Ubiquitous based Control and Monitoring in M2M (Mobile to Machine) Environment

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Abstract: - In this study, the concept of anywhere-anytime control and monitoring in mobile to machine environment was implemented for the development of u-manufacturing and u-machines. In this concept, the communication between the Computerized Numerical Controller (CNC) and the Personal Digital Assistant (PDA) phone was successfully performed anywhere and anytime for the real-time monitoring and control of CNC machines. In addition, the interface between the CNC and the developed application modules was implemented by using Object linking and embedding for Process Control (OPC) and shared CNC memory. With a PDA phone, the machine status and machining data of CNC machines can be monitored in wired and wireless environments such as IMT2000 and wireless LAN. Moreover, CNC machines can be controlled anywhere and anytime.

Key-Words: - Anywhere-anytime, Mobile to Machine, U-machine, Control and monitoring, Wired and wireless

1 Introduction

In recent years, there has been in increase in demand for a convenient environment in which users can achieve their purposes anywhere and anytime [1]. Such demands have also been made with respect to manufacturing system and machine tools [2-3]. In particular, machine tools with open CNC architecture have motivated active research on the control and monitoring of CNC machines [4-6]. This research has spawned numerous studies on remote monitoring and control [7-10], which are vital functions in a wireless environment [3]. Conventional control and monitoring of machine tools focuses on the machine itself or on the relation between CNC machines and peripheral equipment [8-10]. Recently, however, the widespread use of computers and the Internet have led to a proliferation of studies on the remote control, monitoring and diagnosis of CNC machines for distributed global management in manufacturing systems [2, 11]. Most of these studies are based on the client-server local domain in a wired LAN, and, recently, web-based control and monitoring has actually been realized [1-2, 12]. The circumstances mentioned above, which are due to the inferior field environment, are exacerbated by the difficulty of merging machine technology with IT. These two types of technology are now being applied together in manufacturing systems. However, although this merger is possible in a wired network environment, it has not yet been fully realized in a ubiquitous-based wireless and mobile environment [3].

We have therefore tried to develop a solution for mobile control and monitoring of CNC machines in a wireless environment. By finding a method of remotely controlling and monitoring CNC machines, and by enabling various functions to be controlled and monitored anywhere and anytime, we can lay the foundation for developing u-machines.

2 The Scheme of Approach Method for Implementation

Our aim was to enable the control and monitoring between a CNC machine and a PDA phone to be implemented anywhere and anytime. For such implementation, a server-contents module based on the TCP/IP was designed within the CNC of the machine. In addition, we designed a client-contents module by using embedded c++ programming for mobile communication within a PDA phone.

We then used an OPC method and shared CNC memory for a real-time interface between the developed application modules and the CNC domain in order to acquire data on the machine status, the machine running state, the NC program information, the alarm information and the position of the stage axes of real machines. Another reason for adopting this approach was to apply the control data, such as data on the start, hold, emergency stop, reserved start and reserved stop.

To ensure the remote control and monitoring of systems anywhere and anytime in a wireless environment, we used the following process:

◉ A PDA phone was used as a mobile terminal.

◉ The contents of the mobile terminal was programmed with embedded visual c++ for operation in the WinCE.Net operating system.

◉ The server-contents module of the CNC machine communicated with the client-contents module that operated in the mobile terminal. Through the communication, the data for control and monitoring were transferred between the two modules.

◉ To control and monitor a real CNC machine, the interface between the server-contents module and the CNC was performed with the OPC method and by sharing CNC memory.

3 System Configuration

We configured our system as follows: First, we divided the system functions into the two developed modules: the client mobile contents module and the server-contents module. The server-contents module was programmed with standard visual c++, and we executed the developed agent program in the CNC domain.

Next, for the client mobile contents module, we used the developed agent program, which we programmed with the aid of embedded visual c++ for execution in a WinCE.Net 4.2 operating system. This module was designed to operate in a PDA phone (Nexio S155). For the communication between the server-contents module and the client-contents module, we used an IMT2000 (CDMA2000) network and a wireless LAN.

In the next step, we used the server-contents module to obtain the monitoring data, such as the machine status, the alarm information, the NC information, the position of the axes, the CNC screen image, and Universal Serial Bus (USB) camera images. We also used the server-contents module to communicate with the client-contents module. The client-contents module, on the other hand, was used to receive the monitoring data from the server and to show the data on the screen of the PDA phone. In addition, we used the client-contents module to transfer the control data to the server-contents module; for example, data on the machine start, hold, emergency stop, reserved start and reserved stop.

Figure 1, which illustrates the communication between the two contents modules, shows that the client-contents module operates in a PDA phone, and that the communication is performed with a base station through the CDMA2000 network. The base station sends the data transferred by the CDMA2000 network to the Internet. The server-contents module, which is connected to the Internet, operates the CNC machine and transfers the monitoring data, such as the machine status, to the base station through the Internet. The architecture of the server-contents and client-contents using CDMA2000 and wireless LAN is as follows.
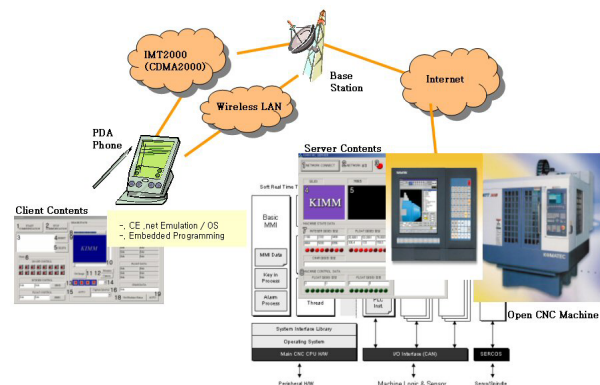

Fig. 1 The system scheme and the communication between two contents

3.1 Server Contents

In Figure 2, which shows the structure of the OPC program in the server contents, there are two server contents models. The models are classified in terms of

the process they use to interface with the CNC machine: that is, either the OPC method or the method of sharing the CNC memory map.

The explanation of Fig. 2 is as follows.

-. Object Linking and Embedding (OLE) dynamic linking library initialization: The OLE initialization is used for the OLE process.

-. Variable initialization: The variables used in the program are initialized. In detail, the basic variables and icons used in the graphic user interface are initialized, as well as the variables for the OLE and communication.

-. Network setting: The state for communication is set up in the server-contents module. To solve network congestion, the packet size is controlled and over-sized packets are avoided. The port number is also set up. The settings for the parameters are saved in static memory to ensure the parameter values can be restored in the program initialization.

-. OPC initialization: The OPC process is initialized with the aid of the OLE to interface with the machine controller. The variables used in the OPC process are initialized and the required classes are created.

-. USB camera initialization: The USB camera is initialized and the initial frame is displayed in the screen.

-. Wait event: The event of the user's command is checked. The command includes the server-contents of Server_Start, CNC_Start, CNC_Hold, CNC_Stop, Self Test, Close.

-. Server start: The communication part of the server side is executed, and the wait data requests a query from the client side. The server-contents module, which creates a new class, charges the created class with the communication process. The created class communicates with the client-contents through a predefined protocol.

-. CNC_Start: The start command of the CNC machine is applied.

-. CNC_Stop:The stop command of the CNC machine is applied.

-. CNC_Hold: The hold command of the CNC machine is applied.

-. Self test: The communication between the server side and the client side is simulated with the aid of random data values when the interface between the server-contents and the CNC is not possible.

-. Close: The server-contents module is closed.

The server-contents module has the structure of an OPC-type program. If the server contents uses the CNC shared memory, the real-time kernel (RTX) application programming interface (API) library is

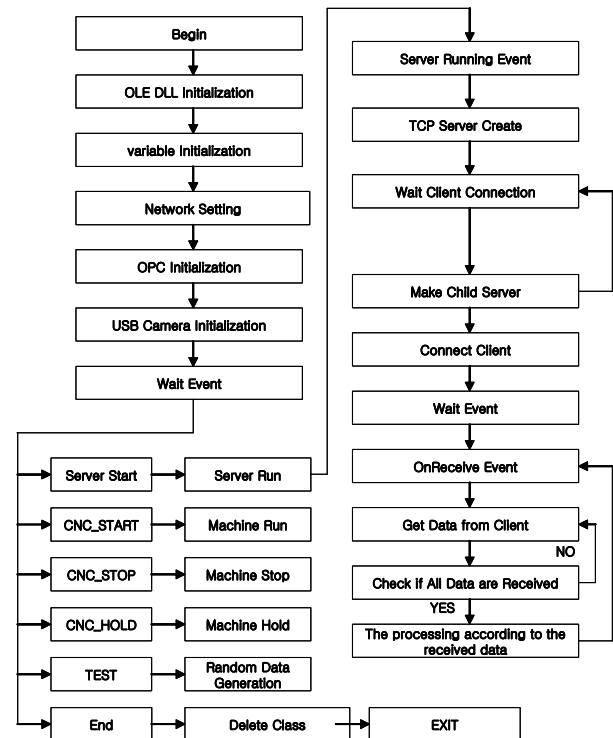used, and the step related to the OPC is replaced with the RTX API part of the server-contents module.

Fig. 2 The structure of the server-contents by using OPC method

3.2 Client Contents

Figure 3 shows the structure of the client contents. The structure of the client-contents module enables the module to connect to the server contents, receive

The structure of the client-contents module enables the module to connect to the server contents, receive monitoring data from the server contents, and send control commands to the server contents. The structure is as follows:

-. Variable initialization: The variables required in the early stage are initialized.

-. Network internet protocol (IP) check: The IP address and port number of the registered server are read. A new IP address and port number can be registered and all registered IP addresses are displayed in a list box of a mobile terminal, such as a PDA phone. If one of the IP addresses in the list is selected, the connection with the server contents is performed.

-. Network connection: The connection to the server contents is tried. If the initial connection is successful, the basic monitoring data from the server are automatically transferred. The control command event of the client user is then awaited.

-. Disconnection: The connection is separated.

-. Start/stop/hold reservation: To execute a reserved command, the commands are executed in reserved time if the control data with a set reserved time are transferred.

-. Machine status check: The machine status data are checked just once.

-. Automatic machine status check: The machine status data are continuously checked.

-. Camera image receipt: If the USB camera is set up, the image data Quarter Common Intermediate Format (QCIF) 176 x 144 size) are transferred and displayed in the mobile terminal.

-. Screen (monitor) image receipt: The screen shot of the CNC is transferred and displayed in the mobile terminal.

-. Screen image position setting: The resolution of the CNC screen is high (generally over 640 x 480), and the data size of the screen image is much bigger than the control command and monitoring data. Therefore, the region of interest (ROI) of the screen is generally monitored by selecting the ROI.

-. Screen image size definition: The received image size is defined by the client user. The size of the CNC screen can be determined through the early communication in the initialization process of the client contents.
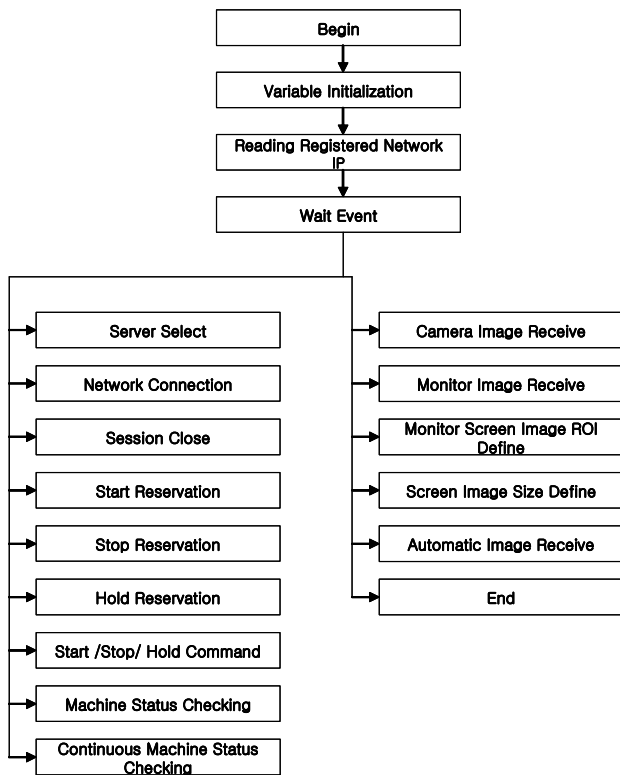
-. Image receive auto: The image of the USB camera, or of the CNC screen, is continuously received from the server side.

-. Close: The client-contents module is closed.

4 The Interface between CNC Machine and Developed Application Module

Applied machine tools have an open CNC architecture. The structure of the CNC architecture is shown in Fig. 4. The open architecture of the CNC map includes the interconnected signals X, Y, G, F and R, where X is the input signal, Y is the output signal of the Programming Logical Controller (PLC), G is the input signal from the PLC to the CNC, F is the input signal from the CNC to the PLC, and R is the relay signal. By accessing the shared CNC memory and alarm log data, the interfacing between the server contents and the CNC domain is performed on same platform and the server contents can be executed as an internal function of the CNC domain. The server contents can extract the key data required for monitoring from the CNC and PLC. Moreover, for remote control, The server contents can apply control commands that have been transferred from the client contents to the CNC and PLC domains.
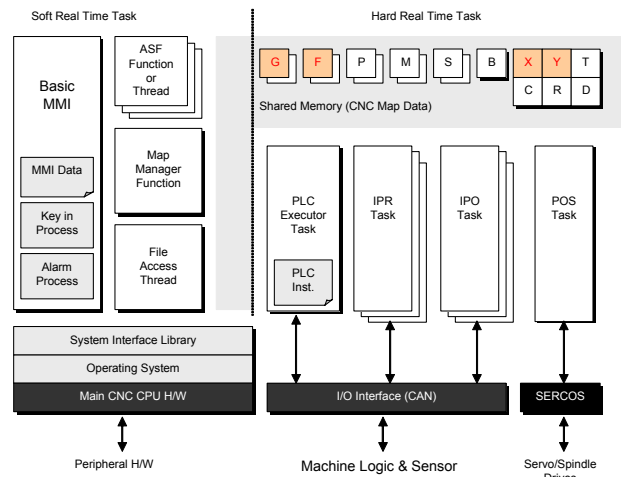
Fig. 3 The structure of client contents

Fig. 4. The structure of the CNC machine with an open architecture controller

Figure 5 explains the interface process between the server contents and the CNC domain. The purpose of the interface process is to acquire information on the real machine status, such as the machine running state, the used NC program name, the current alarm information and the position of the stage axes. The

purpose of the interface process is also to control the CNC machine by using the control command transferred from the client side.

The CNC generally has an RTX for multitasking in an infra platform. Hence, the API functions supported by the RTX are used to access the memory map and alarm data of the CNC domain. The parametric values of the API functions are mutually referred and transmitted by the OPC.
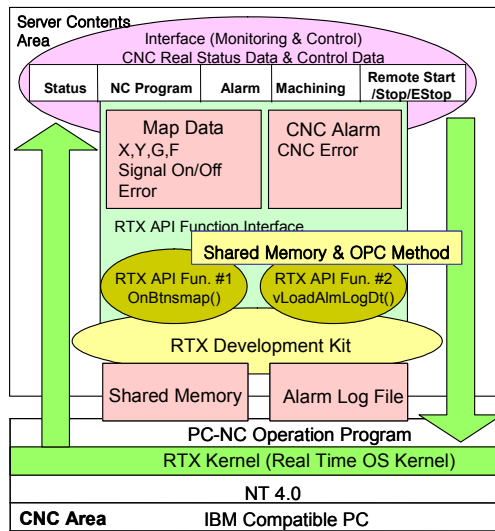

Fig. 5 The interface structure between server contents and CNC domain

5 System Function and Test

5.1 Function

The key functions of our system are as follows:
-. Random status generation and real machine status acquisition
-. Screen capture by selection of the ROI and the captured image transmission
-. USB camera capture and the captured image transmission
-. Transmission of the real machine status and machining information
-. Transmission and execution of the remote control command.

The key functions are explained as follows:
-. The function of generating the random status is designed as a communication test between the server contents and the CNC for when data cannot be acquired from the real machine. The OPC method in the server contents acquires the real data from the machine.

-. The function of the screen capture is to capture the CNC screen when the capture command is transferred from the client to the server contents. When the control command for the capture is received, the parameters for capturing the size and position are concurrently received. The server contents captures the CNC screen in accordance with the given size and position. After the capture, the captured image is compressed to a Joint Photography Experts Group (JPEG) image and transmitted to the client monitor. The default size of the JPEG image is fixed at 176 QCIF for quick transmission. If necessary, the client can change the size.
-. The function of the USB camera capture is to aid the monitoring of the work pieces, peripheral equipment and workplace circumstances.
-. The real machine status and machining information are transmitted at the request of the client side. The transmitted data include the current machine status, the alarm status, information on the machining NC program, information on the stage axes, and the feed status.
-. The remote control commands are performed in the server contents by the control commands received from the client contents.

A detailed explanation of the key functions is given in the two sections, with respect to both the sever and the client. The detail functions of the server-contents are shown in Fig. 6.
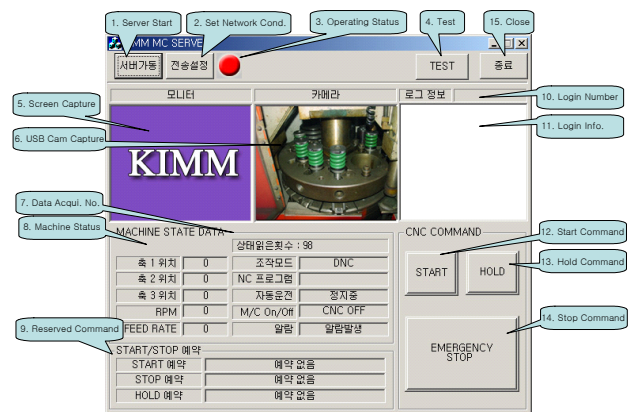

Fig. 6 The main frame of server contents

And we implemented the client contents in a PDA, and used embedded visual c++ for the programming. The functions of the client contents are as follows: making a connection with the server contents, monitoring the data acquisition from the server side, sending the control commands to the server side, acquiring image data from the server side, and various

other related functions. The detail functions of the client-contents are shown in Fig. 7
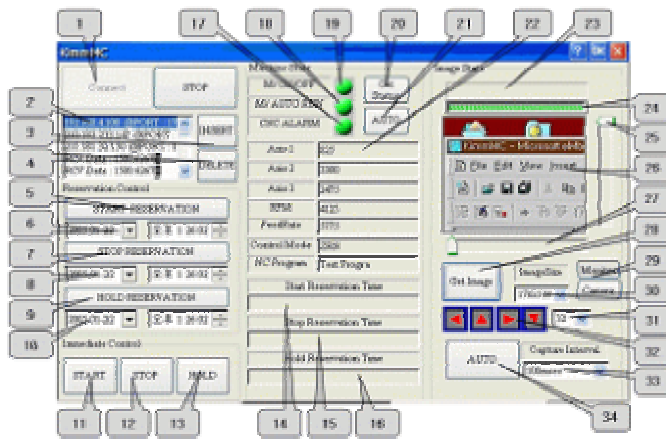

Fig. 7 The main frame of client contents

5.2 Efficiency Test

As shown in Fig. 8, for an efficiency test on the target machine, we used a three-axis milling machine with an open CNC architecture. The stage of the open CNC machine had a spindle and the three axes X, Y, and Z.
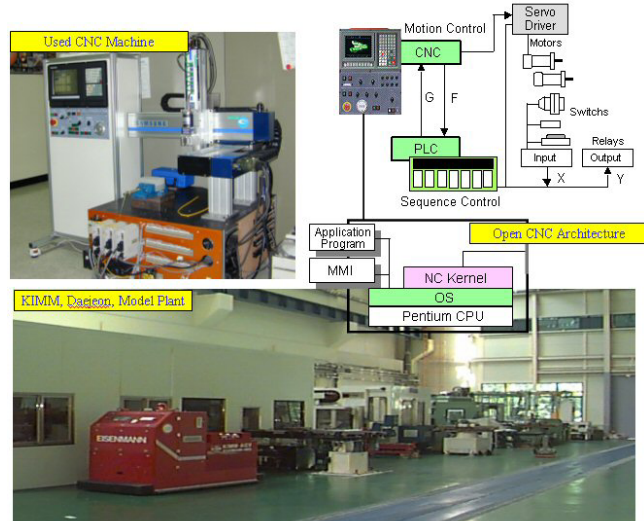

Fig. 8 The CNC Machine and its architecture for the efficiency test

The scenario for efficiency test is as follows:
① Machine monitoring: Initial monitoring of the current status of the machine, such as the running and stopping status and the alarm status.
② Machine operating: Automatic operating by the NC program in the model plant.

③ Changed status monitoring: Remote monitoring, via a PDA phone, of the running status, the selected name of the NC program, the current alarm status, and the position of each axis of the stage.
④ Remote holding command: Remote control via an IMT2000 network or wireless LAN for holding and pausing the current running machine.
⑤ Remote restart command: Remote control via an IMT2000 network or wireless LAN for restarting the current running machine.
⑥ Remote stop command: Remote control via an IMT2000 network or wireless LAN for stopping the current running machine.
⑦ Current status monitoring: Remote monitoring, via a PDA phone, of the current status of the machine status re the stop or emergency stop mode.
⑧ Remote reserved start: Remote control for starting the machine at the reserved time after the reserved time has been set via a PDA phone.
⑨ Status monitoring: Remote monitoring, via a PDA phone, of the machine status re the success of the reserved start.
⑩ Remote reserved stop: Remote control for stopping the machine at the reserved time after the reserved time has been set via a PDA phone.
⑪ Status monitoring: Remote monitoring, via a PDA phone, of the machine status re the success of the reserved stop.
⑫ Bidirectional communication test: Confirmation in an emergency of automatic notification to registered mobile terminals, such as general cell phones.

During the test, we monitored the machine status and key data of the CNC machines in the wired and wireless environments of an IMT2000 network and a wireless LAN, and we successfully showed that a CNC machine could be controlled anywhere and anytime. From the results of the model plant at the Korea Institute of Machinery and Materials, we improved the operating efficiency by more than 50 percent with added advantage of flexible control and quick management in emergencies.

6 Conclusions

Our study on the ubiquitous-based mobile control and monitoring of CNC machines for u-machines was successful. We used a PDA phone for the terminal because of its mobility and screen extensibility. With an embedded programming language, we designed the software for the WinCE.Net operating system, thereby

solving the license restriction of the phone service company such as Qualcomm Co., Ltd., for up-loading developed software contents to a general cell phone.

The communication between the developed contents, such as the server contents and client contents, was performed via a wireless LAN as well as a wireless telephone network. Hence, CNC machines can be controlled and monitored in real time, anywhere and anytime. Moreover, the prompt notification from CNC machines to mobile terminals, such as a cellular phone or PDA phone, can be automatically realized in an emergency.

The results of this study are summarized as follows:
-. By using the OPC method and sharing the CNC memory, we enabled real-time data acquisition of the machine status re the position of each axis of the stage, the NC program, the alarm information and the machining status.
-. To ensure that the monitoring data could be accessed on a PDA phone, we enabled the acquired monitoring data to be transmitted in real time to the client side through an IMT2000 network or a wireless LAN.
-. By selecting the ROI, we enabled the CNC screen of the machine to be captured and transmitted.
-. We enabled the capture and transmission of USB camera images.
-. We enabled real-time remote control and reserved remote control of a CNC machine via a PDA phone.
-. For emergencies, we enabled registered mobile terminals, such as a PDA phone or cell phone, to be notified remotely and automatically without a client request.
-. In a model plant test, we improved the operating efficiency by more than 50 percent, with the added advantage of flexible control and quick management in an emergency.

In short, by implementing the mobile control and monitoring technology in manufacturing system with an efficient approach and system architecture without a special licence restriction, we have laid the foundation for the development of u-machines.

Acknowledgment

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