network environment, some scholars use M2M (Mobile to Machine) to carry out the mobile monitoring of CNC machine tools, construct the model of remote monitoring communications network, put forward using wireless communication technology to display the realtime work status of machine tools in the PDA [6, 7]. However, the present research has been confined to the open CNC machine tools at home and abroad, which mainly develops the mobile monitoring module, uses embedded technology transplanting partial functions of NC system to PDA, and make PDA communicate with CNC systems anytime and anywhere to achieve the purpose of remote real-time monitoring of CNC machine tools.

Considering the predictive maintenance theory as a guide, this paper explored the building of portable data acquisition platform, the data communication warning maintenance and other aspects oriented on non-open CNC machine tools, completed the data communication experiment between the PDA and the computer, studied PDA-based monitoring of CNC machine tools in ubiquitous manufacturing network environment.

2. Overview of PDA-based Predictive Maintenance System

2.1. System Solutions

PDA-based predictive maintenance system monitors the machining process of CNC machine tools by using predictive maintenance theory as a guide. The monitoring objects of CNC machine tools mainly include the machine status, the tool condition, the machining process and the workpiece quality, etc. In the machining process, because the tool condition directly influences the machining quality of the workpiece, this paper selects the tool condition as main monitoring object. In the metal cutting process, the tool can produce a kind of elastic wave. When the tool is broken, the elastic wave is transformed by the power, which spreads out when the plastic deformation and fracture happens in solid. In application, the acoustic emission sensors adsorb on the surface of the workpiece through the magnetic force. Because the acoustic emission signal reflects the lattice change inside the metal materials, which includes the information closely related to the tool wear, it has better forecast characteristics for the tool wear and breakage.

The system scheme is shown in Fig. 1.

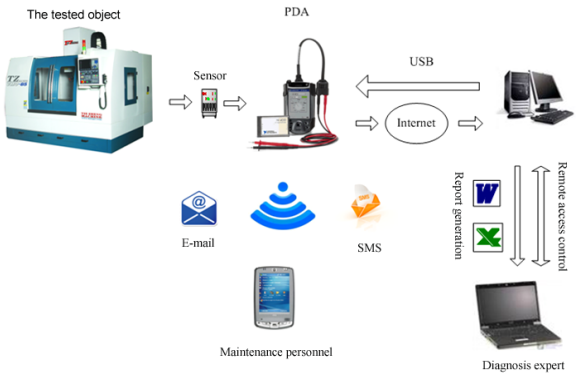

Fig. 1. The scheme of PDA-based predictive maintenance system.

This system collects the signal of the corresponding acoustic emission sensor, acceleration sensor and speed sensor installed on the machine tools through the PDA, and uses the interface and communication function of the PDA sending the data to the computer through the wire or wireless way. The processed data can achieve web publishing function through the network released and report generation way, and can collect the historical data to predict the tool wear. The PDA can also analyze a number of time-frequency information and compare it with preset thresholds. When the signal appears apparently unusual, the PDA uses its communication function to complete the warning operation by SMS or email, and informs the responsible personnel of maintaining CNC machine tools. The PDA can't install the program development environment to develop corresponding program, so the program need to be developed in computer and install it in PDA using the synchronization software through USB interface.

2.2. System Architecture

The system architecture is shown in Fig. 2. The equipment layer includes CNC machine tools that require carrying out the predictive maintenance. The sensor layer is used to set up a portable data acquisition system to gather the data when the equipments are running. The data layer includes the users' data, data collection, and data management. The processing layer mainly analyzes the data collected by the sensors. The function layer includes the functions of the system, including data acquisition, condition monitoring, fault analysis, early warning and maintenance, etc. The human-machine interaction can be realized through the presentation layer and the system can be operated directly by it.

3. Hardware Platform of the Predictive Maintenance System

3.1. Design of the Portable Data Acquisition System

The composition of the portable data acquisition system based on PDA is shown in Fig. 3, where 1 represents the PDA, 2 represents the acquisition card, 3 represents cable, 4 represents the junction box, and 5 represents the sensor.

3.2. Selecting Hardware Module

PDA is the platform of the portable data acquisition system, and its performance directly affects the achievement and implementation of the system functions [8]-[10]. The choice of PDA directly affects the choice of other hardware, so the choice of PDA should be considered as the primary factor of building hardware platform. In this paper, the system uses HP iPAQ hx2490, and its basic parameters are shown in Table 1.

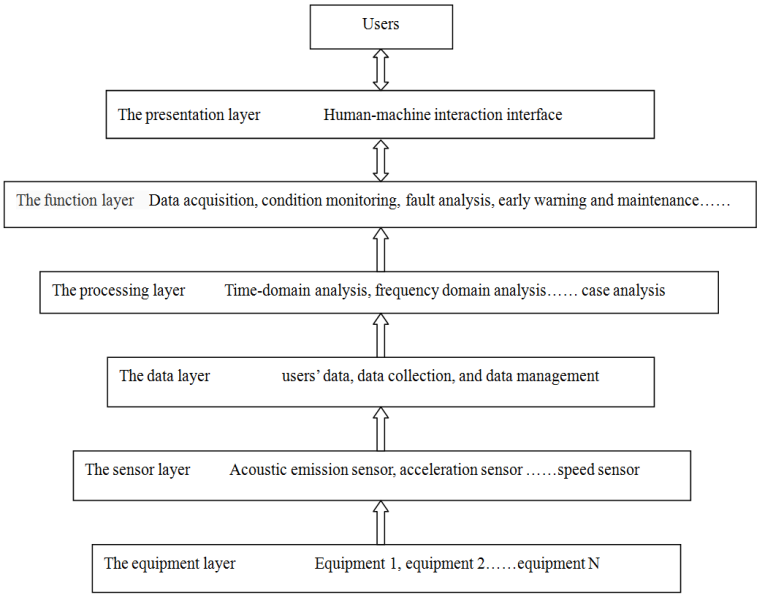

Fig. 2. The architecture of PDA-based predictive maintenance system.

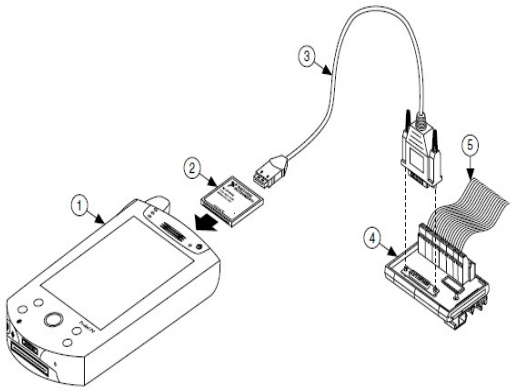

Fig. 3. The schematic diagram of the PDA-based data acquisition system.

Table 1. Basic parameters of HP iPAQ hx2490.

Contents	Parameters
Operating system	Windows Mobile 5.0
Processor type	Intel PXA270
Processor frequency	520 MHz
RAM capacity	64 MB
ROM capacity	128 MB
Expansion slot	SD/MMC/CF Type II card, support SDIO
Data transmission interface	USB/serial/IR/Bluetooth
Battery capacity	1440 mA

The system proposed in this paper selects the NI CF-6004 data acquisition card. Its single-channel rate is the 200 kS/s. It has 14-bit resolution data acquisition of 4-channel 132 kS/s sampling rate, and connects with the PDA by CF Type II slot.

This system uses PXR15 acoustic emission sensors, LC0120 piezoelectric acceleration sensor and optical reflection-directional sensor WO-RNMW. The sensors connect the PDA by the SH-15-15 cable and CB-15 junction box. The real configuration system is shown in Fig. 4.

Fig. 4. The picture of the configuration system.

4. Development Environment of the Predictive Maintenance System

4.1. LabVIEW Mobile Module

The installation of the software development environment and the development of the system cannot be achieved in the PDA. The software development is completed in a desktop computer or laptop, and the program is made run on the PDA platform by software development kit (SDK).

The Mobile module of NI LabVIEW expands the development environment of LabVIEW into PDA.

Using this module, the users can develop the application programs in LabVIEW environment and download completed application programs to the PDA. The Mobile module of NI LabVIEW can compile VI running in designated PDA, and download completed application development to the PDA.

4.2. DAQmx Base Driver

The communication between the PDA and CF-6004 data acquisition card can be realized through the application programming interface (API) provided by DAQmx Base.

DAQmx Base supports many operating systems including Windows, Linux, Mac OS X and Pocket PC. Using DAQmx Base driver the user can develop the application software in multi-platform LabVIEW graphical development environment. Simple programming interface, programmable channel, task generation and high integration of the LabVIEW make the development of the application program become very simple. The driver software also includes immediately available LabVIEW VI and C function examples, and these examples are similar to that of NI-DAQmx software with complete functions.

4.3. Microsoft ActiveSync

Microsoft ActiveSync software provides the data synchronization between personal computer and PDA, which is a kind of data synchronization software based on the devices of Windows Mobile. Microsoft ActiveSync instantly provides available synchronization experience with Microsoft Outlook and personal computer based on Windows. Microsoft ActiveSync can act as the gateway between Windows-based personal computer and Windows Mobile-based devices, which allows transmitting Outlook information, Office documents, pictures, music, videos and application program between the personal computer and the devices. In addition, ActiveSync can directly synchronize with Microsoft Exchange Server, so it allows the users leaving the personal computer to get the latest email, calendar data, tasks and contact information through wireless way.

5. Program Development of the Predictive Maintenance System

5.1. Program Development of Data Acquisition and Communication

The communication of CF-6004 data acquisition card with the PDA can be realized through the application programming interface (API) provided by DAQmx Base. The data acquisition program mainly uses read function, start function and stop function of the DAQmx. In addition, API provides a DAQmx Base task constant, which allows being created and set in task configuration. In order to be able to use DAQmxBase API, the corresponding tasks must be created first. The task is predefined configuration of an input channel of data acquisition card, and the new tasks will be related to concrete channels and attributes. In order to make projects be created and generated in the PDA memory, the task constants must be created and connected to the Base function of DAQmx.

After completing the task configuration and program generation, there will be a small amount of code in program block diagram. Then the developer can delete the code and put While cycle. The exit button connected to the end button of While cycle. The run button connected to the branch selector of the branch structure. Considering the limited processing ability of PDA, the delay time is set to 100ms. The true branch of the branch structure is executed when the start button is pressed. After placing the Start Task VI and the task constant, the While cycle will begin. The value of "Wait until milliseconds" timer is set to 50 to control the speed of loop processing. The data acquisition cycle uses the Boolean “or” functions to terminate. Similarly, with the data acquisition cycle terminated, the data acquisition program uses DAQmx Base stop task function placed outside the cycle to achieve the termination of data acquisition tasks. The block diagram of data acquisition program is shown in Fig. 5.

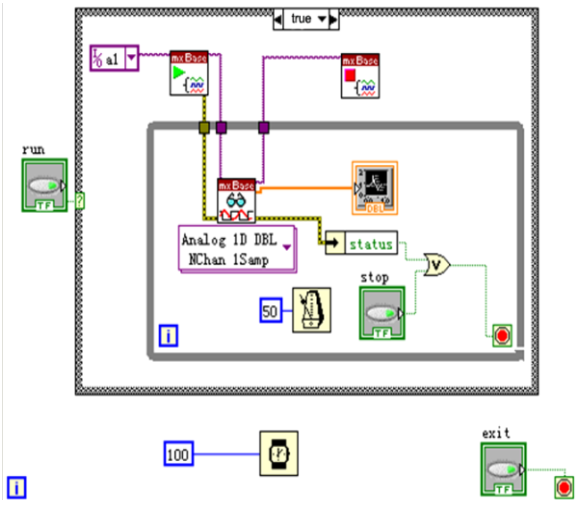

Fig. 5. Block diagram of data acquisition program.

In order to prevent the loss of data, the producers and consumers model is used as the design model of data acquisition and storage program when the sampling rate is relatively high. The block diagram of data acquisition program based on the producers and consumer model is shown in Fig. 6.

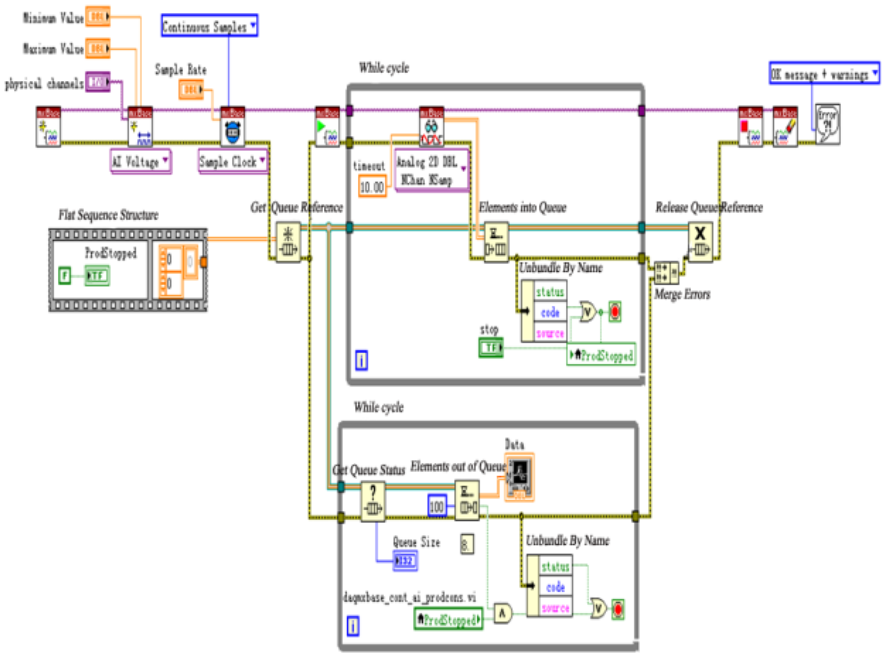

Fig. 6. Block diagram of data acquisition program based on producers and consumer model.

This paper combines the portable data acquisition system with network connection so that the collected data can be sent to the laboratory computer immediately for permanent storage and further analysis. Data communication test is mainly on the portable data acquisition module based on mobile devices and sends the data to the server program of the specified PC through the network. The layout of network transmission system is shown in Fig. 7.

In LabVIEW, the user can directly call the released TCP VI and related sub-VI of TCP modules to complete the writing of the process. This paper uses the C/S (client/server) communication mode in software design. The function of its VI program is divided into two parts. On one hand, it processes the host work in the server, completes data reception, and provides the related processing of the data. On the other hand, it collects data in the client and transmits it. The block diagram of the client program is shown in Fig. 8. The block diagram of the server program is shown in Fig. 9.

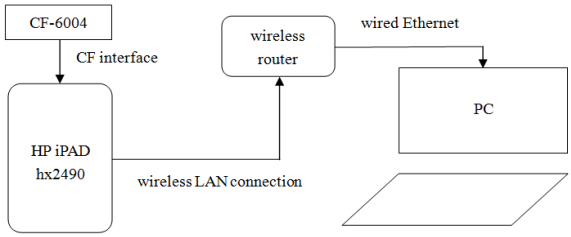

Fig. 7. The layout of network transmission system.

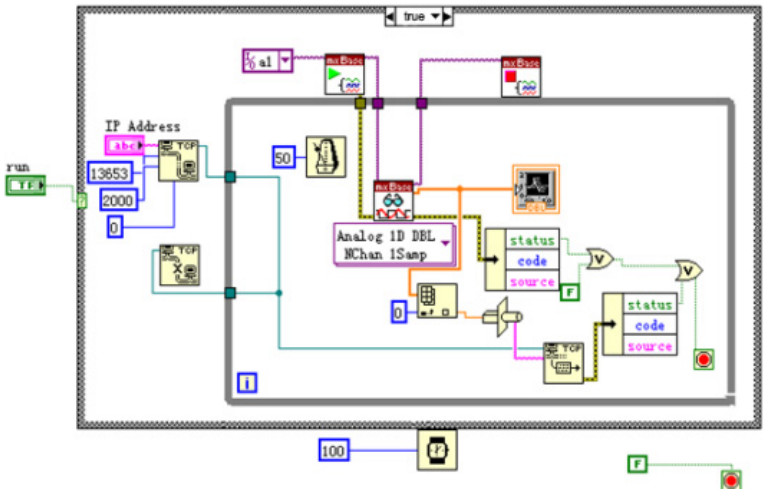

Fig. 8. Block diagram of the client program.

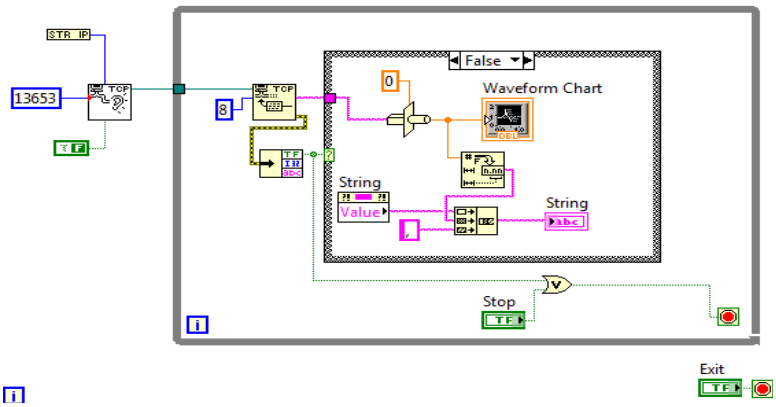

Fig. 9. Block diagram of the server program.

5.2. System Module Development

The screen size of PDA is very limited, so the system uses the tab control overlapping the front panel control on the front panel and necessary abbreviations to the use screen size effectively. In addition, the system adopts the top-down design method and achieves the development of complex programs by decomposing it into some program modules with specific functions and tasks.

In order to maintain the CNC machine tools in time, the predictive maintenance system develops the warning module. If the signal exceeds preset threshold during the data collection process, the warning module will send the abnormal data to designated mailbox. Remote worker receives the alarm information and makes the diagnosis of receiving fault data to realize the remote monitoring. Some interface about triggering the warning status while beyond the threshold is shown in Fig. 10.

Email warning can be realized by the SMTP communication protocol node of LabVIEW. If collected data in the machining process exceeds the preset warning value, PDA automatically sends data to designated mailbox. Using SMS warning function needs to install SMS driver in the PDA first. After the driver is installed, the PDA can use the related functions of SMS to develop SMS warning program and realize SMS warning when programming. The diagram of email warning is shown in Fig. 11.

The program diagram of SMS warning is shown in Fig. 12. The related interface of email and SMS warning is shown in Fig. 13. The system also designs the login module using the attributes of Key Focus and completes the report generation module using the Office report generation toolkit, etc.

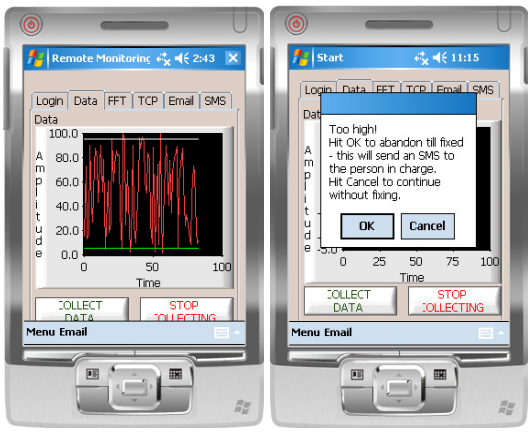

Fig. 10. Trigger warning interface while beyond the threshold.

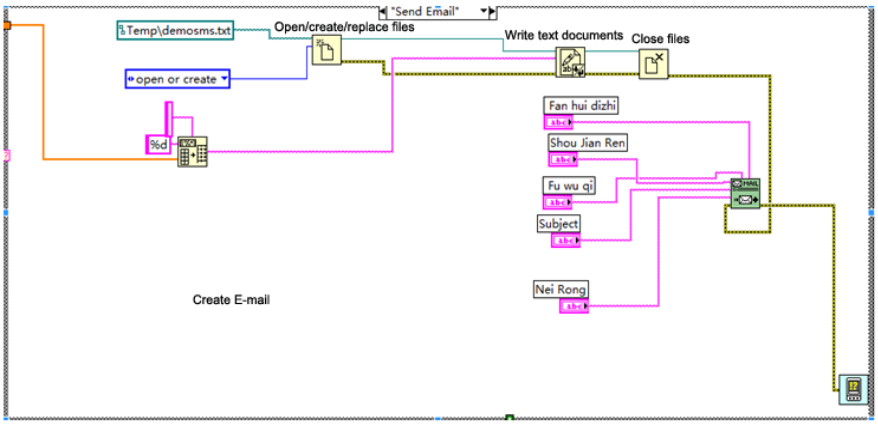

Fig. 11. Program diagram of Email warning.

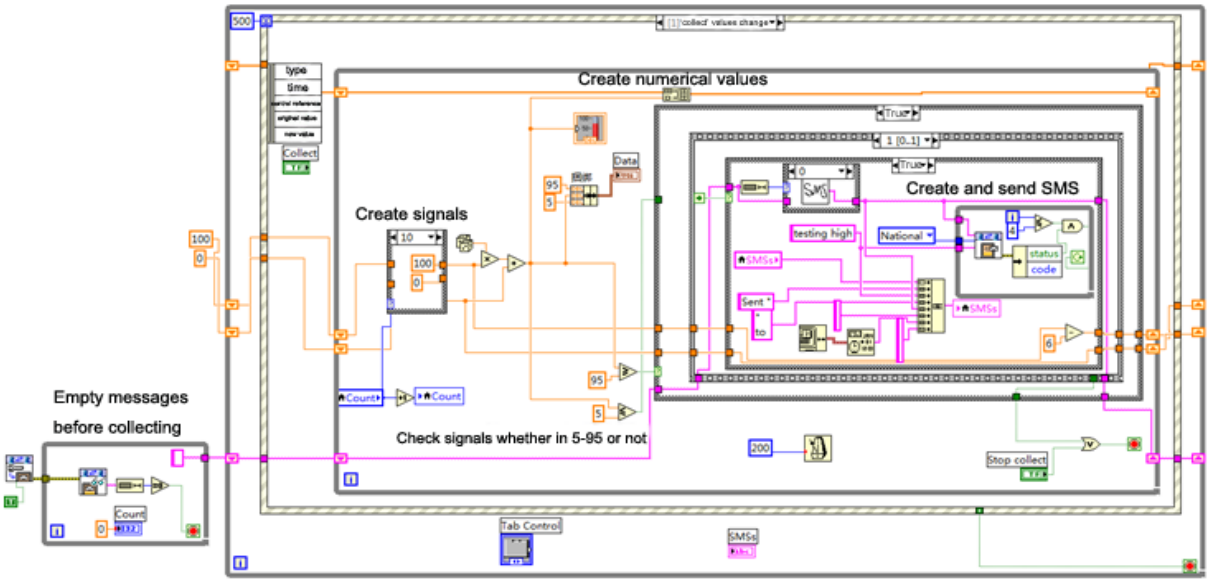

Fig. 12. Overall diagram of the SMS warning program.

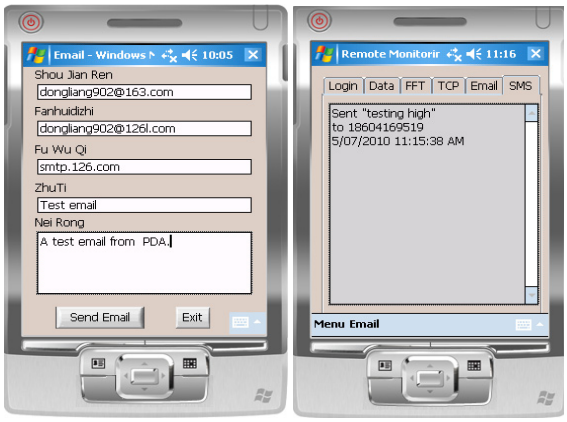

Fig. 13. Email and SMS warning interface.

6. Conclusions

The research on the predictive maintenance system of CNC machine tools based on PDA is of great theoretical significance and practical application value. The PDA-based monitoring of CNC machine tools presented in this paper not only got rid of the space restrictions, but also provided a new platform and methods for the information acquisition, transmission, processing of machine tool. With the platform of PDA, this paper completed the design of portable data acquisition system based on PDA, built the PDA hardware platform, developed the data acquisition program and communication program based on PDA, and achieved the effective collection, storage, and transmission and other operations of the data.

Using the predictive maintenance theory as a guide, this paper carried out positive exploration on the design of portable data acquisition platform, data communication, the early warning maintenance, completed the test of the data communication program between the PDA and the computer, made explorative research on using the PDA to monitor CNC machine tools under ubiquitous manufacturing network environment.

Acknowledgements

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