"Direct Robot Control", a Function for Cooperation between Industrial Robots and Computerized Numerical Control

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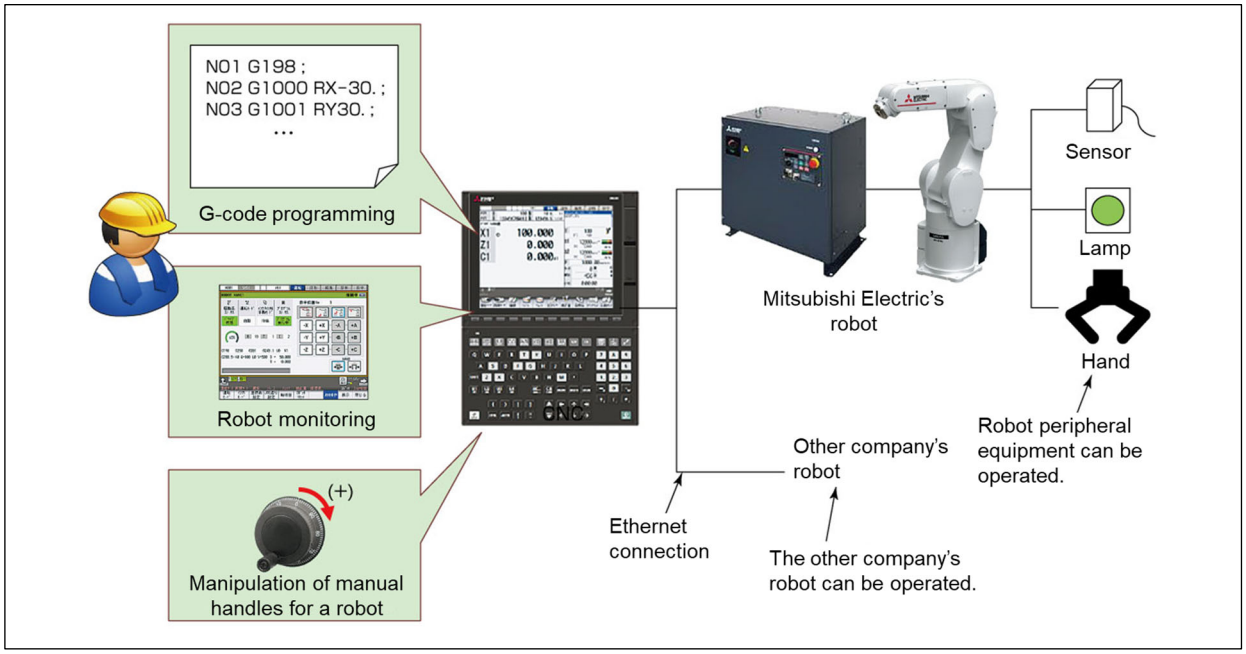
There has been a clear trend in recent years for machine tools to work together with automation systems and other systems to improve productivity. In particular, industrial robots for automating machine tools have been attracting attention in exhibitions and elsewhere. In addition, the demand for industrial robots has been increasing worldwide, fueling demand for machine tools equipped with robots. In view of this trend, we have developed a new cooperative function, "Direct Robot Control", which is specific to Mitsubishi Electric Corporation's computerized numerical control (CNC) and which enables cooperation with industrial robots. Its characteristics are listed below.

(1) The system has a simple configuration in which the CNC and robot controllers are connected via Ethernet.[*1] Setting up production with conventional machine tools equipped with robots takes much time and cost. Our Direct Robot Control dramatically reduces such time and cost.

(2) Even users who are inexperienced with robots can easily control them using G-codes and can easily perform operations required to control robots, such as JOG operations and teaching of robots, by CNC. In addition, an interactive mode makes it easy to program G-codes for robot control.

(3) By using conventional CNC functions, it is possible to ensure cooperative control between machine tools and robots, which also reduces the processing time.

(4) Robots manufactured by different robot vendors can be made to perform the same movement by the same operation from the CNC.



Direct Robot Control, a function for cooperation between CNC and industrial robots

By using this function, robots can be controlled from the CNC in a simple system configuration in which our CNC is connected to robot controllers via Ethernet. Robot control by G-code programs, monitoring of robot conditions, and control required for robots, such as JOG operations and teaching, can be executed from the CNC screens or by manipulating the manual handles of machine tools. Even machine tool users who are inexperienced with robots can operate robots easily.

[*1] Ethernet is a registered trademark of Fuji Xerox Co., Ltd.

* *Nagoya Works*

1. Introduction[1, 2]

Machine tools are widely used to process parts and dies with high accuracy and efficiency in various manufacturing industries such as automobiles, various types of machines, and electronic devices. As machine systems are controlled by the CNC, the machining performance and ease of use of machine tools have been improved for many years. There has been a clear trend in recent years for machine tools to work together with automation systems and other types of systems to further improve productivity.

In particular, industrial robots for automating machine tools have been attracting attention in exhibitions and elsewhere. Examples include using robots to load/unload workpieces to/from machine tools and using robots to remove burrs on workpieces that were cut by machine tools. As the demand for industrial robots has increased worldwide, the demand for CNC machine tools with robots has also been increasing.

In view of this trend, we have developed a cooperative function, Direct Robot Control, which is specific to our CNC and enables cooperation with industrial robots. By using this function, robots can be more easily controlled from machine tool CNC using G-codes, and machine tools and robots can be controlled in a cooperative way, which contributes to machine tool automation.

This paper describes the latest technologies developed for Direct Robot Control.

2. System Configuration Using Direct Robot Control[3]

Direct Robot Control is used in systems in which the CNC is connected to robot controllers via Ethernet. Parameters (Internet Protocol (IP) address and port number) required for Ethernet connection can be set to establish an environment in which robots are directly controlled from the CNC (Fig. 1).

On the other hand, in conventional configurations, a higher-level controller that performs sequence control of the CNC and robot controller needs to be prepared and a sequence program needs to be programmed to control the CNC and robot in a cooperative way. However, Direct Robot Control can reduce the following time and cost required to configure a system:

(1) Cost for a higher-level controller
(2) Time and cost required to establish an environment (e.g., wiring to connect the higher-level controller, CNC, and robot controller)
(3) Time required to write a sequence program

Reducing such time and cost can encourage machine tool builders who have not handled industrial robots to develop machine tools equipped with robots.

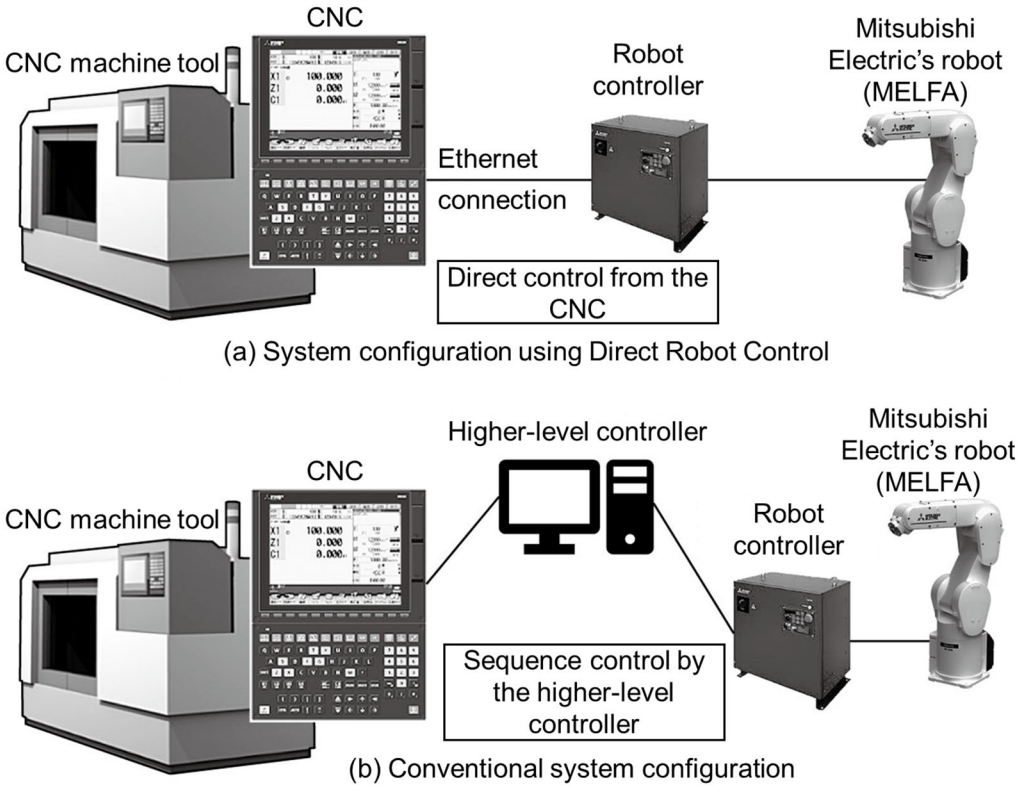


Fig. 1 System block diagram

3. Direct Robot Control Functions

3.1 Easy control of robots using G-codes[3]

G-codes for robot control are used to directly control robots from the CNC. In addition, a robot operation mode can be selected on the dedicated CNC screen for robots and operations required for robots (e.g., JOG operations) can be performed from the CNC (Fig. 2).

Previously, to control machine tools and robots, it used to be necessary to learn G-codes for machine tools and a robot programming language, which required a great deal of time. Direct Robot Control allows operators who have used machine tools to quickly learn how to use robots.

In addition, when production is started using machine tools with robots, G-code control can be used or manual operations can be performed graphically from the dedicated screen for robots, which makes it easy to check the robots' behavior. This eliminates the need for support from system integrators who understand robot operation well, thus reducing the cost for production start and adjustment.

3.2 Teaching of robots by CNC[3]

Industrial robots are often controlled by the teaching playback method. In this method, command points (location and orientation) at which robots operate are recorded (teaching) in advance and the robots operate at the recorded command points.

Teaching from the dedicated CNC screen for robots has been made possible to achieve similar control from the CNC. On this screen, an operation mode can be selected and JOG operations can be performed as well. Therefore, teaching can be executed while robot JOG operations are performed with the same usability as robot manipulation using the teaching pads that come with conventional robots (Fig. 3). Thanks to this usability, users who are familiar with robot operation can intuitively operate robots.

3.3 Easy programming in interactive mode

An interactive and intuitive robot programming screen is provided to create G-codes for robot control (Fig. 4).

The robot programming screen displays images of robot behavior along with guidance, which makes programming easy without having to learn G-codes for robot control (Fig. 5).

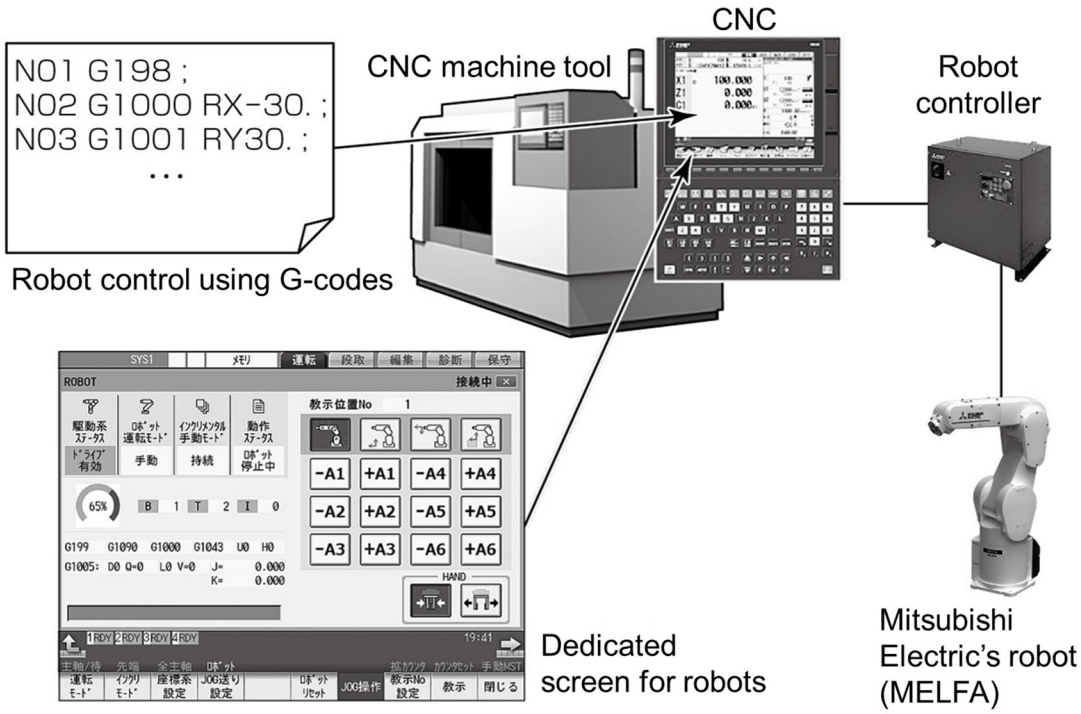


Fig. 2 Robot control using G-codes

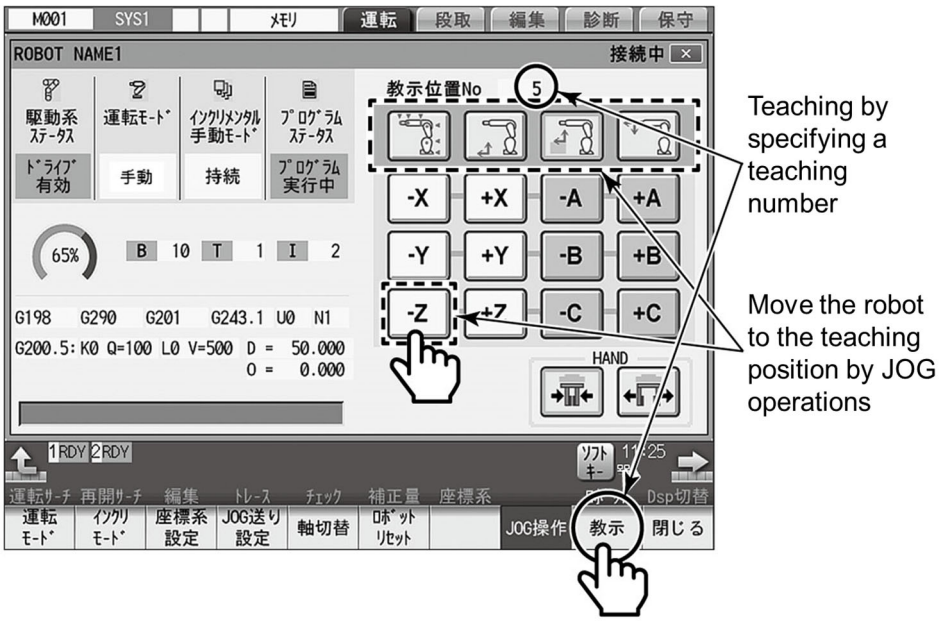


Fig. 3 Dedicated screen for robots

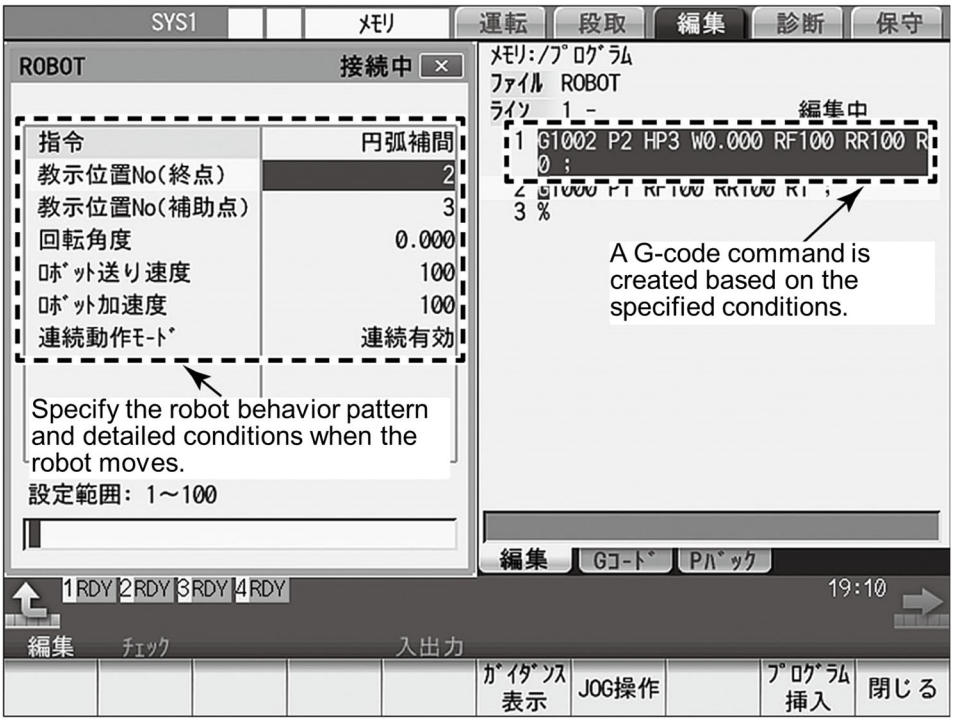


Fig. 4 Robot programming screen

3.4 Cooperative control of machining and robot control[3]

Because the CNC executes a robot control program, using CNC functions makes it easy to realize cooperative movement of the machine tools and robots. Figure 6 illustrates an example in which a machine tool machines unprocessed workpieces and the robot loads and unloads workpieces and removes burrs from the machined workpieces.

In this example, the CNC's function for block control of systems is used to perform machining by the CNC and removal of burrs by the robot at the same time without revising the CNC programmable logic controller (PLC). In addition, the machining is started after the upstream manufacturing processes (manufacturing processes (1) and (2)) required for machining are complete (Fig. 7). Users can realize efficient processing involving robots by revising the processing programs.

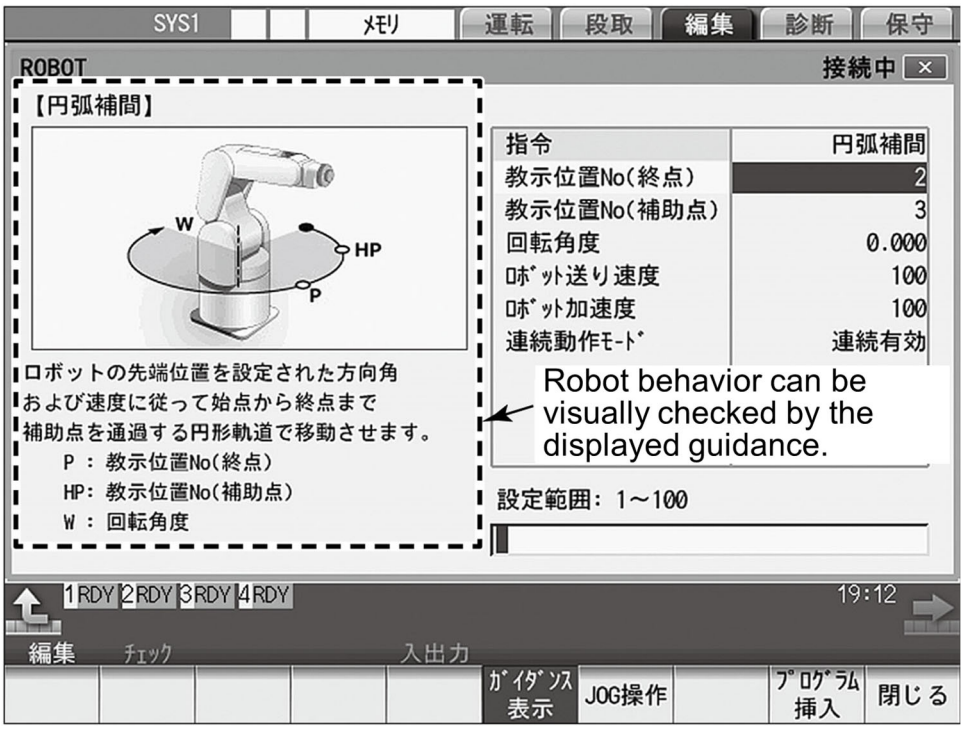


Fig. 5 Guidance on the robot programming screen

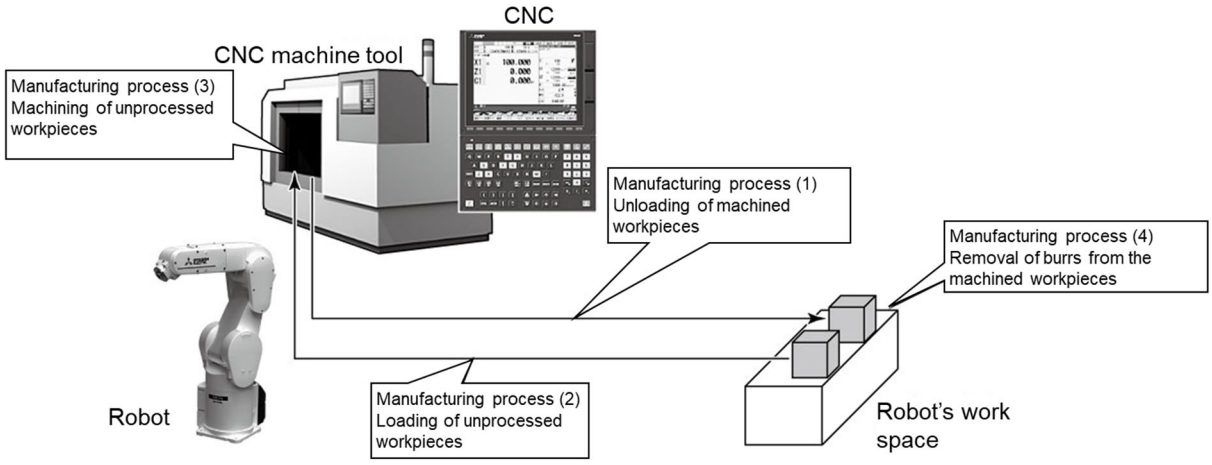


Fig. 6 Example of cooperative control between a machine tool and robot

3.5 Device control of robot controllers by CNC

Without increasing the number of wires between the CNC and robot controllers, device control of robot controllers can be performed from the CNC. To realize this, the CNC sends commands to robot controllers to set and refer to robot digital signals via Ethernet (Fig. 8).

For example, in robot control by using a hand that comes with a robot (robot hand), the contacts of the digital input (DI) and digital output (DO) of the robot hand and robot controller are connected and the robot controller's device control is used to control the robot hand and check its state. For this function, the aforementioned robot-side environment is not changed; the robot hand is directly controlled and its status is directly checked from the CNC.

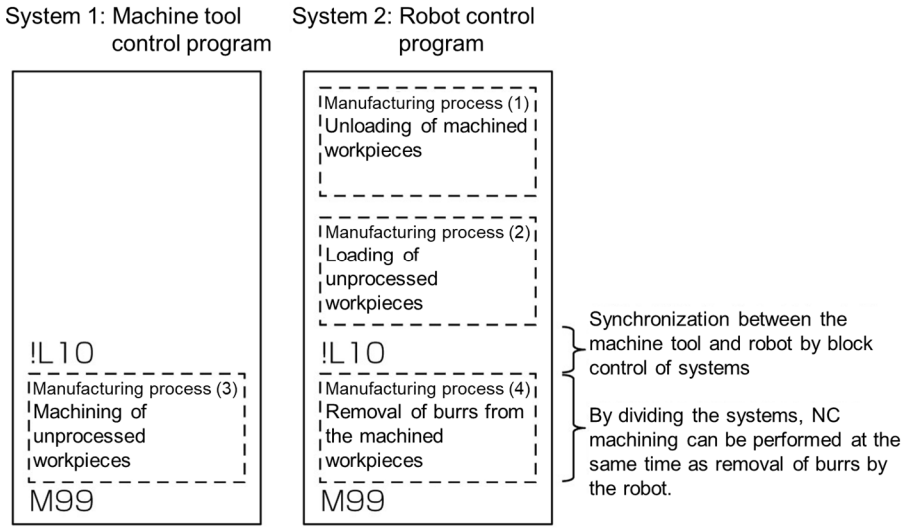


Fig. 7 Example of processing programs for cooperative control between a machine tool and robot

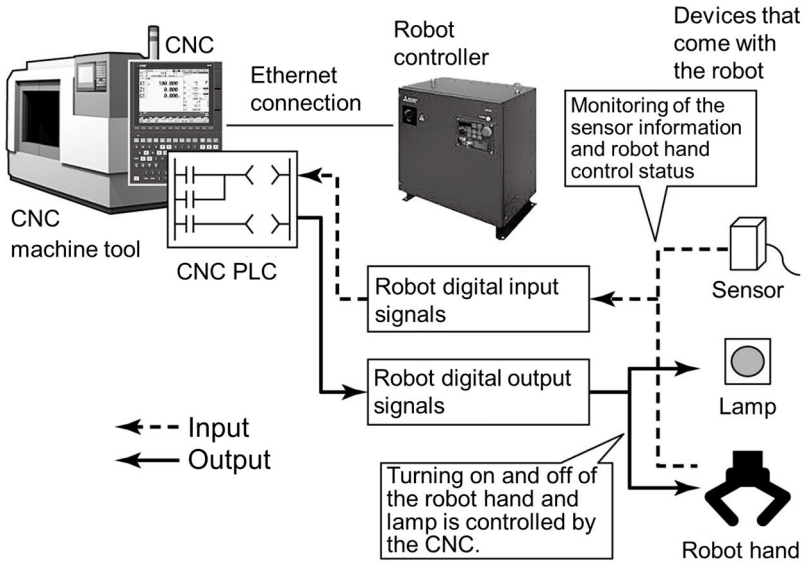


Fig. 8 Device control of a robot controller by CNC

3.6 Manipulation of robots by manual handles[3]

Machine tools generally have manual handles (manual pulse generators). At the time of setting up and other tasks, they are manipulated to control the axes of the machine tools. In this new function, robot manipulation can also be controlled using machine tools' manual handles.

For robot manipulation with manual handles, as is the case with manipulation of machine tools, "handle mode," "axis selection," and "movement scaling" can be set. Positioning control of each axis of a robot or end position is possible. This makes it easy for existing machine tool users to manually manipulate robots.

3.7 Control of robots manufactured by multiple robot vendors[4]

Robots manufactured by multiple robot vendors can be controlled from the CNC. Currently, our CNC can be connected to our "MELFA Series" robots or KUKA Roboter GmbH's robots. The same G-codes can be used to control robots manufactured by different robot vendors in a similar way.

In addition, we provide machine manufacturers with an application programming interface (API) for control and condition monitoring required for industrial robots. Machine manufacturers can use this API to develop their original robot screens and establish easy-to-use systems involving machine tools and robots (Fig. 9).

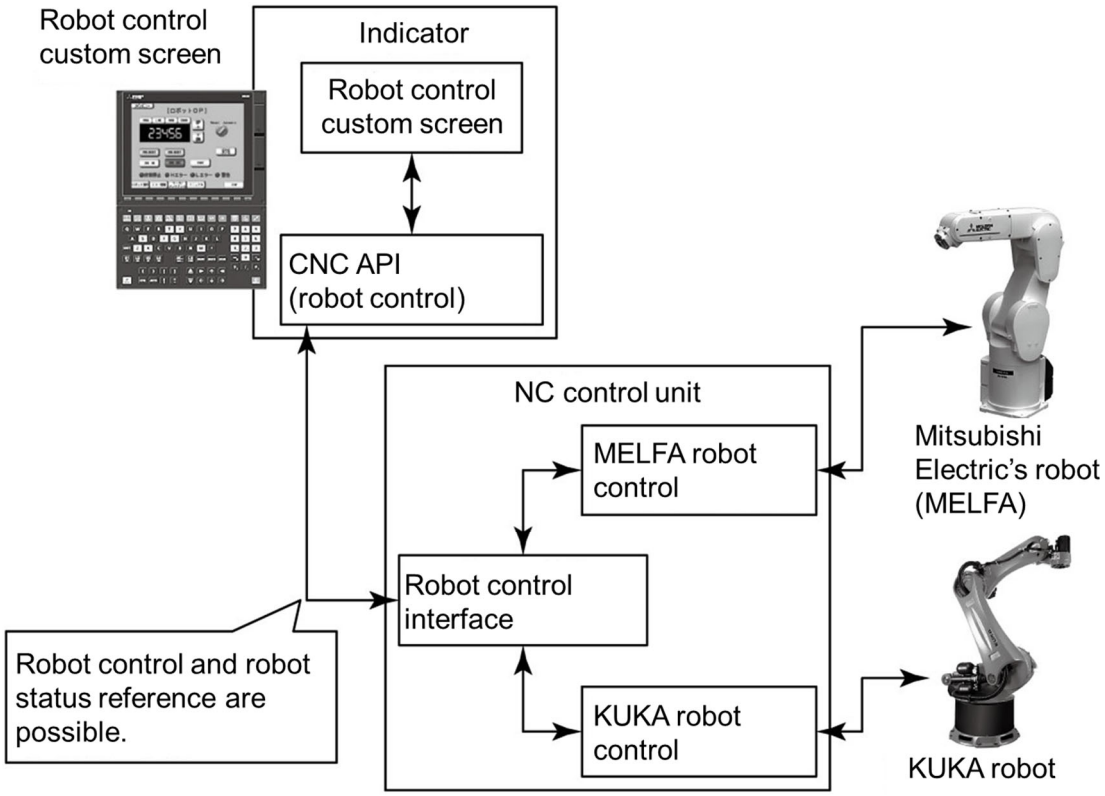


Fig. 9 Robot control API

4. Conclusion

This paper described the cooperative function, Direct Robot Control, which enables cooperation between the CNC and industrial robots. This function helps improve productivity by developing machine tools by actively using industrial robots and simplifying the configuration of automation systems.

We will continue development to expand the functions in line with changing market needs in the future.

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