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Mitsubishi Electric

ADVANCE

Factory Automation

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Changes for the Better

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ADVANCE

Factory Automation

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Precis

Mitsubishi Electric introduces FA solutions through practical examples as a company contributing to a future vision of factories that support social information network infrastructure, whether through the use of data on manufacturing sites and the visualization of production sites or driving productivity higher on machining sites.

Overview

Author: *Fumihiko Kimura**

Futue Factory for Supporting Information Networks in Social Infrastructure

The role of every factory is changing dramatically. Future factories are shifting from the typical independent and closed competitive organization to an open hub structure that shares information with society as an information network in social infrastructure. Some examples include the manufacturing and usage data about electric vehicles used to manage traffic and regulate power provided to social information networks. The use of this data is expected to eliminate wasteful use of resources and improve resource productivity in revolutionary ways. To succeed in these breakthroughs, factories must experience a comprehensive digital transformation. The foundations of this transformation are reforms to the designs and models of every factory process based on a "To-Be" perspective, which requires information about processes and product be converted as much as possible into digital data. This means fully implementing model-based engineering and digital twin concepts. Modularization and interoperability are essential aspects in leveraging this data as information for social infrastructure and will enable standardization as well as the use of this data outside of industrial domains. It is vital to sort intellectual properties into core technologies which act as a source of corporate competitiveness and collaborative technologies to share with society, which requires information management frameworks. People can use the factory assets in a variety of ways from social information networks with this kind of digital transformation. These new high-added value industrial activities contribute to greater global sustainability and resilience while realizing a quality of life that permits human diversity.

* *Professor Emeritus, The University of Tokyo*

Data Science Tool "MELSOFT MaiLab"

Author: *Shota Nakano**

1. Introduction

Many manufacturing companies would like to leverage data to improve production sites. Although a majority of these companies have shown interest in data-driven enhancements, few have been able to shift this interest into action. A major obstacle inhibiting these businesses from taking action is a lack of knowledge and human resources skilled in data analysis within their organizations. In other words, these companies need a tool to easily adopt and use data analysis. While the hope is for a tool that can be used without any specialized knowledge, companies still want customizability, including compatibility with their own programs used to overcome unique problems.

Mitsubishi Electric developed the Data Science Tool MELSOFT MaiLab as a solution for a tool that can act as the data scientist, generate diagnosis models, and propose production enhancements, which eliminates the data science knowledge barrier for employees in charge of production improvements. The intuitive User Interface (UI) and compatibility with independent programs facilitate customization and encourage data-driven production sites.

2. MELSOFT MaiLab Overview

The overall process to enhance production sites by leveraging data consists of collecting data from programmable controllers and sensors, analyzing the data that has been collected, creating a diagnosis model, and embedding that diagnosis model into the production process (Fig. 1). The phase to analyze the data and create a diagnosis model breaks down into five additional steps. Each of these steps is tedious and takes time while also requiring knowledge about statistics or other data analysis skills. These necessities make the barrier to start using data quite high.

MELSOFT MaiLab takes advantage of AI to automate the data analysis and diagnosis model creation process, effectively eliminating the knowledge barrier to realize data-driven enhancements to production sites. The software goes beyond only data analysis and diagnosis model creation as well to support the entire process from data collection and analysis to use and operational monitoring of the diagnosis model in production.

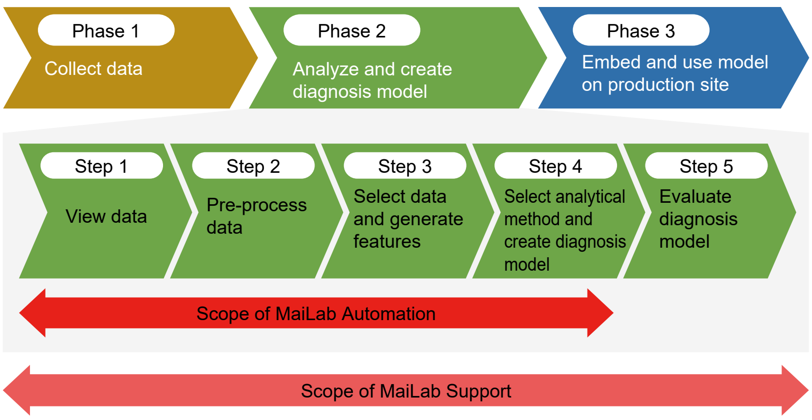


Fig. 1 Flow of data-driven enhancements

*Nagoya Works

3. MELSOFT MaiLab Features

3.1 Simple analysis

One AI analysis support feature is the Automated Machine Learning (AutoML) function. AutoML achieves simple data analysis and diagnosis model creation that anyone can use.

Whether the purpose of the model is detecting Abnormalities, predicting the future, or inputting training or other data, MELSOFT MaiLab can automatically generate an ideal diagnosis model to accomplish those objectives by simply asking the users questions (Fig. 2).

The software also provides a score based on the parameters and graphs the evaluation results for the test data to assess the quality of the diagnosis model generated by the AI system. This score not only supports the creation of diagnosis models but also summarizes the training results and accuracy in addition to helping users determine whether to embed the model into the production process (Fig. 3).

3.1.1 State-of-the-art data pre-proccessing functions

Data pre-processing before creating a diagnosis model is vital to improve the accuracy. This includes properly organizing the relevant data, narrowing the data set necessary for an analysis, and assessing the data quality. MELSOFT MaiLab offers five functions to automatically process and optimize data (Fig. 4):

(1) Waveform data processing

This function extracts interval waveform data as the sensor measurements change with time and performs featurization of the data that has been extracted.

(2) Imputation of missing data

This imputation process properly inserts missing data (values left blank due to a lack of sensor data).

(3) Addition of new data

This function automatically identifies variables that largely impact diagnostic processes to create and input these variables as new features. The software also calculates the higher priority between those variables to add as new features.

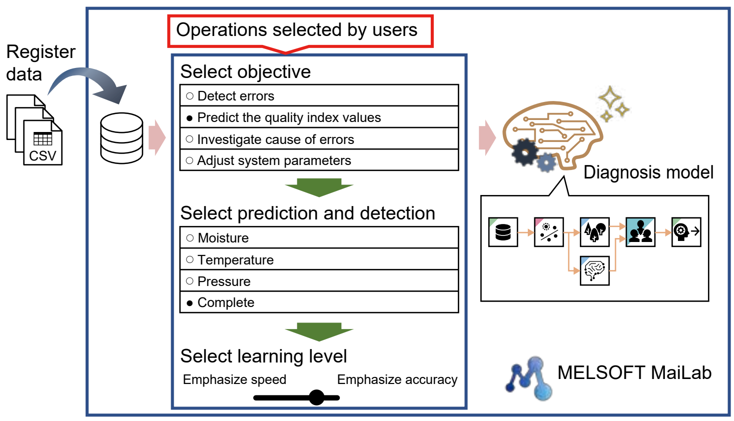


Fig. 2 Steps of automated AI training

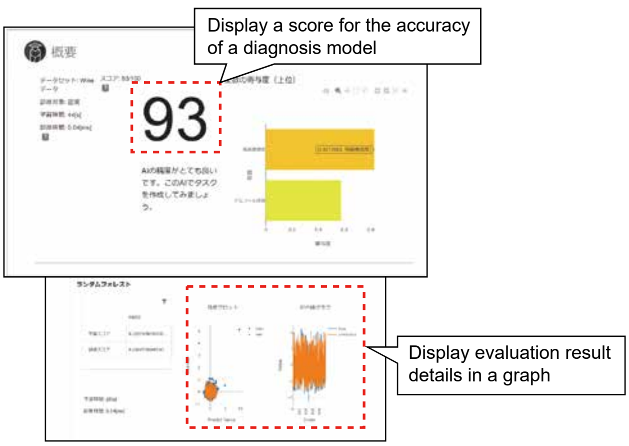


Fig. 3 Screen displaying learning results

(4) Encoding

The encoding process converts data in a format that cannot be used for training into a data format that can be used for training while retaining the features of the original data.

(5) Scaling

The scaling process converts data into an equivalent scale to properly use for training to make the evaluation of training results easier.

3.1.2 Effective and highly accurate machine learning

The software automatically executes machine learning by analyzing data in advance. The data pre-processing does not automatically process the data but rather tunes the data for more effective machine learning and combines multiple algorithms to execute machine learning using highly accurate predictions.

MELSOFT MaiLab provides three functions to mine data and generate higher quality diagnosis models by automating the entire machine learning process.

(1) Hyperparameter optimization

A hyperparameter is a parameter used to control the behavior of each learning algorithm. MELSOFT MaiLab explores and optimizes each learning algorithm because the prediction results and accuracy vary according to the parameter settings.

(2) Various learning algorithms

MELSOFT MaiLab offers deep learning and a variety of other machine learning processes in addition to the typical statistical process. These new machine learning processes can perform training with higher quality representations through highly complex data.

(3) Ensemble learning

The ensemble learning process combines prediction results from multiple learning algorithms to improve predictive performance. Each learning algorithm obtains different results even when learning and making predictions on the same data sets because the calculation methods differ for each algorithm. A single learning algorithm presents bias in the results due to the data and algorithm features when making predictions. Ensemble learning learns the pros and cons of each learning algorithm to realize more highly accurate predictions than any single algorithm alone (Fig. 5).

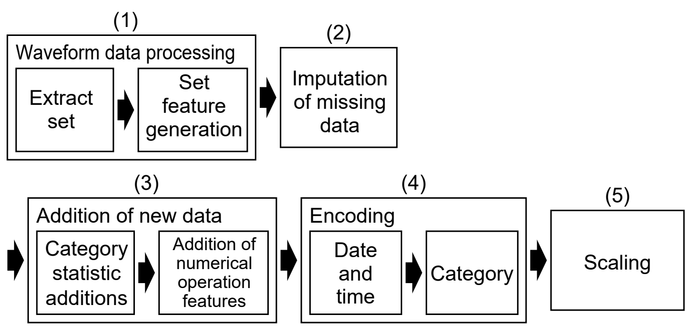


Fig. 4 Flow of data pre-processing

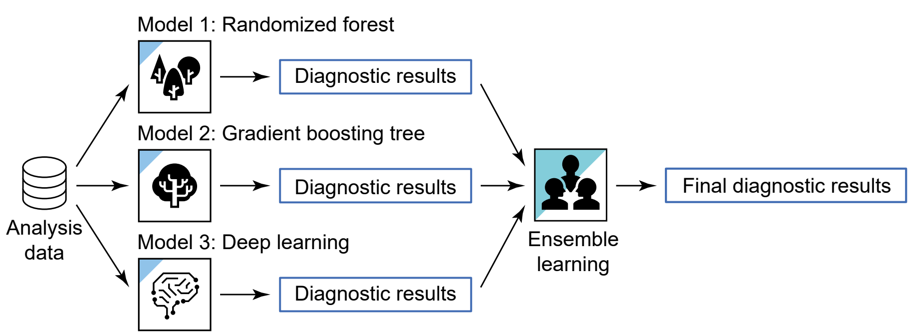


Fig. 5 Illustration of ensemble learning

3.2 Flexible diagnosis model customization

Users can use a dedicated editor to verify and edit diagnosis models automatically generated by the system from data input through predictive results output (Fig. 6). The icons in the figure indicate the function blocks packaged for data processing and analysis methods. Users can arrange and connect these blocks using mouse operations to easily edit a diagnosis model.

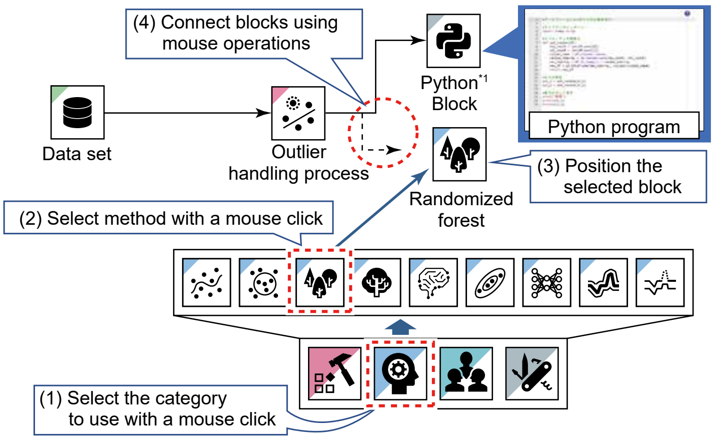
The user can also enhance data and other pre-processing to improve the diagnosis model automatically generated by the software. This even gives users the freedom to create their own pre-processing and diagnostic algorithms to create diagnosis models from scratch. This enables users to capitalize on their own knowledge in data analysis when creating a diagnosis model.

MELSOFT MaiLab provides a function block to embed python code written by users as well. This lets users link MELSOFT MaiLab with their own original processes to improve the accuracy of the diagnosis models (Fig. 7).

3.3 Use of Data for Greater Acceptability

On-site application of diagnosis models for data-driven improvements to production facilities must achieve everything from status monitoring to predictive detection using the data generated in real time on site. Typical data analysis software does not generally offer a function to use diagnosis models in production operations. This usually requires users to configure a separate system. MELSOFT MaiLab can both create diagnosis models and facilitate use of those models in production either on the same computer or deployed to another computer for use in production as is (Fig. 8).

Additionally, MELSOFT MaiLab provides functions to link data with the Mitsubishi Electric MELSEC-series programmable controllers and basic Edgecross software. These links can shorten the time required from implementation to use in production as well as reduce costs.



*1 Python is a registered trademark of the Python Software Foundation.

Fig. 6 Model editing operations in the editor

Pre-processing Function Block		
Imputation process	Outlier handling process	Scaling
Numerical operation	Dimensionality reduction	Set generation (Waveform extraction)
Set feature generation	Subset formation	
Analytical function block		
Deep learning	Gradient boosting decision tree	Randomized forest
Auto encoding	k-nearest neighbors algorithm	Similar waveform recognition
Multiple regression	MT method	Guard band

MT: Mahalanobis−Taguchi

Fig. 7 List of analysis function blocks

4. Application Example

MELSOFT MaiLab facilitates the creation of diagnosis models and use of those models on-site in production, even without a data scientist, by leveraging deep learning and other machine learning methods. As one example of issues to data-driven production on-site, many manufacturing businesses face the challenge faced when trying to share and utilize the knowledge of skilled workers.

4.1 Recommendations for optimal control parameters

Skilled workers can make decisions on the best settings for control parameters based on their intuition and experience. The problem is that this kind of knowledge is tacit knowledge, which is lost when those skilled workers retire.

MELSOFT MaiLab sets and learns from production data and the control parameters decided upon by these skilled workers to create diagnosis models that propose control parameter settings equivalent to those set by skilled workers (Fig. 9). In this way, the software enables employees with little experience to set the same parameters as skilled workers.

4.2 Estimation of the probable causes of problems

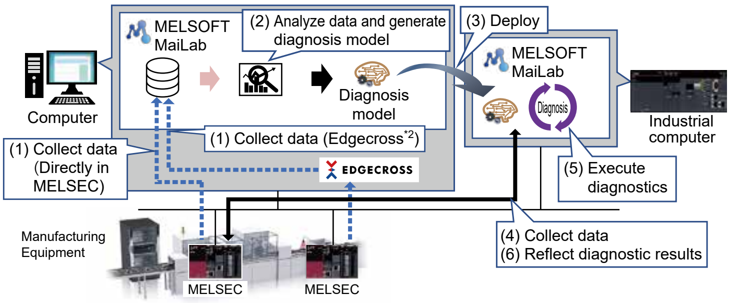
Anyone can estimate the probable causes of device malfunctions or product defects by investigating the causes of a past issue. However, it requires time for an employee with little expertise and experience to directly tackle these types of problems.

MELSOFT MaiLab can infer the probable causes based on the status when a problem occurs by learning from data about the status and type of issues encountered in the past. These capabilities support investigations into the cause of problems that require experience and expertise, which in turn shortens the time required to identify the probable causes. As a result, manufacturers can reduce the downtime of equipment and help improve productivity.

5. Conclusion

In light of the business landscape, Mitsubishi Electric developed MELSOFT MaiLab as a software with a variety of features to offer total support of data use on production sites.

Data analysis and AI are rapidly evolving. As these powerful technologies continue to become more diverse, the industry faces a serious lack of human resources and skills in data analysis. Mitsubishi Electric will continue to contribute to manufacturing solutions and production enhancements by broadening new technologies and expanding the application scope.



*2 Edgecross is a registered trademark of the Edgecross Consortium

Fig. 8 Example of the system configuration

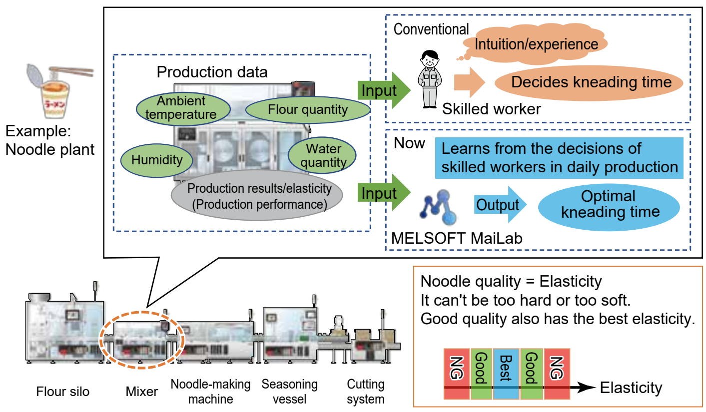


Fig. 9 User case to propose optimal control parameters

Production Site Visualization Using Mobile Applications

Authors: *Yasuhiro Hara** and *Takahiro Kaneko**

1. Introduction

The GOT2000 Series (hereinafter "GOT") provides a lineup of industrial touch panel interfaces developed based on an "Easy & Flexible" concept. These touch panels have garnered tremendous praise for connecting to a variety of FA devices to visualize the entirety of a production system. The market responded well to GOT Mobile (Fig. 1) as a remote Mitsubishi Electric GOT solution that can monitor and operate equipment connected on production sites remotely from computers, tablets, and other mobile terminals. This favorable reception has increased the demand for the Company to develop additional functionality.

However, GOT Mobile must always have a web browser running, otherwise users cannot quickly identify any on-site issues remotely from a computer or mobile terminal.

To provide even faster remote notifications about the status of production sites, Mitsubishi Electric released Pocket Mobile as a mobile app compatible with GOT Mobile in May 2021 so that users can not only receive notifications about alarms triggered on production sites

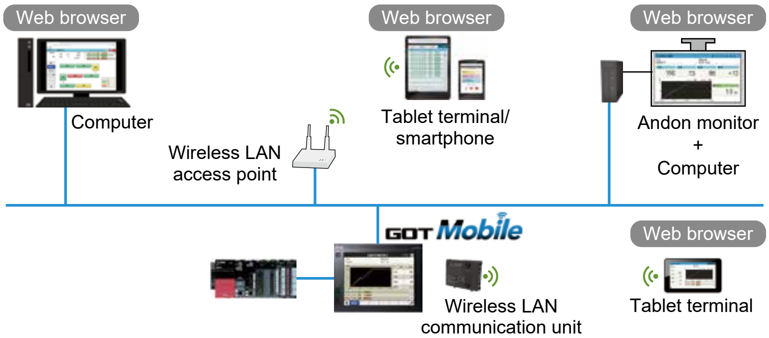


Fig. 1 GOT Mobile system configuration

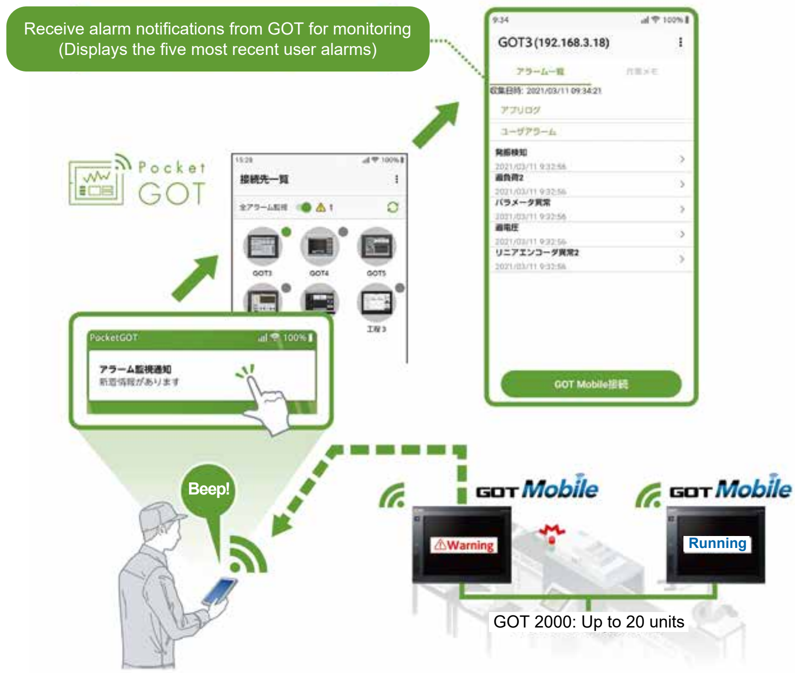


Fig. 2 Remote error identification

*Nagoya Works

but also remotely monitor and operate equipment from a computer or mobile terminal.

This paper describes the Pocket GOT features as well as the technologies and innovations made to realize those functions.

2. Pocket GOT Features

2.1 Remote error notifications

Pocket GOT is a free Android*1 mobile app available on the Google Play store. Pocket GOT can notify remote users about alarms triggered on a production site sent from an on-site GOT via a mobile terminal using sound, vibrations, and warning banners. Therefore, operators no longer need to have a web browser running on their mobile terminal to quickly learn about any on-site production problems (Fig. 2).

*1 Android is a registered trademark of Google LLC.

2.2 Verification of equipment statuses and alarm logs

Users can display a dedicated GOT Mobile screen by launching a web browser using GOT Mobile from the Pocket GOT app linked to the Mitsubishi Electric GOT Mobile remote solution. In this screen, users can view alarm logs and on-site information related to alarm notifications via a remote mobile terminal (Fig. 3).

2.3 Consolidated working memo display

Users can send working memos (daily and other reports) that include pictures created on a mobile terminal with Pocket GOT installed to the GOT. FA Application Package iQ Monozukuri Process Remote Monitoring[1] makes system configuration without any expert knowledge easy while enabling a shift to IoT production equipment. By using this FA application package, users can aggregate working memos from the GOTs installed on each line of the production site. This enables employees to display all of the working memos in a form format on an office computer as well as share pictures, images, and the registered text information (Fig. 4).

3. Pocket GOT Development

3.1 Application configuration

Pocket GOT runs as three different types of mobile applications: a native application that runs independently as an application installed on a device, a web application that runs in a web browser without requiring any installation, and a hybrid application that does require installation but runs the main functions in a web browser.

Pocket GOT must always run as a background process on mobile terminals to receive alarms triggered on production sites on those mobile terminals. Because the web and hybrid applications that run in a web browser

Fig. 3 System status and alarm history

Fig. 4 Collective display of working memos

cannot run functions requiring the application to run in the background, Mitsubishi Electric adopted a native application with no limitations on background functions (Table 1).

3.2 Development environment

Users need support for platform-agnostic environments (iOS*2/Android) on mobile terminals used to install Pocket GOT. Therefore, Mitsubishi Electric adopted Xamarin*3—Microsoft's cross-platform development environment—as the development environment for Pocket GOT to take advantage of Visual C#*3 and Visual Studio*3 knowledge and the success of its other products.

*2 iOS is a registered trademark of Cisco Technology, Inc.
*3 Visual C#, Visual Studio, and Xamarin are registered trademarks of the Microsoft Corporation.

4. Technologies and Innovations to Realize Functionality

4.1 System configuration

This section describes the Pocket GOT system configuration. Pocket GOT consists of an alarm notification function to remotely notify users of abnormalities at production sites (Fig. 5[1]) and a working memo function to create inspection reports about production sites (Fig. 5[2]). The alarm notification function transmits data via the HyperText Transfer Protocol (HTTP) for server-client communications using the same port. The proven communications library built into GOT Mobile sends alarm requests via an HTTP connection (Fig. 5[3]). GOT Mobile operates as a function to receive these requests and notify users about the details of any alarms (Fig. 5[4]). The working memo function operates as a feature to send data that consists of text and images recorded on production sites to the GOTs using the File Transfer Protocol (FTP) (Fig. 5[5]).

Any user who has installed the FA Application iQ Monozukuri Process Remote Monitoring (Fig. 5[6]) to collect and visual data from multiple systems on a computer can acquire working memo data from GOTs (Fig. 5[7]) and collectively display all of the working memos in the HyperText Markup Language (HTML) format (Fig. 5[8]).

4.2 Alarm notification methods

There are two alarm notification methods: local notifications to display notifications issued internally by the mobile application on a mobile terminal and online notifications to receive and display notifications issued from a cloud server via an internet connection on a mobile terminal. Local notifications benefit from minimal

Table 1 Comparison of Mobile Application Format

Selection point	Native application	Web application	Hybrid application	Priority
Functional limitations of terminal*1	No limitations	Limitations	Some limitations	High
Network connection	Not required	Required	Sometimes required	↑
System Configuration	Simple configuration	Complex configuration	Complex configuration	
Operational stability	High	Platform dependent	Platform dependent in some circumstances	
Universality of terminal	Low	High	Low	
Universality of program	Low	High	High	Low

*1 Camera, communication, and other functions

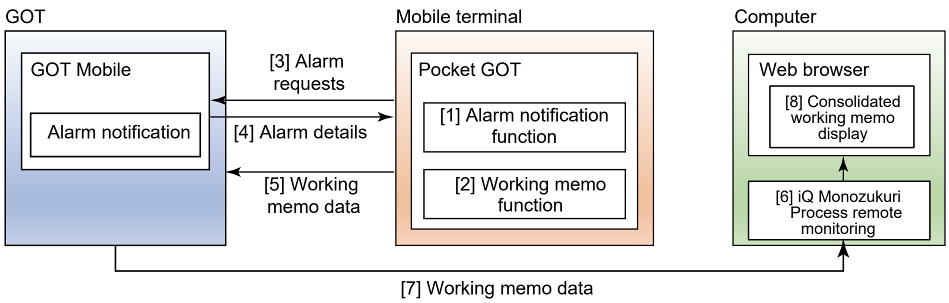


Fig. 5 Pocket GOT system configuration

notification functions to offline terminals but suffer from a high-level of complexity to ensure operation during the sleep state. Online notifications benefit from a simple implementation of notifications via background processes, but suffer from an inability to provide notifications to offline terminals without an internet connection in addition to the complex configuration of the notification server (Fig. 6).

Pocket GOT can send notifications to offline terminals and incorporate methods to realize local notifications that are easy to implement. This sequence sends requests for the status of alarms to the GOTs. The GOT receives this alarm data and generates an internal Pocket GOT notification if there is a new alarm (Fig. 7).

4.3 Segmentation of communication processes for mobile terminals in sleep mode

Pocket GOT runs as a foreground and a background application when the mobile terminal is in an active state. As a foreground application, the mobile terminal prioritizes the operation of the mobile app, which in turn has essentially no operational limitations. As a background application, the mobile application runs but the mobile app screen is not displayed. In this state, there are operational limitations to the mobile app because the mobile app has a lower operational priority than other applications that are displayed on screen. The mobile terminal also severely limits the operations of the mobile app if in sleep mode.

Taking into account the various risks resulting from these operational limitations, Pocket GOT utilizes a system that operates as a foreground process even when running in the background or when in the sleep mode. However, the mobile terminal does have an issue of delays in processing regular alarm requests from Pocket GOT to the GOTs.

Therefore, Pocket GOT receives data for only the latest alarm from a GOT for alarm requests sent to the GOTs. By changing the internal process to determine the necessity of a notification process comparing the current alarm with the previous alarm data, Pocket GOT reduces processing in the sleep mode and retains the periodicity. This segmentation of the communication process realizes a framework that can regularly execute

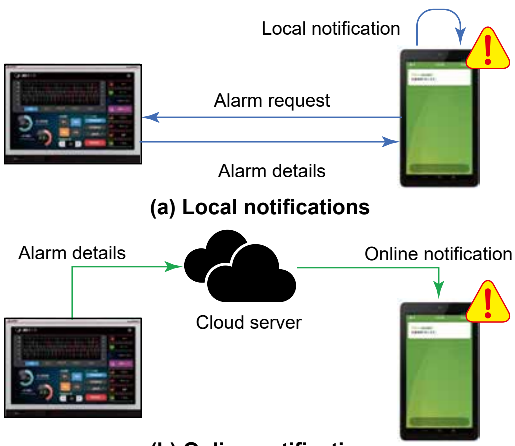


Fig. 6 Local and online notifications

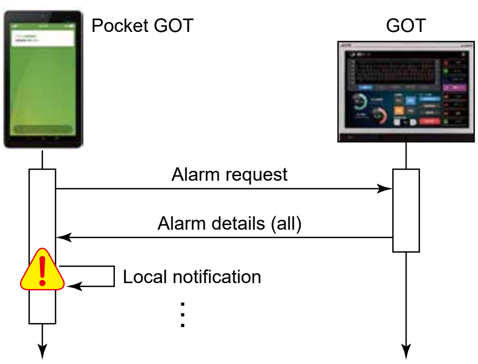


Fig. 7 Sequence of local notifications

Pocket GOT processes in the background, even when in sleep mode (Fig. 8).

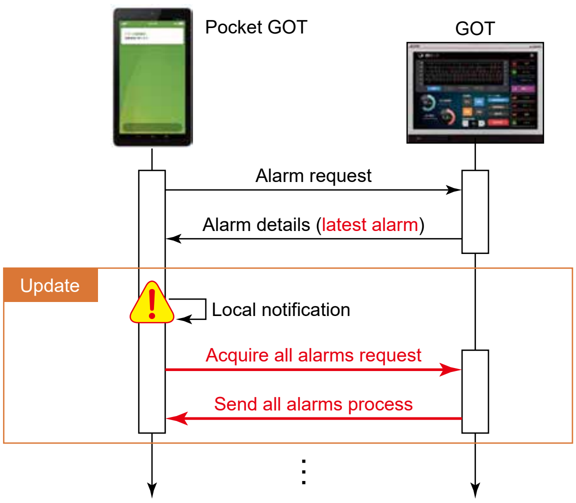


Fig. 8 Segmentation of communication processes

5. Conclusion

This paper has described the ways in which manufacturers can easily adopt the Mobile App Pocket GOT as a simple and low-cost solution that more rapidly visualizes any on-site issues that arise through links to the GOT2000 series, GOT Mobile, and iQ Monozukuri Process Remote Monitoring.

In the future, Mitsubishi Electric will pursue further usability and broader functionality for users.

Reference

(1) Okojima, S., et al. : FA Application Package “iQ Monozukuri PROCESS REMOTE MONITORING,” Mitsubishi Denki Giho, 94, No. 4, 236-239 (2020)

CPU Module "MELSECWinCPU" of Programmable Controller "MELSEC iQ-R Series"

Authors: *Tsubasa Masui** and *Takahiro Watanabe**

1. Introduction

Manufacturing businesses must promote and pursue work-style reforms as the working population dwindles and the needs of working people diversify due to an aging society with a declining birthrate. Greater productivity per hour has been raised as one potential solution to work-style reforms. To successfully implement this strategy though, a digital transformation of the information handled on site is essential. However, various challenges manifest as the needs for this digital transformation of information using computers grow, such as cutting costs for data process engineering and computer maintenance and management.

To overcome these challenges, Mitsubishi Electric released its MELSEC iQ-R Series programmable controllers as products to collect and analyze production site data (Table 1). This lineup of products eliminates the need to create programs dedicated to each application to reduce the engineering costs required for adoption. The MELSEC iQ-R Series also features environmental durability and a long-term reliable supply of modules, which can reduce maintenance and management costs.

However, the needs for a digital transformation of information have become more diverse and sophisticated. Customers have begun to pursue optimal ways to manage, analyze and use this data on their production sites. To satisfy those needs, the MELSEC iQ-R Series MELSECWinCPU developed with a Windows*1 operating system enables independent application development, the use of a wealth of applications, and more.

Users can connect the MELSECWinCPU to other programmable controller modules to promote the use of Internet of Things (IoT), Artificial Intelligence (AI), and data analysis. These links allow manufacturing businesses solutions to not only cut costs for data process engineering as well as computer maintenance and management but also overcome many other challenges.

This paper outlines the MELSEC iQ-R Series MELSECWinCPU before describing solutions to the challenges faced by manufacturing businesses using the MELSECWinCPU.

*1 Microsoft and Windows are registered trademarks of the Microsoft Corporation.

Table 1 Information devices in the MELSEC iQ-R Series

Name	Features
MES interface module	The module enables direct connectivity between IT system databases and programmable controller systems.
OPC UA server module	The module enables users to mount an OPC UA server directly to the base unit of programmable controllers.
Recorder module/ camera recorder module	These modules are dedicated recording (logging) modules for corrective maintenance system. Users can aggregate time-stamped data about all devices and labels right after any problem arises with every scan of the programmable controllers.
High-speed data logger Module/ High-speed data communication module	These modules enable high-speed data sampling synchronizing the production status and other data with each programmable controller scan in an easy format to process and aggregate.
C Intelligent Function Module	This module includes VxWorks*2 in the operating system to execute C/C++ programs. The module is also compatible with Linux*3 to facilitate links to cloud services and Python*4 programs.

MES: Manufacturing Execution System, OPC: Open Platform Communications, UA: Unified Architecture

*2 VxWorks is a registered trademark of Wind River Systems.

*3 Linux is a registered trademark of Linus Torvalds.

*4 Python is a registered trademark of the Python Software Foundation.

**Nagoya Works*

2. MELSEC iQ-R Series MELSECWinCPU

2.1 MELSEC iQ-R Series

The MELSEC iQ-R Series is a lineup of Mitsubishi Electric programmable controllers developed to overcome challenges in manufacturing businesses from a standpoint of TCO reductions. Programmable controllers are control devices used in factory automation. These products combine specialized modules by function to configure into systems tailored to each customer's application. These customers can take advantage of the broad MELSEC iQ-R Series lineup of proven programmable controllers to configure these systems. Additionally, highly precise control linking the programmable controller CPU and motion CPU or the open integrated network CC-Link IE TSN can realize seamless high-speed communication between information systems and production sites.

2.2 MELSECWinCPU

MELSECWinCPU adopts Windows as its operating system to achieve data processing similar to a computer in a programmable controller environment. The MELSECWinCPU specifications are shown in Table 2. The MELSECWinCPU can run a wide variety of applications on its Windows operating system. It also lets users develop applications in C/C++, Visual Basic*9 and C#. Furthermore, the MELSECWinCPU offers the same standard interface as a personal computer. Users can combine various peripheral devices for computers with the MELSECWinCPU to configure a system right for each application.

*9 Visual Basic is a registered trademark of the Microsoft Corporation.

3. MELSECWinCPU Features

3.1 Standalone Windows startup function

The updates to applications running in Windows and the backups requiring system restart, which stops operation of the entire programmable controller system. This has been one challenge of a programmable controller system running the Windows operating system. To solve this problem, Mitsubishi Electric has equipped the MELSECWinCPU with a system control function independent of the Windows operating system, which enables Windows to restart while other system modules continue running. This function improves the system operation rate because Windows can restart without stopping control using the multiple CPU system configuration consisting of a programmable control CPU and motion CPU (Fig. 1).

3.2 Adoption of Windows 10 IoT Enterprise LTSC 2019

The MELSECWinCPU uses Windows 10 IoT Enterprise LTSC 2019. Windows 10 generally issues functional update programs to add new functionality and quality update programs to rectify any security vulnerabilities or repair flaws. Windows 10 IoT Enterprise LTSC 2019 issues quality update programs but does not provide functional update programs. Therefore, a programmable controller using Windows 10 IoT Enterprise LTSC 2019 can always stay up to date while enabling stable system operations.

Table 2 MELSECWinCPU Specifications

Item	Description
OS	Windows 10 IoT Enterprise LTSC 2019
Programming language	C/C++, Visual Basic, C#
MPU	Intel Atom*5 E3930 Dual Core
Main memory	4GB
Internal storage	60GB
External I/F	USB3.0:1ch, USB2.0:3ch
	Ethernet*6(1000BASE-T):2ch
	RS232:1ch
Display I/F	HDMI*7
Memory I/F	SDHC/CFast*8

LTSC: Long-Term Servicing Channel, MPU: Micro Processing Unit, SDHC: SD High Capacity

*5 Intel Atom is a registered trademark of the Intel Corporation.

*6 Ethernet is a registered trademark of the Fuji Film Business Innovation Corporation.

*7 HDMI is a registered trademark of HDMI Licensing Administrator, Inc.

*8 CFast is a registered trademark of CompactFlash Association.

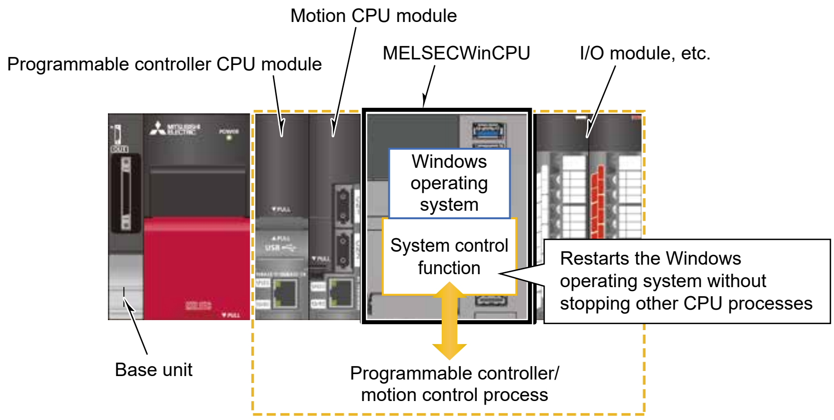


Fig. 1 Standalone Windows startup function

3.3 Easy access to each programmable controller module

MELSECWinCPU provides MELSEC Data Link Functions as methods of communication between Windows programs and each programmable controller module. These MELSEC Data Link Functions come as libraries that can be executed using C/C++, Visual Basic and C# programs in the Windows operating system, which enables the MELSECWinCPU to access each programmable controller module. In addition to accessing each programmable controller module connected to the same base unit, the MELSEC Data Link Functions can access the CPU modules via a network. The MELSECWinCPU also provides these MELSEC Data Link Functions as communication libraries that do not rely on any specific communication channel. Therefore, users can easily access modules by simply specifying a specific parameter for the module to access, such as a slot or network number. This type of access makes it easy to connect to various programmable control modules and a wide variety of Windows applications, peripheral devices, and other assets. Users can develop programs in an environment that they are familiar with because MELSECWinCPU supports Visual Studio*10 as an environment for program development.

*10 Visual Studio is a registered trademark of the Microsoft Corporation.

3.4 Robust hardware

The MELSECWinCPU does not use cooling fans, disk drives, or any other drive components to offer the same environment stability as other MELSEC iQ-R Series modules. It also features the same MELSEC iQ-R Series environment stability and long-term reliable supply of modules, which can reduce maintenance and management costs. Thanks to the Reliability, Availability, and Serviceability (RAS) equivalent to the programmable controller CPU, users can configure a system more reliable and robust than one using personal computers.

4. MELSECWinCPU Solutions for Manufacturing Businesses

4.1 Technology to reduce the data process engineering costs

Manufacturing businesses struggle to reduce engineering costs related to linking data and control processing. Ladder logic primarily used in manufacturing businesses is known for its strengths in control processes, such as used in programmable controllers. On the other hand, C and other high-level programming languages are proficient in the data processing necessary for complex operations, such as those used in numerical analyses, even though these languages are not as good for programming the control processes of programmable controllers. That is why systems that require both data and control processing sometimes combine a computer environment proficient at data processing and a programmable controller system proficient at control processing.

However, an integrated computer and programmable controller system requires communication programs for both the computer and controller, which increases the engineering costs necessary to develop the communication programs. Moreover, users often need to undertake development beyond the desired added value for equipment and systems, such as that to take into account the impact the communication program has on the programmable control system, which results in excess engineering costs.

The MELSECWinCPU overcomes this problem by linking to the programmable control system using MELSEC Data Link Functions. These MELSEC Data Link Functions eliminate the need for communication programs on existing programmable controllers to make connections with a wide range of programmable controller modules easy. Through this innovation, users can introduce MELSECWinCPU to an existing programmable control system when adding data processing on existing equipment to realize control processing on equipment via conventional programmable controller modules and data processing via the MELSECWinCPU. Users can then shift their focus to the development of functions that provide added value to equipment and systems while reducing the engineering costs related to linking data and control processing (Fig. 2).

4.2 Reduction of computer maintenance and management costs

Manufacturing businesses struggle to reduce the computer maintenance and management costs to use both data and control processing. These maintenance and management costs primarily consist of the costs to develop hardware and software resulting from production stoppages due to computers and expansion boards for computers and the costs to handle the impact of irrelevant functional updates of the operating system on existing programs.

The lifecycle of computers and the expansion boards for these computers is not only relatively short, but the reliable acquisition of these components is also difficult. On top of that, the expansion boards for the computers often used for I/O control, analog control, and motion control differ manufacturer to manufacturer, which results in compatibility issues and meticulous tuning. The need for hardware and software development to adapt to any discontinued products or specification change often drives maintenance and management costs up as well. Furthermore, automatic functional updates to the operating systems can also impact programs

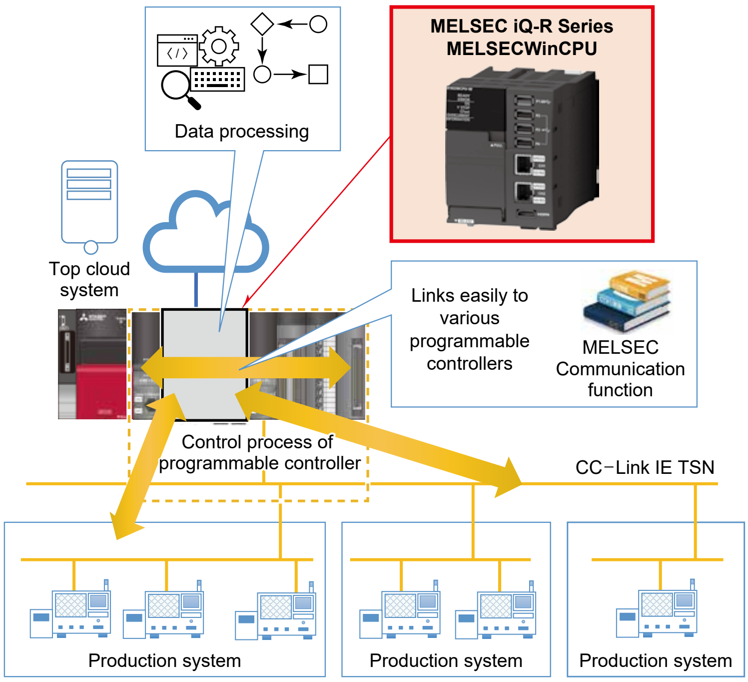


Fig. 2 Links between information and programmable controller processes

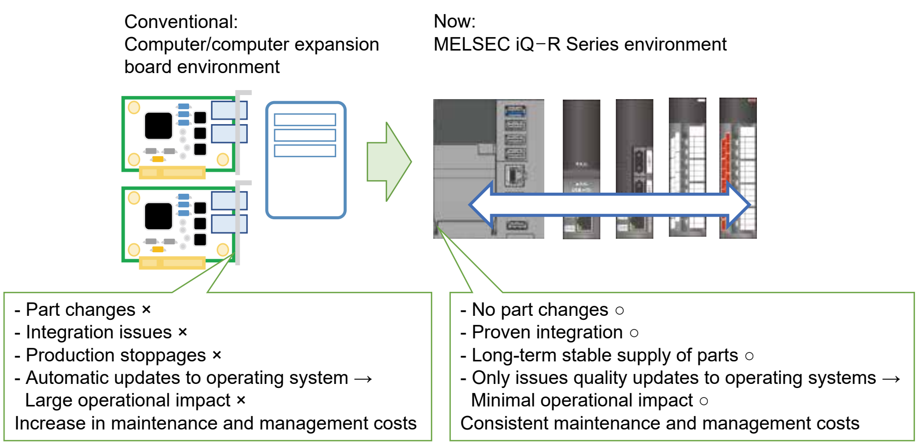


Fig. 3 Computer-MELSECWinCPU management and maintenance costs

already running in the production system, which makes maintenance and management costs an issue when using a Windows operating system for factory automation applications.

MELSECWinCPU addresses these issues that have just been described through the use of a broad range of MELSEC iQ-R Series modules and Windows 10 IoT Enterprise LTSC.

The use of MELSEC iQ-R Series modules even ensures a long-term stable supply of components. MELSECWinCPU can link to a variety of programmable controller modules, making a combination of a variety modules with guaranteed compatibility. These features enable users to reduce engineering costs related to maintenance and management resulting from typical system changes. The adoption of Windows 10 IoT Enterprise LTSC 2019 minimizes the impact on existing equipment because Microsoft only issues quality update programs and not functional update programs (Fig. 3).

5. Conclusion

This paper has provided an overview of the MELSEC iQ-R Series MELSECWinCPU. MELSECWinCPU enables the use of a Windows operating system as the programmable controller environment to reduce costs for data process engineering and computer maintenance and management, which have been obstacles standing in the way of a digital transformation of information using computers.

Simulator "NC Virtual Simulator" to Support Manufacturing Digital Transformation

Authors: *Toshihiro Azuma** and *Yuki Ito**

1. Introduction

The manufacturing industry is quickly expanding the use of IoT, AI and other leading-edge technologies recently in addition to earnest efforts aiming to enhance productivity through a digital transformation of manufacturing processes and data links. Manufacturing businesses must pursue not only systems supporting variable-mix variable-volume production that can adapt to the rapid changes in supply and demand but also efforts to enhance the efficiency of prior inspections as well as quantify and standardize machining expertise due to a lack of skilled workers resulting from an aging society with a declining birthrate. The COVID-19 pandemic has made support for autonomous, automated and remote systems more imperative globally as the world struggled with restrictions in daily life at production plants.

In light of these circumstances, Mitsubishi Electric strives to model equipment design, production, operation, and maintenance processes in a virtual space and develop digital twin systems that support optimization of the entire value chain (1). The NC Virtual simulator was developed this time to replicate the real movements of NC machine tools in a virtual space to realize high-fidelity simulations under the same conditions as the actual machines.

2. Purpose and Features of the NC Virtual Simulator

The NC Virtual Simulator is an application that reduces the workload on machining sites and enhances operational efficiency and productivity by spearheading a greater digital transformation of processes in the engineering chain from product design through trial machining (Fig. 1).

The simulator is a Windows*1 application intended for use by design departments mainly in charge of creating process designs and machining programs for machine users. This software replicates the actual machining environment to make the hand off between design departments and machining sites go more smoothly. By using the same system data (machining conditions and parameters, calibrations, functional options, etc.) as the NC machine tool, the simulator achieves high-fidelity 3D simulations replicating not only the positional control but also the real Computerized Numerical Control (CNC) movements from smoothing, acceleration and deceleration to servo response delays. This level of fidelity has the distinct ability to detect various machining flaws that could only be discovered through trial machining in a virtual space (on a computer).

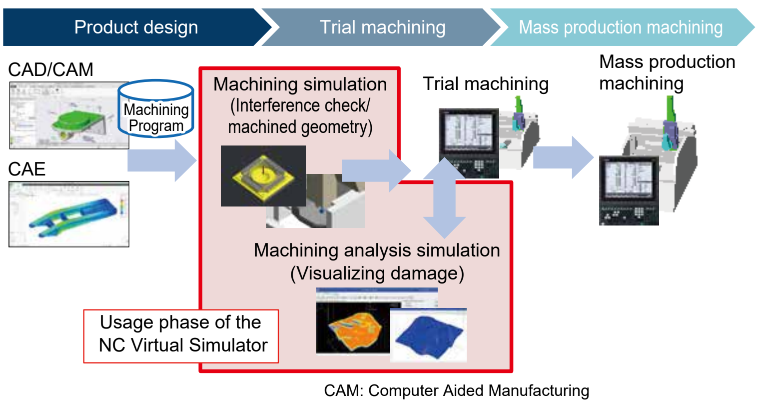


Fig. 1 Utilization phase of the NC Virtual Simulator

*Industrial Mechatronics Systems Works

The machine model simulations even support links to the NC Trainer2 plus, an existing Mitsubishi Electric product supporting customization development, which engineers can use as a tool to help improve the ease of machine design (machine model design using CAD) and ladder development by NC machine tool manufacturers.

*1 Windows is a registered trademark of the Microsoft Corporation.

2.1 Function to replicate NC machining tool movements in a virtual space

The NC Virtual Simulator runs in Windows on the same software as the real CNC machine and virtually models the feedback loop of the drive unit in the virtual space. It even has a function to synchronize the actual CNC system data to reproduce real CNC movements virtually (Fig. 2). These functions enable engineers to confirm authentic simulations tracking tool movements of the real CNC machine in addition to alarms and other alerts triggered on the actual CNC machine all in a virtual space.

The NC Virtual Simulator can even replicate the machining flaws that simulations at the CAD/CAM command level cannot as well as detect improper NC settings in advance. These capabilities help reduce rework sent back to the design departments from machining sites and workload on machining sites.

2.1.1 Simulation generating NC command positions

Unlike a block-level simulation in a CAD/CAM machining program, the NC Virtual Simulator utilizes the CNC software built into the actual CNC machine to enable a simulation that meticulously replicates the NC command position generation reflecting the acceleration, deceleration and other such parameters. More specifically, the emulation of real-time operations in the operating system running the CNC software at a CPU command level precisely reproduces periodic interrupt, task sequences, and other CNC software functions. By incorporating these functions, the simulator can simulate smoothing, acceleration, deceleration, and other processes generating command positions in a virtual space.

The combination of 3D machining and machining analysis simulation functions outlined later in this paper enables the NC Virtual Simulator to detect machining flaws not expressed by CAD/CAM simulations. These results let users make the detailed adjustments—such as fine tuning small level differences, acceleration, deceleration, and other parameter settings in the machine program—usually made by machining sites based on the results of trial runs but earlier in the design stage.

2.1.2 Drive response simulations

The NC Virtual Simulator provides a function to simulate the feedback loop process of drive units to reproduce the surface accuracy while taking into account the impact of response delays of the drive unit in addition to the CNC command positions. A simulation that includes the response delays in the feedback loop of drive units reproduces tiny deviations from the CNC command path, such as on the inner circumference.

These simulation results give users greater insight into up-front inspections at the design stage or prevent rework when issues arise on site in later phases after the design stage.

2.1.3 Links to NC machining tools

Users can reflect settings in simulations by simply importing system data exported from the real CNC machine such as machining conditions and parameters, calibrations, and functional options into the NC Virtual Simulator. This provides a function to easily match the

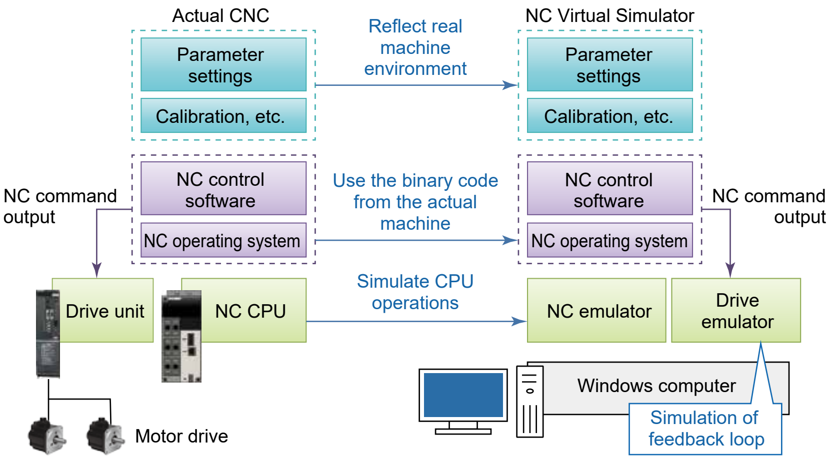


Fig. 2 Simulations of NC machine tool operations in a virtual space

various settings of the NC Virtual Simulator to those of the actual CNC machine without any manual settings, whether the machining program or NC parameters.

Mitsubishi Electric is also in development of a function to transfer data with the NC through a network. This function enables user to reflect any adjustments to the machining program or parameters made in the NC Virtual Simulator to the real CNC machine to resolve potential issues, such as mistaken or forgotten settings which can happen when reflecting these changes manually on the actual CNC machine.

2.2 3D machining simulations

The NC Virtual Simulator provides functions for two 3D machining simulations: a workpiece simulation that displays the geometry of a workpiece during machine and upon completion as a three-dimensional model as well as a machine simulation that displays the operation of machine parts and detects any interference between these parts.

Users can take advantage of the workpiece simulation (Fig. 3) to verify the machining of a workpiece as well as the geometry upon completion using a three-dimensional model. This simulation helps users estimate the time required for machining as well as confirm whether there are any burrs due to a missing machining process.

Users can take advantage of the machine simulation (Fig. 4) to verify the axial movement of machine parts using a three-dimensional model. This simulation helps users check for any machine interference between the parts, parts and tools, or tools and workpieces. The machine simulation even provides a warning and stop function in the event of any interference.

These simulations provide a tool for users to safely and quickly verify the machining program operations as well as check and correct the parameter settings virtually without every running the actual CNC machine.

2.3 Machining analysis simulations

Machining analysis simulations displays a color map distinguishing differences in machining by color, whether the position and speed along small segments or the acceleration rate. These color maps make it easy for users to visually identify any sudden changes. The simulations also link each segment of geometry with the relevant program block so that users can identify which block of the machining program corresponds to a geometry path.

Users can take advantage of machining analysis simulation results to visually identify minute changes in geometry, analyze the cause of subtle surface damage in the machining, or revise machining programs.

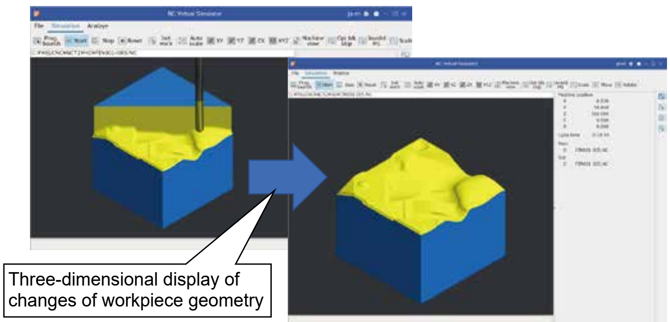


Fig. 3 Workpiece simulation

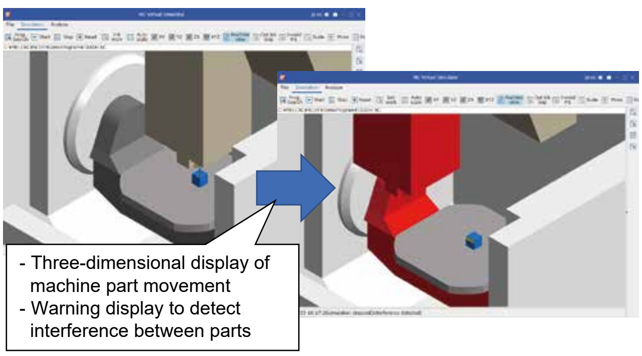


Fig. 4 Machine simulation

2.3.1 Color map display

The color map from a machining analysis simulation (Fig. 5) isolates and displays the speed, acceleration rate, and other values using 256 different colors.

For example, users can use these color maps to easily identify neighboring paths with different acceleration rates. This provides visual results to check and correct any issues in the machining program for those corresponding areas (tiny level discrepancies, differences in neighboring machining paths, etc.)

Users can also highlight values within a specific range to check and modify the values of parameters for any speed or acceleration rate outside of the tolerance range.

2.3.2 Program link display

The NC Virtual Simulator can also add data to link the machining program blocks to the command position data generated by the NC to display the block corresponding to specific geometry by clicking the path displayed on the 3D model (Fig. 6).

This lets users easily check the corresponding block of problem paths found in the color map described in 2.3.1 to correct in the machining program.

2.4 Toggle function to prioritize speed or accuracy

As described in 2.3, the NC Virtual Simulator is unique for its ability to accurately reproduce operations of real CNC machines. However, in some cases, users may need an easy way to quickly check for any issues in the geometry of the completed workpiece (burrs due to missing machining processes) or for mechanical interference.

To do this, users can select a mode prioritizing simulation speed that does not replicate all of the command positions output by the NC but rather narrows down those that are within the tolerance range to enhance the simulation speed.

Users can take advantage of the mode prioritizing speed to first deal with missing machining processes, mechanical interference, and other major issues before using the mode prioritizing accuracy to eliminate tiny machining flaws.

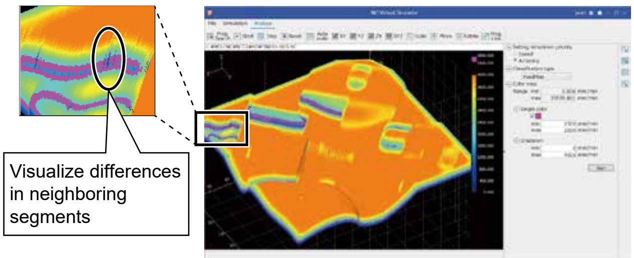


Fig. 5 Color map display

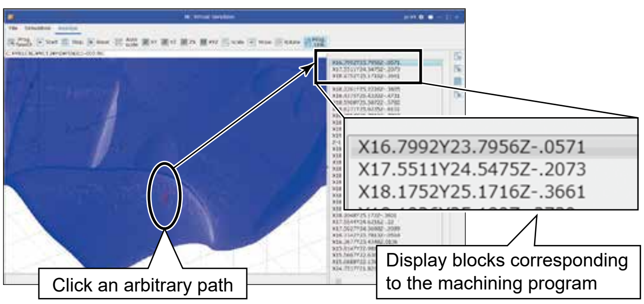


Fig. 6 Program link display

2.5 Links to NC Trainer2 plus

Mitsubishi Electric is in development of a function that will provide a link to the NC Trainer2 plus, which is an existing Mitsubishi Electric application used as a tool for machining operation training, the creation of ladder circuits of machine manufacturers, and development of customized screens (Fig. 7). This specific framework will enable users to run simulations by linking the operations executed in NC Trainer2 plus with the NC Virtual Simulator.

For example, this cross-software compatibility lets designers of machine manufacturers use NC Virtual Simulator to check for any interference while verifying the operation of a workpiece when developing a ladder circuit.

3. Conclusion

This paper has described the features of the NC Virtual Simulator developed as a tool to closely reproduce machining processes of NC machining tools in a virtual space to discover machining flaws and programming mistakes earlier in the design stage that are typically only found during a trial run. These simulations contribute to greater productivity on machining sites. Mitsubishi Electric will continue to consider various market needs and drive forward product development that provides even higher user value in a way that contributes to a better digital transformation of manufacturing businesses for a greater shift to smart factories.

Reference

(1) Fujita. T., et al. : Development of Machine Tool Digital Twin based on FA-IT Integrated Solution, Japan Society of Mechanical Engineers, Vol. 124, No. 1231, pp. 22-25, 2021

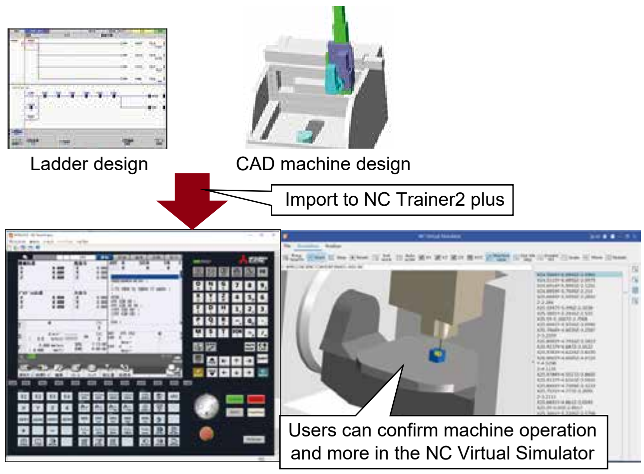


Fig. 7 Function to link to NC Trainer2 plus

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