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AI/Big Data Analysis Platform in JFE Engineering

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Abstract:

JFE Engineering launched a remote plant monitoring and operation system in 2014, and opened GRC (Global Remote Center) in March 2018. In November 2018, a platform for data analysis was released for internal use to create an environment for utilizing AI and big data. In this article, we will introduce the functions of the platform and examples of AI/big data usage at our company.

1. Introduction

The core business of JFE Engineering Corporation is plant construction. The main products of the company include waste-to-energy (WtE) power plants, biomass power plants, LNG plants and bridges. Among these products, privatization of the operation of WtE power plants is progressing, and there is an increasing trend toward DBO (Design, Build and Operate) projects, in which companies present unified bids that include both plant construction and operation.

When performing plant operation, JFE Engineering prioritizes efficiency and stability, as price-competitive plant operation is possible by improving efficiency and stability.

In these circumstances, the company has made the following efforts related to AI and big data.

- Opening the Global Remote Center (GRC) in March 2018 to conduct remote monitoring and remote operation of plants
- Release of the data analysis platform Pla'cello™ in November 2018

Thus, JFE Engineering is continuing to improve its system for faster realization of efficiency and stability in plant operation by analyzing the large volumes of data which plants possess.

This paper introduces efforts related to AI and big data at JFE Engineering.

Chapter 2, entitled "Remote Monitoring and Remote Operation of Plants," introduces remote monitoring and operation by the GRC.

Chapter 3, "Data Analysis Platform," describes the functions and merits of introduction of Pla'cello, which was developed by JFE Engineering.

Chapter 4, "Introduction of AI in WtE Power Plant," presents examples of AI-related products of JFE Engineering in the WtE power plant field.

2. Remote Monitoring and Remote Operation of Plants

The GRC, which JFE Engineering opened in March 2018, collects plant operating and running data and provides remote monitoring and remote operation services via a network using secure, large-volume high-speed optical lines.

2.1 Overview of GRC

Photo 1 shows an inside view of the GRC. The GRC has equipment, including a large number of monitors, a TV conference system, headsets, *etc.*, for conducting remote monitoring and remote operation.

The desk layout in the GRC has a two-stage configuration consisting of a flat desk in front and a curved desk in the rear. The desk in front has seats for the operators who actually perform remote monitoring and remote operation, and a large number of monitors, headsets and other equipment are arranged so that the information necessary for remote monitoring and /

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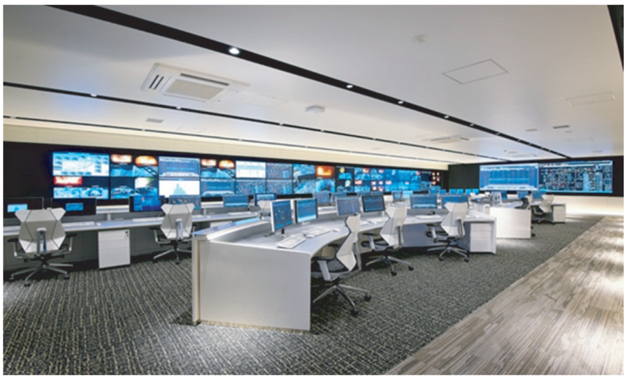

Photo 1 Inside view of Global Remote Center

operation can be provided smoothly to the operators. The desk in the rear has seats for plant design engineers, who conduct data analysis and perform operator support, and enables the design engineers to acquire necessary information in a concentrated manner.

As of December 2019, the GRC was conducting remote monitoring of 71 facilities. The Center has spare capacity for monitoring and operation of an increased number of facilities in the future, and plans to expand remote monitoring and remote operation to a total of 100 facilities within fiscal year 2020.

2.2 Transition of Remote Monitoring Service

The GRC introduced in section 2.1 passed through several stages before reaching its present form. This transition is outlined below.

- 2003: Start of remote maintenance service for monitoring and control devices
- 2014: Opening of Remote Service Center
  Start of remote monitoring and remote operation of WtE power plants
  Start of accumulation of plant running and operating data
- 2016: Plant data storage platform changed to cloud
- 2018: Opening of GRC, and expansion of objects of remote monitoring and remote operation to power plants, water treatment facilities and solar power generation facilities

In particular, accumulation of plant running and operating data, which began in 2014, was an epoch-making effort at the time, and as a result, this early start of data accumulation had a large impact on the construction of the data analysis platform described in Chapter 3.

2.3 Security Measures of GRC

In addition to remote operation of social infrastructure centering on WtE power plants, the GRC also stores running and operating data. Therefore, absolutely sure security measures have been implemented to prevent physical intrusion from outside, cyberattacks via the network, spoofing, *etc*. Some of these measures are described below.

2.3.1 "Physical" isolation from outside

Although the GRC is located in the JFE Engineering Yokohama Head Office, the building that houses the GRC is independent from the outside, and persons who have been approved in advance can only enter rooms in the GRC by passing through electronically-locked doors. The history of entry/egress is not only stored as a log in the security system, but is also recorded in video form, and the log and video records of entry/egress are checked periodically for discrepancies. As proof that security measures have been realized at a high level, the GRC has acquired CSMS (Cyber Security Management System) certification.

2.3.2 "Theoretical" isolation from outside

In addition to the physical isolation described above, the GRC is also a space which is theoretically isolated from the outside. The three external cloud platforms, that is, the plant, GRC and data storage platforms, are connected by a VPN (Virtual Private Network) and form an independent network which is also isolated from the company's intranet. Network traffic during connection with the outside is monitored by the SOC (Security Operation Center) and appropriate measures are taken, including instantly cutting off the network in case an anomaly is discovered.

3. Data Analysis Platform

JFE Engineering implemented a data analysis platform which can provide operational support utilizing AI based on the data accumulated by the GRC, and began operation of this platform in November 2018. Because the idea of "making plants smarter by an AI brain" is incorporated in this platform, the platform was christened "Pla'cello^{TM}," a coinage that combines

Fig. 1 Logomark of Pla'cello^{TM}

the English word "Plant" and the Italian "Cervello" (brain). The Pla'cello^{TM} logomark is shown in **Fig. 1**.

3.1 Basic Concept of Pla'cello^{TM}

Pla'cello was implemented based on the following concepts, assuming wide use in JFE Engineering.

3.1.1 Adoption of tools with excellent GUI features

It is generally said that data science requires a knowledge of the three regions of "information technology," "statistics" and "domain knowledge," that is, knowledge of a particular field. However, as illustrated in **Fig. 2**, many engineers in JFE Engineering have achieved a high level of competence in "domain knowledge" through actual plant construction and operation, but do not necessarily have an adequate knowledge of "information technology" or "statistics."

For this reason, data analysis-related tools with excellent GUI features were adopted in Pla'cello, enabling engineers without programming skills to use the platform.

3.1.2 Creation of user-friendly environment for time-series data

The most general type of data handled by JFE Engineering is time-series data generated by plants. Time-series data includes sensor data and state data, data on operation by operators and other types. As a distinctive feature of this data, the data cycle has a constant interval, and large numbers of data are collected and stored simultaneously (**Fig. 3**). By independently developing a system that facilitates the handling of time-series data, the company created a platform which enables easy data analysis by its engineers.

3.1.3 Design prioritizing security

Since Pla'cello mainly handles data from infrastructure facilities that support society, the magnitude of the social impact in case of an information leak or other data-related problems was a concern. Therefore, careful attention was paid to the security design of the platform.

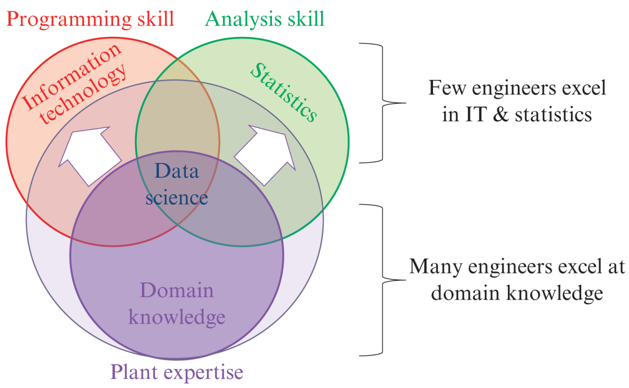

Fig. 2 Three elements required for data science

3.2 Basic Configuration of Pla'cello^{TM} Ver. 1

Figure 4 shows the basic configuration of Pla'cello Ver. 1. In Pla'cello, plant data are collected via the above-mentioned VPN circuit and stored in a cloud environment. New knowledge is obtained from this data by processing with an ETL (Extract Transform Load) tool, visualization and analysis by a BI (Business Intelligence) tool and machine learning by a ML (Machine Learning) tool. The following presents a brief description of each of the three tools (ETL, BI, ML) that are the constituent elements of Pla'cello Ver. 1.

3.2.1 Data processing by ETL tool

As its English name suggests, the ETL tool is a tool which extracts, transforms and loads data. Plant running data are used as the input data for the subsequent BI and ML stages. Because plant running data are difficult to use in their raw form, data processing is performed by ETL, and the raw data are transformed into a form which is easy to use in the following processes. Data processing is performed by batch processing, and

TimeStamp	PI105	PI106	PI107	PI108	PI109	PI110	PI111	PI112	PI113
2018/08/01 00:00	24.813	34.251	35.200	23.562	26.548	6.549	8.955	30.693	36.977
2018/08/01 00:10	24.827	34.265	35.204	23.561	26.554	6.548	8.828	30.830	36.980
2018/08/01 00:20	24.773	34.265	35.130	23.561	26.549	6.538	8.864	30.784	36.966
2018/08/01 00:30	24.800	34.265	35.155	23.562	26.545	6.528	8.888	30.830	36.984
2018/08/01 00:40	24.827	34.275	35.186	23.563	26.547	6.526	8.969	30.865	36.980
2018/08/01 00:50	24.867	34.261	35.169	23.568	26.551	6.526	9.021	30.648	36.997
2018/08/01 01:00	24.827	34.290	35.190	23.568	26.551	6.523	8.983	30.798	36.994
2018/08/01 01:10	24.880	34.272	35.176	23.565	26.548	6.517	9.049	30.847	37.026
2018/08/01 01:20	24.773	34.268	35.155	23.565	26.556	6.521	9.088	30.641	36.997
2018/08/01 01:30	24.800	34.275	35.162	23.563	26.558	6.524	9.126	30.763	36.990
2018/08/01 01:40	24.800	34.275	35.165	23.568	26.566	6.526	8.891	30.892	37.001
2018/08/01 01:50	24.880	34.268	35.169	23.566	26.566	6.526	8.773	30.718	36.963
2018/08/01 02:00	24.773	34.282	35.183	23.563	26.577	6.526	8.678	30.815	36.956
2018/08/01 02:10	24.827	34.297	35.186	23.561	26.586	6.526	8.640	30.910	36.952
2018/08/01 02:20	24.893	34.282	35.179	23.562	26.589	6.523	8.556	30.742	36.949
2018/08/01 02:30	24.867	34.275	35.172	23.558	26.580	6.523	8.580	30.753	36.956
2018/08/01 02:40	24.867	34.272	35.179	23.565	26.583	6.526	8.720	30.865	36.952
2018/08/01 02:50	24.880	34.293	35.186	23.565	26.583	6.527	8.661	30.767	36.970
2018/08/01 03:00	24.867	34.234	35.193	23.563	26.583	6.526	8.608	30.878	36.959
2018/08/01 03:10	24.840	34.265	35.204	23.566	26.590	6.527	8.731	30.808	36.956
2018/08/01 03:20	24.880	34.268	35.197	23.568	26.590	6.530	8.654	30.770	36.956
2018/08/01 03:30	24.893	34.279	35.193	23.566	26.612	6.535	8.731	30.830	36.963
2018/08/01 03:40	24.800	34.279	35.197	23.561	26.615	6.533	8.619	30.847	36.959
2018/08/01 03:50	24.813	34.261	35.204	23.565	26.615	6.538	8.731	30.791	36.966

Fig. 3 Example of time series data

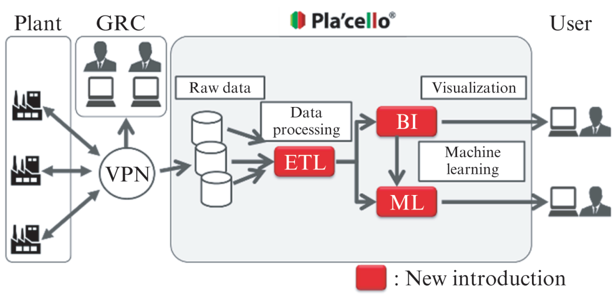

Fig. 4 System structure of Pla'cello^{TM} Ver. 1

the data are stored in cloud storage at periodic intervals.

In processing of time-series data, three types of data are generated:

- Raw data with only header processing
- Decimated data, such as minute-to-minute, hourly, and daily data, *etc*.
- Statistical data, such as maximum and minimum values, *etc*.

These data are used appropriately in the following processes according to the purpose of use.

3.2.2 Data analysis and visualization by BI tool

The BI tool is used in analysis and visualization of the data processed by the ETL tool. Many of the functions of the BI tool are similar to those of Excel and other spreadsheet programs. However, in comparison with spreadsheet programs, flexible analysis is easy with the BI tool, as data are narrowed down and replaced with visualized parts, and data linkage between the visualized parts is simple.

BI tools are almost essential tools in the process of data analysis and are used by many employees. However, as a result of a survey of the commercially-available tools in the market, no tool with an abundance of functions for handling time-series data was found. Therefore, JFE Engineering carried out customized development from its own point of view based on a commercial tool, and increased and strengthened the functions for handling time-series data.

Because one aim of this customized development was to provide a full lineup of visualization components, an environment that enables analysis and visualization of time-series data was implemented by adding the following visualization components to a commercial BI tool as add-ons.

- Time-series graph tool
- Scatter diagram tool
- Process flow visualization tool

3.2.3 Machine learning by ML tool

The ML tool is used to obtain new knowledge from the data which are the object of analysis by applying machine learning. Conventionally, machine learning was generally performed by writing a program in a programming language such as Python. However, in recent years, the popularization of ML tools that operate under a GUI environment has made it possible to realize machine learning without writing a complete program or by writing only a minimal program, and this has reduced barriers for performing machine learning.

From the viewpoint of a ML tool for handling time-series data, the company adopted a specialized ML tool for time-series anomaly sign detection. In combination with this, a ML tool which can perform general numerical data analysis was also adopted, and machine learning is conducted by using these two types of tool appropriately, according to the purpose.

3.3 Effects of Introduction of Pla'cello™

A variety of effects were obtained in JFE Engineering by introducing Pla'cello, as introduced below.

3.3.1 Time saving and cost reduction

The existence of Pla'cello as a standardized tool in JFE Engineering has greatly reduced the required time and cost when responding to projects.

At JFE Engineering, engineers who possess domain knowledge frequently perform data analysis in addition to their own essential work, and the selection of a tool, learning how to use the tool and the use of the tool itself were extremely time-consuming.

Standardizing those tools greatly reduced the time required to select and learn how to use tools. Moreover, cost reductions could also be achieved, since data analysis work that had been outsourced in the past can now be performed in-house.

3.3.2 Aggregation of project information

With the release of Pla'cello in JFE Engineering, company employees made many requests for AI and big data-related project information, and those items are promoted by simultaneous progress of the aggregation of project information and expansion of the range of that information by the following approach:

- For items with a high degree of technical difficulty, response exclusively by AI engineers who excel in data analysis.
- For items with a low degree of technical difficult, response by engineers in the user department with technical guidance by AI engineers.

3.3.3 Spontaneous use by users

Because a platform like Pla'cello exists in the company, the number of cases in which users themselves perform data analysis using tools has increased.

This kind of spontaneous use of tools in user departments was the intended mode of use when Pla'cello was implemented, but spontaneous use by users had been expected to take time. The background of this earlier-than-expected spontaneous use is thought to include several factors, including (1) heightened needs for data analysis in user departments, (2) good match between the tools provided and the needs of the user departments and (3) heightened knowledge among users as a result of education conducted in the user departments.

3.4 Pla’cello™ Ver. 2

Pla’cello Ver. 2 (**Fig. 5**) was released in December 2019, about 1 year after the release of Ver. 1 in November 2018. The following new functions and functional improvements were incorporated in Ver. 2, prioritizing improvement of functions that were inadequate in Ver. 1.

1) New introduction of application tools (application development)
2) Functional improvement of ML tool (new introduction of deep learning tool)
3) New introduction of data preparation tool
4) Functional improvement of BI tool (strengthening of customizing function)
5) Improvement of performance and stability of ETL tool

The following introduces the above items 1) to 3).

3.4.1 New introduction of application tool

The application tool (hereinafter, APP tool) means an application development environment. Because the BI tool includes a report function, an APP tool is not necessary in cases where the user interface within the range of the visualization function provided by the BI tool is sufficient. However, an APP tool is necessary in order to satisfy requests for functions such as

- Data input,
- Visualization which cannot be constructed with the BI tool, and
- Linkage with other applications.

As in the case of the above-mentioned ML tool, programming-less use of APP tools is also progressing, and the number of so-called “low coding application development” products is increasing. This company also selected one low coding application development product for addition to the Pla’cello lineup.

3.4.2 Functional improvement of ML tool (new introduction of deep learning tool)

Section 3.2.3 mentioned that two products were selected as ML tools for Pla’cello, but these were both ML tools for numerical data. After the release of Pla’cello Ver. 1, handling of image data other than plant time-series data increased rapidly, and it was necessary to introduce a ML tool capable of handling unstructured data such as voice, images, text, *etc*.

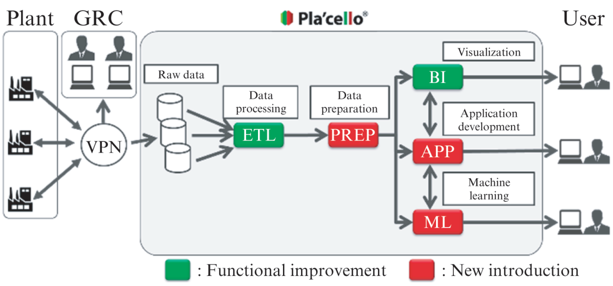

Fig. 5 System Structure of Pla’cello™ Ver. 2

As a ML tool for use with unstructured data, a deep learning tool that operates in a GUI environment was introduced. Although it has been pointed out that deep learning has the disadvantage of a black-box judgment logic, it is thought that deep learning generally has higher performance than white-box type models. Because deep learning can also be applied to numerical data, deep learning is used in this company by switching tools based on requirements such as the type of target data, the required accuracy, the accountability of the model and other considerations.

3.4.3 New introduction of data preparation tool

The data preparation tool (hereinafter PREP tool) is a tool for data processing, and its functions are similar to those of the ETL tool. While the ETL tool performs regular processing of all data input into the system, the PREP tool is different in that the target data are narrowed down and processing is carried out focusing on a certain purpose. Based on this characteristic, the ETL tool is used in the ICT department, and the PREP tool is used by user departments.

After the release of Pla’cello Ver. 1, there was increasing number of requests from user departments to the effect that “we want to do data conversion ourselves.” The PREP tool was added to the Pla’cello lineup in response to this need.

3.5 Future Outlook for Pla’cello™

In Pla’cello, it was generally possible to introduce the basic functions assumed at the time of planning by the development up to Ver. 2. As the future direction, we hope to realize functional improvements that further enhance the distinctive features of Pla’cello as an original data analysis platform of JFE Engineering. As concrete improvements, the following are assumed.

1) Connection with the in-company core system
2) Development of an optimization calculation engine
3) Development of a reinforcement learning engine
4) Product integration with in-company product groups

4. Introduction of AI in WtE Power Plant

As an example of operation support using AI, this chapter introduces “Introduction of AI in WtE Power Plant.”

4.1 Overview of Operation Support Using AI

As the main stream in the construction and operation of WtE power plants, conventionally, a local government consigned the construction of the plant to a private-sector company like JFE Engineering, and after completion, the plant was operated by the local government itself. However, with the progress of privatization in recent years, private companies have also contracted to operate plants after completion in an increasing number of cases. For two reasons, namely, to strengthen the company's competitiveness in order to undertake commissions for plant operation and to address the shortage of veteran plant operators, JFE Engineering is rapidly implementing a system that makes it possible to operate WtE plants with a minimum number of personnel. One means of realizing this is remote monitoring and remote operation from the GRC, as introduced previously in Chapter 2. In addition, the company recently began operation support using AI.

At JFE Engineering, operation support using AI mainly consists of the following two approaches:

1) Labor-saving in plant operation
2) Labor-saving in responding to inquiries

Of the above, 1) will be introduced in the following section.

4.2 Work Performed in Plant Operation

In operation of a WtE power plant, operators perform mainly two types of work.

4.2.1 Monitoring and operation of DCS

The first type of work performed by operators is monitoring and operation of the DCS (Distributed Control System). Although operation of a WtE power plant is normally performed by automatic operation, cases in which the automatic operation program is not adequate for sound plant operation may occur. In preparation for these cases, operators normally check that the WtE power plant as a whole is sound, and perform operation by manual intervention if some type of abnormality is detected.

4.2.2 Combustion image monitoring of incinerator

The second type of work performed is combustion image monitoring of the incinerator. Although the purpose of this monitoring is to confirm the soundness of the plant, as in the previous section, incinerator combustion image monitoring is necessary as method for detecting signs of abnormalities more quickly, as there is a cause-and-effect relationship between continuing incinerator combustion in an unsound condition and loss of the soundness of the total plant.

4.3 Improvement of Plant Operation

The previous section explained the two types of plant operation work performed by operators. Abnormal events occur in the following order:

1) Occurrence of a cause of combustion abnormality
2) Occurrence of a combustion abnormality (= possible to confirm abnormality by combustion image)
3) Abnormal combustion process (= possible to confirm abnormality by sensor)

Accordingly, abnormality detection from combustion images should be performed first, and an abnormality diagnosis of the combustion process including the result of abnormality detection should then be carried out.

4.4 Construction of Combustion Image Analysis System

JFE Engineering constructed a "Combustion Image Analysis System" in order to automate detection of combustion abnormalities and began actual operation in October 2018. As shown in **Fig. 6**, this is a system which makes image judgments of combustion images utilizing AI at a predetermined cycle and notifies the operator of the result of pattern classification of the combustion condition. The system has made a large contribution to reducing the load on operators and realizing automatic operation.

Although the Combustion Image Analysis System utilizes machine learning of images, the following issues arose in system implementation.

- A large number of images was necessary for the initial learning of the incinerator.
- Some deviation in the range of photography by the incinerator monitoring camera occurred as a

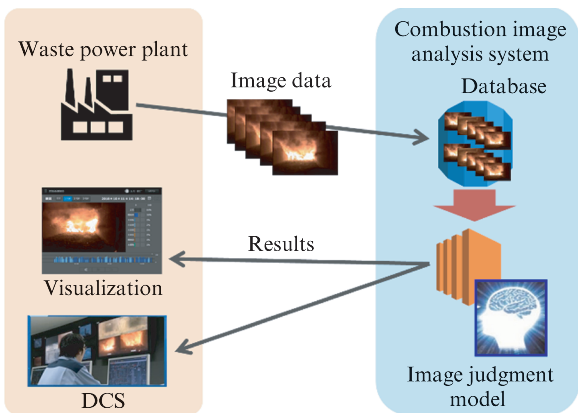

Fig. 6 System structure of Combustion Image Analysis System

result of inspections, *etc*.

These problems were solved by technical ingenuity.

5. Conclusion

As examples of the use of AI and big data in JFE Engineering, this paper introduced the Global Remote Center (GRC, Chapter 2), data analysis platform (Chapter 3) and an example of introduction of AI in a WtE power plant (Chapter 4).

For further strengthening of the security measures of the GRC introduced in Chapter 2, measures will be expanded to include not only the GRC itself but also the control system on the base side. Pla'cello, which was introduced in Chapter 3, is steadily accumulating actual results in the company in spite of the short time since completion, and is expected to make a substantial contribution to expansion of the AI-related work of the company in the future. In addition to continuing functional improvements such as improvement of the time series-related operability of Pla'cello and handling of short-cycle data, further dissemination of Pla'cello, including improvement of the training system and support system, *etc*. will also be promoted.

The policy of "labor-saving in plant operation" by utilization of AI introduced in Chapter 4 will not only strengthen the system of remote support for operation by incorporation in new WtE power plant projects in the future, but will also be developed horizontally to other types of plants, such as water treatment facilities and biomass power plants.

AI is a revolutionary technology which will change the current of the times, and that trend is also progressing in the construction industry. In the future, JFE Engineering will continue to respond proactively to this trend, and will work to achieve enhanced product competitiveness and operational efficiency by utilizing AI.