Easy-to-Use AI-enabled Recorders and PLCs

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Yokogawa has a solid track record in AI analysis based on its experience and knowledge of industrial automation (IA). To meet customers' needs for introducing easy-to-use AI functionality to manufacturing sites and product development, we have incorporated AI functionality based on our advanced AI technology into recorders and programmable logic controllers (PLCs).

The AI future pen function, which predicts and draws data in the future, is implemented in the GX/GP series as standard. The AI anomaly detection function, which automatically detects unusual equipment behavior that could indicate trouble and enables users to perform predictive maintenance, is built into the GA10 software as standard for use with Sushi Sensor. Furthermore, we have developed the e-RT3 Plus industrial AI platform, which enables users to efficiently develop AI applications by using various Python-based software libraries.

This paper explains these products and their development strategies and describes how AI applications are used on site and what values they deliver.

INTRODUCTION

In product development and manufacturing sites, there is a need to increase productivity and maximize profits while maintaining existing equipment with optimal costs. Strict quality requirements must be satisfied and advanced equipment maintenance must be carried out even as production equipment ages and skilled workers retire.

In recent years, AI and analysis tools have been attracting much attention as a way to solve these problems.

Based on its extensive domain knowledge accumulated in various fields of industrial automation (IA) such as oil, chemicals, steel, food, and pharmaceuticals, Yokogawa has developed original AI technology for the IA business and has carried out many practical analyses [(1)-(9)]. These include consulting services using machine learning and other technologies in many plants, where we have accumulated extensive experience in predictive analysis of equipment abnormalities, root-cause analysis, and product quality predictive analysis. These advanced AI technologies have now evolved into a solution business in which we offer value-added consulting services to customers.

However, consulting services are time-consuming and costly, making it difficult to introduce AI into product development and manufacturing sites. Nevertheless, there is still demand for easy-to-use, AI-enabled products; customers want to try AI and incorporate it into their products.

Therefore, we incorporated our advanced AI technologies into existing products that are already widely used in product development and manufacturing, thus bringing AI to diverse

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fields ranging from consulting to the workplace. This paper introduces these AI-enabled products.

PRODUCTS TO BE AI-ENABLED

In product development and manufacturing sites, there is a need to improve productivity and maximize profits while maintaining existing equipment with optimal costs. Customers therefore want to introduce easy-to-use AI-enabled products, which overcome the following three challenges.

(1) Ensure product quality: predict the trend of product quality, detect the possibility of problems in the field, and help operators to make appropriate decisions and actions.
(2) Enable advanced equipment maintenance: detect signs of unusual behavior in equipment to prevent shutdown and production stoppages.
(3) Enable customers to develop their own AI functions: provide an environment that allows customers to add AI functions to their own products and equipment.

To meet these challenges, we developed easy-to-use AI functions and incorporated them in our existing recorders, data logging software, and controllers, all of which are widely used in product development and manufacturing sites. Regarding Challenge 1, we added the AI Future Pen and Future Alarm functions to the SMARTDAC+ GX/GP series paperless recorders. Based on the collected data, these proprietary functions can draw predictive waveforms in real time and issue alarms. Regarding Challenge 2, we incorporated an original AI anomaly detection function into the GA10 data logging software. This function can detect signs of abnormality based on the collected equipment data. For Challenge 3, based on the e-RT3 Plus, we created an industrial AI platform that supports the Python programming language[i]. This platform allows customers to develop their own AI applications and improve productivity. These AI-enabled products are described in detail in the following sections.

SMARTDAC+ GX/GP SERIES PAPERLESS RECORDERS WITH AI FUTURE PEN

Recorders are common devices in the field, so we made them AI-enabled to allow AI to be simply used in the field. Specifically, we developed the AI Future Pen function and added it to the latest SMARTDAC+ GX/GP series paperless recorders.

The GX/GP series come with excellent features; the touchscreen interface is easy to use just like portable information terminals, and the modular structure allows the system to be configured flexibly and expanded. The panel-mounted GX series is mainly used for process monitoring, while the portable GP series is used for test and measurement (Figure 1).

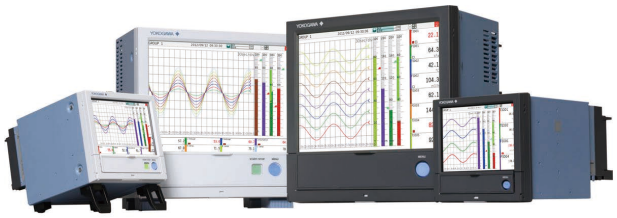

Figure 1 External view of the SMARTDAC+ GX/GP series paperless recorders

Recorders are typically used to record and retrieve measured data in real time. In 1950, Yokogawa released Japan's first electron-tube-type self-balancing recorder called the ER. Since then the company has led the industry for 70 years by releasing recorders that incorporated the latest technologies such as microprocessors, memories, and networking, culminating in the GX/GP series recorders. While retaining their reliability and functionality, we made the GX/GP series recorders AI-enabled by adding the AI Future Pen and Future Alarm functions as standard. These functions are explained in the following sections.

AI Future Pen

In addition to their main role, recorders often work as a monitoring device to detect changes in trend. Operators in the field look at the displayed trend waveforms up to the present and intuitively predict the state in the near future.

Like human operators, AI Future Pen predicts the near future based on the data up to the present and extrapolates the current waveforms into the future. Table 1 shows its specifications and Figure 2 shows an example of the screen.

Table 1 Specifications of AI Future Pen for GX/GP series

Item	Specifications
Max. number of channels	10
Prediction range	Recording period × 60 points (e.g., up to 30 minutes ahead in 30-second cycles)
Recording cycle	Valid for 1 second or longer

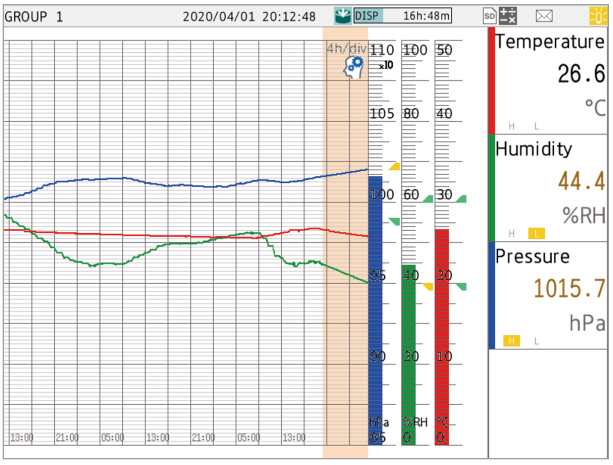

Figure 2 Trend screen of AI Future Pen (waveforms in the orange area are predicted)

i A general-purpose programming language that is widely used in AI development. Python is designed to be easy to use. It can be used to code a variety of programs in fewer lines. It has various open source libraries that are useful for developing AI applications such as machine learning.

A simple linear model is used as an algorithm for predicting the future. Gaussian white noise (normally distributed noise with equal intensity at all frequencies) is assumed to be contained in measurement values. Based on time-series changes in the measurements, machine learning is applied to the latest measurements sequentially to estimate plausible states (value and slope). Since a linear model is used, the future waveform is also linear with a plausible slope (Figure 3). Therefore, AI Future Pen is suitable for predicting linear phenomena that vary slowly, not for nonlinear phenomena that fluctuate sharply.

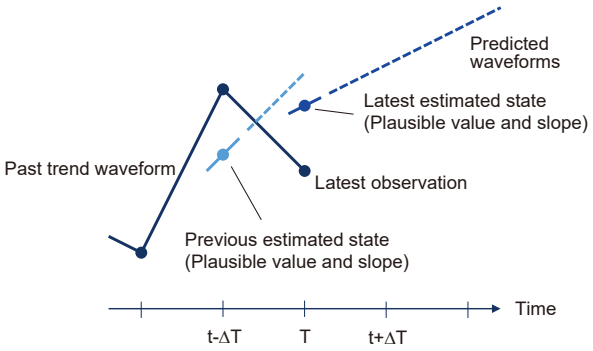

Figure 3 State estimation using a linear model

Future Alarm Function

When the waveform predicted by AI Future Pen reaches the predetermined upper or lower alarm limit, the Future Alarm function displays a warning on the screen. Possible alarms are listed on the summary screen (Figure 4). In addition, the form of alarm can be set as a contact output or email notification. This means that field operators do not need to continuously monitor the trend waveform displayed by AI Future Pen on the screen; they can see possible problems at a glance and deal with them in advance.

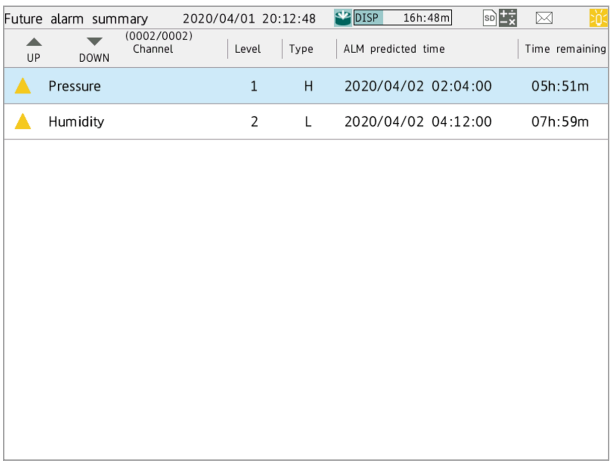

Figure 4 Screen of the Future Alarm Summary

GA10 DATA LOGGING SOFTWARE WITH AI ANOMALY DETECTION FUNCTION

A likely application for the Industrial Internet of Things (IoT) is predictive maintenance of plant equipment. Appropriate maintenance work can be performed in a timely manner through a trend analysis with time-series data obtained from a large number of measurement points [10].

Yokogawa's GA10 is handy software for collecting data from numerous measurement points and monitoring the condition. This software communicates with a variety of equipment (recorders and data loggers) distributed in factories and premises via a network. To make it easier to perform predictive maintenance, an AI anomaly detection function was added to the GA10 as standard. An anomaly is a sign of unusual behavior of equipment whose state is shifting from normal to abnormal. The AI anomaly detection function detects this transition.

AI Anomaly Detection Function

It is relatively easy to import measurement data from IoT sensors mounted on equipment into the GA10 and monitor the trend. However, it is not easy to determine whether the trend indicates abnormalities or not. Temperature and pressure can be relatively easily handled; when these parameters go beyond upper or lower limits, it is likely to mean an abnormality. However, this is not always applicable to vibrations of rotating machines. When it is difficult to determine the state simply by setting a threshold value, monitoring depends largely on the skills of individual workers, who monitor the trend of data and determine any signs of abnormality based on their expertise and other factors.

The AI function in the GA10 detects anomalies in target equipment on behalf of skilled workers, determines the state, and indicates it on the monitoring screen (Figure 5). This function reduces the monitoring workload of skilled workers and helps non-skilled workers to detect signs of abnormality.

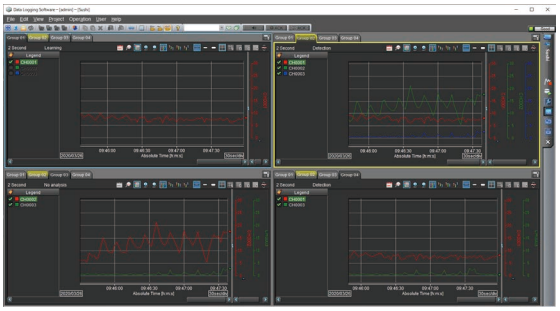

Figure 5 AI anomaly detection screen
(The orange frame at top right shows equipment with an anomaly.)

As a machine learning algorithm for this function, we used a clustering algorithm, which first learns data on normal states as a baseline, checks whether the current state is close to the baseline dataset or not, and if it is not, the algorithm

determines the state as unusual (anomaly). There is no need to learn data on abnormalities in advance. This means that even if such data are not available, signs can be detected immediately.

Application to Industrial IoT Sensors

Yokogawa has developed the Sushi Sensor, a wireless solution for the industrial IoT that monitors the trend of equipment condition. This Sushi Sensor uses the LoRaWAN® standard, which is one of the low power wide area (LPWA) wireless communication protocols, to measure the vibration, temperature and pressure of plant equipment. The measured data are sent to the cloud or on-premises servers via a gateway. The data are used for preliminary diagnosis of the trend of the equipment condition [11][12].

The GA10 software is already used as a viewer for the on-premises operation of the Sushi Sensor. With the AI anomaly detection function, the GA10 can detect signs of equipment failure, and achieve a simple, easy maintenance to approach to condition-based maintenance (CBM), which is one of the expected benefits of Sushi Sensor (Figure 6).

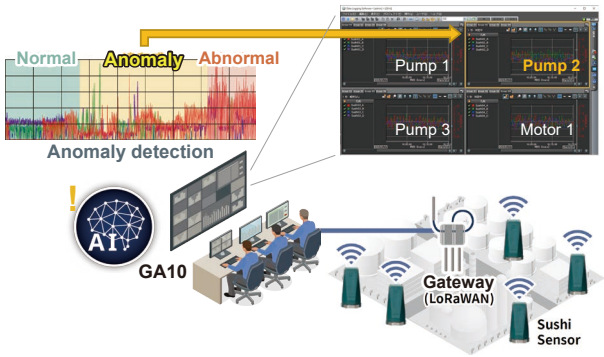

Figure 6 Configuration of the Sushi Sensor AI anomaly detection

Although the GA10 detects signs of abnormality (i.e. an unusual state), these are not always actual abnormalities or failures. If data on both normal states and abnormalities are available for learning in advance, more accurate judgments can be made. However, it is difficult to obtain data on abnormalities in advance at the initial stage of data analysis in an actual plant [7]. The algorithm of the AI anomaly detection function can detect anomalies in equipment even if there are no such data available.

This function makes it possible to detect unusual conditions among numerous equipment in the plant and automatically identify the equipment that requires closer monitoring. In this way, the AI anomaly detection function in the GA10 offers an easy, effective step to CBM.

e-RT3 PLUS INDUSTRIAL AI PLATFORM SUPPORTING PYTHON

Conventionally, industrial equipment is controlled by programmable logic controllers (PLC) with a program developed in a language such as IEC 61131-3. In recent years, however, there is an increasing need to incorporate functions other than the control logic and to satisfy customers' new development approach (shifting from making things, to how best to use and combine them). In 2015, Yokogawa released the e-RT3 Plus for the Japanese market. The e-RT3 Plus is a C/C++ language programming controller running on the Linux OS with more than 90 open source software (OSS) programs pre-installed. Since it enables efficient development, the e-RT3 Plus has been widely used as an edge computing platform for developing various manufacturing equipment and facilities [13].

Meanwhile, a standard programming language for developing AI applications is Python, which comes with a wealth of libraries for data analysis and machine learning. However, there is another issue involved in developing AI functions: since developed AI components are eventually incorporated into industrial equipment, their environmental resistance and stability must be considered, in addition to usage and service life.

Therefore, along with the global release of the e-RT3 Plus, Yokogawa has developed the F3RP70-2L, a CPU module that supports Ubuntu, a common Linux distribution. This module enables the e-RT3 Plus to support Python and use its libraries (Figure 7). The e-RT3 Plus has now become an industrial AI platform worldwide for efficiently developing applications using Python and OSS.

Figure 7 External view of the e-RT3 Plus industrial AI platform

Developing AI Applications

The hardware specifications of the newly developed F3RP70-2L CPU module are the same as those of the existing F3RP71-2L. The new module becomes AI-enabled simply by inserting an SDHC card containing the Linux (Ubuntu) image file. This file is available on Yokogawa's website.

The file contains Python libraries. Therefore, engineers can quickly start programming AI applications including machine learning. In addition, it is possible to add any applications and Python libraries by executing package management commands (apt, pip3, and so on).

Configuring I/O modules is time-consuming for IT engineers, so the new F3RP70-2L module comes with a function to facilitate this task for major I/O modules. Simply by editing a JavaScript Object Notation (JSON) format file, IT engineers can easily configure I/O modules and concentrate

on developing AI applications.

Incorporating AI Applications

It is difficult to determine whether using AI will yield the expected results such as better productivity and efficiency. Therefore, the proof of concept (PoC) process is repeated in the development process to verify the feasibility. In many cases, inexpensive single-board computers are used for this task, but this is a problem for final products, which must satisfy the requirements of environmental resistance and stable supply in addition to desired functions. Therefore, the e-RT3 Plus is an ideal AI platform because it has excellent environmental resistance, stable supply, and a solid track record in actual use, and so can be incorporated in products. In addition to AI applications developed through the PoC process, the integration of the e-RT3 Plus AI platform with various inputs and outputs makes the target device highly sophisticated (Figure 8).

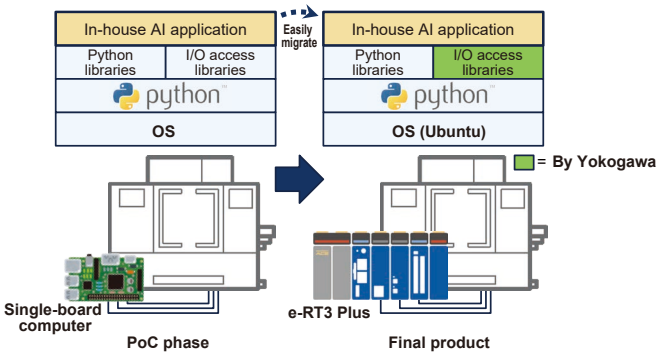

Figure 8 Incorporating into final products

Multi-CPU configuration is also possible. The e-RT3 Plus and a sequence CPU module of Yokogawa's FA-M3 series PLC can share roles; the sequence CPU module performs device control that requires high speed while the AI application of the e-RT3 Plus is responsible for advanced AI judgment (Figure 9). This allows IT engineers to focus on developing AI applications and operational technology (OT) engineers to concentrate on developing device control. After the completion of each development phase, IT and OT can be integrated in a single e-RT3 Plus.

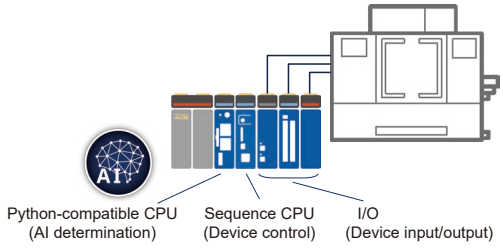

Figure 9 IT/OT integration in the e-RT3 multi-CPU configuration

BENEFITS OF INTRODUCING AI-ENABLED PRODUCTS

As stated earlier, in product development and manufacturing sites, there is a need to increase productivity and maximize profits while maintaining existing equipment at optimal costs. The following benefits are expected by introducing the AI-enabled products described in this paper.

(1) Ensuring product quality

By measuring environmental parameters such as temperature and humidity and monitoring utility consumption and remaining tank capacity, it is possible to index and predict product quality, or check for possible problems which may trigger an alarm by a certain time in the future. As a result, countermeasures can be taken in advance, ensuring stable production.

(2) Detecting signs of equipment abnormalities

It is possible to detect signs of abnormality in various equipment that would otherwise result in plant shutdown. Proper preventive maintenance can then be performed before abnormalities occur, minimizing the impact on production and improving availability rates.

(3) Enabling customers to develop their own AI applications

Customers can use various Python-based software libraries to develop and implement their own AI applications, greatly reducing the development period. Because the e-RT3 Plus has excellent environmental resistance, this industrial AI platform is expected to deliver the same performance both in development labs under controlled conditions and at manufacturing sites under harsh conditions. Seamless development and implementation enhance the construction of AI systems.

We expect the developed AI-enabled products to be effective for monitoring and recording various signals such as voltage, current, temperature, flow rate, and pressure. These applications include environmental monitoring and equipment management in a wide range of industries; performance evaluation tests in product development and production processes; and safety and reliability evaluation tests in the quality inspection process.

CONCLUSION

There is a need to use AI-enabled products (mainly, recorders and PLCs) in product development and manufacturing sites. This paper described how to develop such products, how to implement them in the field, and the values provided by AI. Yokogawa has released various products that are widely used in the field. We will continue making them AI-enabled to offer new value to customers.

Yokogawa believes that the use of AI is not limited to detecting abnormalities in equipment by using machine learning or other techniques but extending to the control for ensuring product quality and preventing abnormalities before they occur. We have already been working on this challenge toward practical use [14].

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