Edge AI Unit, MR100

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Abstract

Since the 1990s, we have been supplying industrial controllers to semiconductor manufacturing companies. Due to recent technological developments in the field of Internet of Things (IoT) and Artificial Intelligence (AI), manufacturing industries call for the introduction of "predictive maintenance."

Under predictive maintenance, the service provider monitors the machineries or facilities during normal operations; if there are potential warning signs (any symptom of fault or failure), it will inspect, repair, or replace, faulty parts.

Unlike the "preventive maintenance" that conducts scheduled maintenance (inspecting, repairing, or replacing parts and components at a predetermined points), predictive maintenance can make efficient replacements of parts and components.

For the purpose of predictive maintenance, we developed the Edge AI Unit, MR100.

1 Preface

To perform "predictive maintenance" to semiconductor manufacturing equipment and various automatic machines, we developed the Edge Artificial Intelligence (AI) Unit, MR100. We installed the RZ/T1 Series embedded processor by Renesas Electronics Corporation. The MR100 is a device using Edge AI (AI algorithms on a hardware device) that collects sensor data from equipment with a sensor device which detects the equipment anomaly based on the collected data.

A feature of the MR100 is that it can be retrofitted to equipment for measuring and it can decide locally based on the machine learning results without connecting to the external networks such as the cloud. In the semiconductor industry, they demand that repair and inspection service providers help prolong the operational life of used semiconductor manufacturing equipment. For this reason, this unit is appropriate for predictive maintenance. In the semiconductor industry, sending device production information to external networks like the cloud is prohibited. The MR100 can start AI learning once the customer prepares a PC running Windows OS and connects it to the MR100. We can expect many similar applications in the semiconductor industry.

2 Outline of the MR100

2.1 Independent Decision Making Based on AI Learning

Fig. 1 shows connections between the MR100 and equipment. In order for the MR100 to perform an AI-based decision, it is necessary to "learn" the specific unique feature of sensor data from that equipment through the setup process. Since there are many algorithms/techniques needed for AI learning, the MR100 uses an "auto-encoder" unsupervised learning technique for Neural Networks (NNs) and the auto-encoder mechanically detects

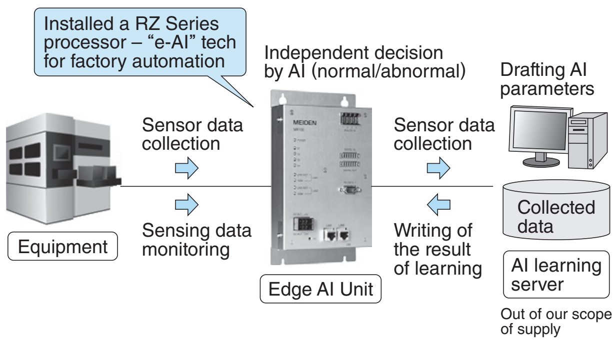


Fig. 1 Connections between the MR100 and Equipment

The relationship in connections between the MR100 and equipment is shown.

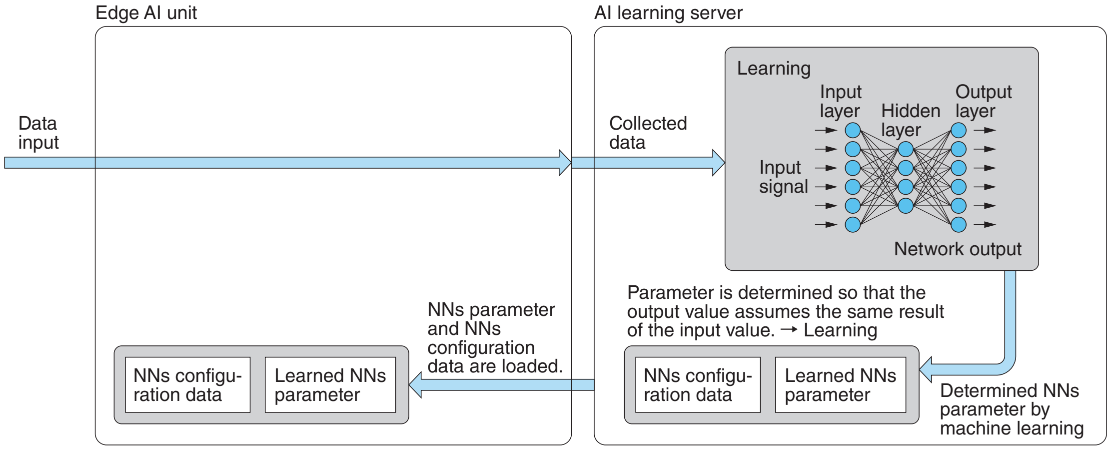


Fig. 2 Method of AI Learning

The method of AI learning is shown for an Edge AI unit and AI learning server.

and learns the regularity in the collected sensor data and then applies the learned results into the anomaly detection.

Currently, the semiconductor manufacturing industry anomaly detection of equipment is made through a system called the Fault Detection and Classification (FDC) system. The FDC is a statistical analysis on sensor data from the equipment. Since professional knowledge like statistical analysis is needed for the FDC, predictive maintenance for equipment faces the issues of different levels of anomaly detection due to different skill levels of each analyst. Meanwhile, predictive maintenance by the MR100 is made by AI-based decision making, and as such, the data analyst does not require such professional knowledge as a statistical analysis. Fig. 2 shows the method of AI learning. The data collected by the MR100 is transferred to the AI learning server where the AI learning parameters are established based on the data gathered with a help of the AI learning program. Fig. 3 shows the AI learning parameters. The AI decision is made possible by simple loading the sensor data onto the MR100. After the data loading operation, the MR100 can be operated locally without connecting to the AI learning server. The MR100 identifies the deviation between the AI learned sound data waveform and the just uploaded sensor data waveform; if the deviation level exceeds the pre-determined values (deviation value deemed to be anomaly), the MR100 will detect and determine it as an anomaly. Such a specified value is set up according to the level of expertise of the user by drawing on the experiences of the facility management. The AI learning program

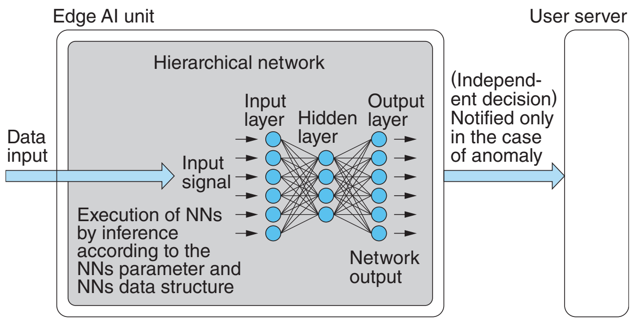


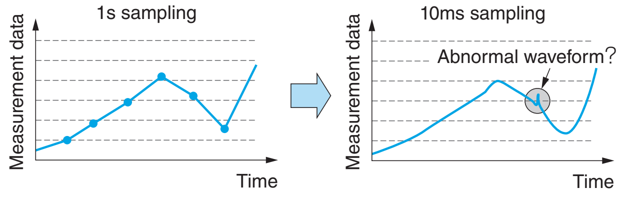
Fig. 3 AI Learning Parameters

This shows a concept of AI learning parameters which are drafted on the data collected by using the AI learning program.

is also made by the user by using the machine learning framework (libraries), like “TensorFlow” or “Caffe.”

2.2 Data Processing by the Edge Computing

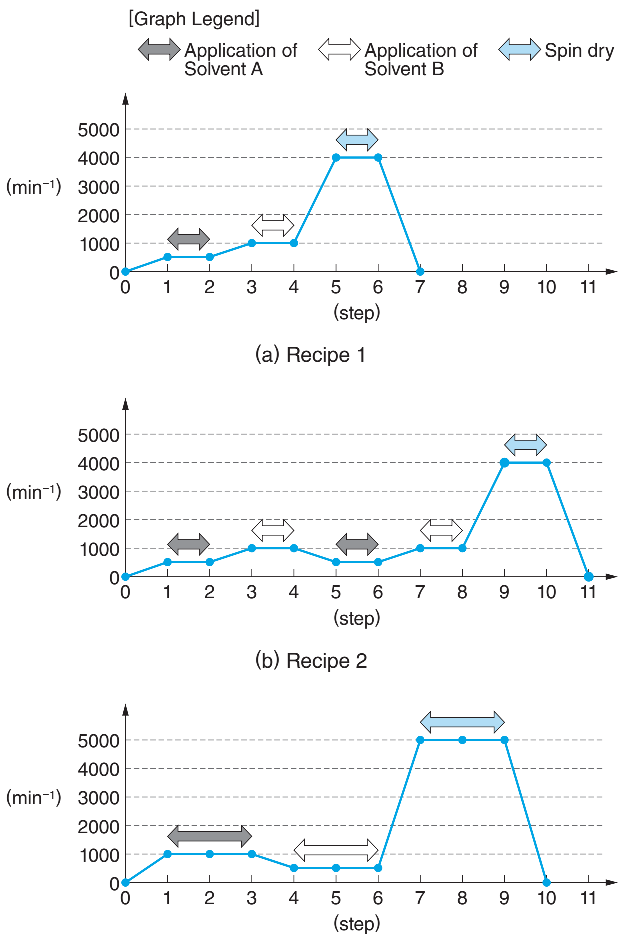
Since the MR100 is installed with μITRON-a real-time OS for embedded systems, it can collect sensor data at much higher speed than other general-purpose OSes. Fig. 4 shows the difference in data collection. By virtue of high-speed sensor data collection, it is possible to capture previously omitted waveforms due to the slow speed of the conventional model. This model can detect an anomaly in more highly accurate manner. Since the MR100 can locally detect an anomaly in the sensor data by AI decision, it can upload the result to the upstream IT System only when such anomaly is detected. Thanks to this edge computing, the network load can be reduced in comparison with a



(a) Conventional data collection (b) High-speed data collection

Fig. 4 Difference in Data Collection

A difference is shown between former data collection and high-speed data collection by the MR100. Thanks to the high-speed data collection, it is now possible to capture previously omitted waveforms.



(a) Recipe 1

(b) Recipe 2

(c) Recipe 3

Fig. 5 Difference in Semiconductor Manufacturing Equipment

The difference in semiconductor manufacturing equipment is shown with sample patterns.

previous system performing the AI decision at an upstream IT system. Since the networks are connected with various IT devices and communication units, the heavy network load can substantially affect the production volume.

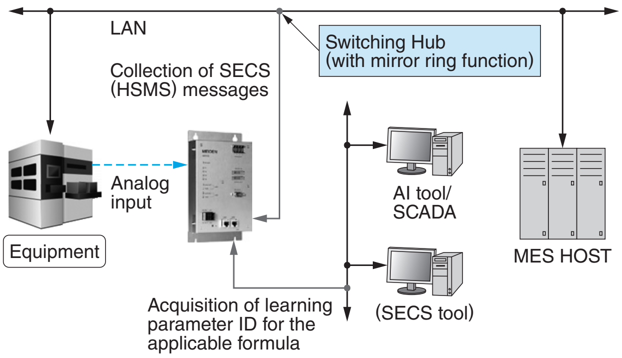


Fig. 6 Communications Network in Semiconductor Manufacturing Plant

Communications network and positioning of the MR100 in semiconductor manufacturing factory are shown.

2.3 Conformity to SEMI Equipment Communications Standard (SECS)

Fig. 5 shows the difference in semiconductor manufacturing equipment. The semiconductor manufacturing equipment performs different controls according to the type of a product being manufactured, even if the same process chamber※1 is used. Since the control patterns (such as quantity and timing) are different every time, multiple learning parameters are needed that have learned the sensor data for the execution of each particular formula※2. These multiple learning parameters must be used properly according to the characteristic of the execution formula. Fig. 6 shows a communications network in a semiconductor manufacturing plant. While the MR100 monitors the SECS communication messages between semiconductor manufacturing equipment and the MES HOST, the MR100 decides the execution recipe at the given process chamber in the semiconductor manufacturing equipment, and automatically switches the learning parameters applicable to the formula.

2.4 Method of Management

Before use, various settings are required for the MR100 in order to determine where and how the MR100 collects the sensor data and where the result of the decision on the collected data is alerted. In the case of the MR100, communication interface specifications are disclosed to our product customers and setup software is prepared/procured by the customers. Fig. 7 shows an image of MR100 setup software and Fig. 8 shows that of the data notifications. By setting up various operating conditions in advance, it is also possible to notify of the

Fig. 7 **Image of MR100 Setup Software**

An image of MR100 setup software is shown.

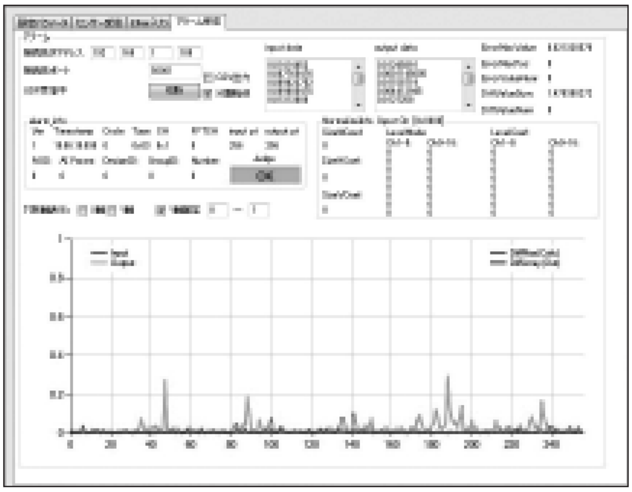


Fig. 8 **Image of Data Notifications**

Data notifications for the MR100 in its normal state are shown.

Table 1 **MR100 Specifications**

A list of MR100 Specifications is shown.

Item		Specifications
MPU		RZ/T1 Main CPU: ARM Cortex-R4F (600MHz)
NOR Flash Memory		128MB (512Mbit × 2)
SDRAM		128MB (512Mbit × 2)
EEPROM		16kB
SPI Flash		64MB
Various interfaces	Analog Input (AI)	8ch (Single end: 8ch/ Differential: 4ch) ※Input voltage: ±12V
	Digital Input (DI)	4ch ※Rated input voltage: DC24V
	Digital Output (DO)	4ch ※Rated output voltage: DC24V
	Serial port (RS-232C) Transfer rate:115.2kbps (Max.)	2ch
	LAN (100BASE-TX)	3 ports
	LED	Power source LED (Green), general-purpose LED × 4, LED for LAN (LINK/ACT, SPEED)
	DC 24V source	6pin
	USB host (USB2.0)	1 port
	DIP switch	8bit × 1
Dimensions		W140 × H200 × D47mm
Mass		Approx. 1kg
Working temperature		0～45℃
Working humidity		30～85%Rh (without dew condensation)
Environment		Freedom from corrosive gases and/or conductive dust
Cooling system		Natural air cooling
Applicable standard		Nil
RoHS		RoHS-compliant

anomaly detection only if it occurs, or if the occurrence of a fault together with data is during normal operation.

3 MR100 Hardware (H/W) Specifications

Table 1 shows the MR100 specifications. As an input interface for the sensor data, an analog input port is provided that consists of 8 channels for single end inputs. The sampling speed is set up to 50μs. If any anomaly is detected in the sensor data, an error alarm signal is generated and transmitted via the Ethernet or digital output port to external equipment. A USB 2.0 interface is located in the base section of this unit so that the sensor data can be saved by using a USB device. For better user interface, major interfaces are put together on the front panel of this unit. The dimensions and mass are W140 × H200 × D47mm (protruded parts excluded) and 1kg respectively. It is an easy-to-manage size. For installation, a dedicated mounting metal fitting is provided for easy fitting for the DIN Rail Mounting.

4 Postscript

According to a trial calculation by a research company in Japan, the AI markets for Japanese manufacturing industry are estimated to become 1 trillion yen in 2021. As such, we intend to offer a one-stop service in order to support our customers from the early Edge AI Unit introduction study stage unit to a stage where our products are being used for their mass production operations. At the introduction study stage of our potential user, we will lease an MR100 starter kit that contains a MR100 unit, a set of acceleration sensor and trial version software (a setup software and an AI learning program) so that the potential user can test drive if our MR100 can fit with their manufacturing equipment. We supplied our past industrial controllers mostly for semiconductor manufacturing equipment. We will develop the sales of the MR100 mostly for semiconductor manufacturing equipment. By drawing on our accumulated expertise, we will develop the sales of the MR100 into non-semiconductor manufacturing equipment like various automation equipment. We will work on improving the functions of the MR100.

(Notes)

※1. Chamber: A hermetically sealed vessel where chemical or physical reactions are caused.
※2. Recipe: Inputting data to specify the processing method and parameters for the process at the manufacturing equipment.