An Easy-to-Use and Customizable Data Science Tool for Predictive Maintenance in Manufacturing

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ABSTRACT

Even if many manufacturing companies have attempted to utilize data analytics for predictive maintenance but have not been able to do so. This is because predictive with data requires both knowledge of equipment in production site and knowledge of data science, and such workers are scarce. Another problem is that it takes time and effort to apply the created machine learning models on site and to develop applications for monitoring the diagnosis results.

Therefore, we developed "MELSOFT MaiLab". The application has an intuitive interface and functions to automatically create machine learning models, making it possible for workers with no knowledge of data science to easily create machine learning models for predictive maintenance. The application also has functions for deploying the created machine learning models to the production site and monitoring the diagnostic results.

1. BACKGROUND

In recent years, improvement of production sites with data analysis become more active. In particular, AI-based predictive maintenance is popular in the field of equipment maintenance.

On the other hand, there are few examples of actual manufacturing sites conducting data analysis and utilizing the analysis results. The main reasons for this are the lack of experts of data analysis. Therefore, there is a need for data analysis tools that can analyze data without data analysis knowledge.

When we asked our clients to identify their requirements for data analysis tools in the manufacturing industry, they responded that the following features were needed.

- Knowledge of data analysis not required
- Customizability

- Both tabular data and waveform data can be analyzed
- Easy to deploy models to production sites

Customizability can help increase accuracy if a user has unique expertise in data processing. As waveform data analysis is common in the manufacturing industry. Therefore, it is necessary to be able to analyze not only tabular data but also waveform data. The ability to deploy the model to a PC in production sites to perform diagnostics is important when real-time capability is required or when diagnostics need to be performed in an offline environment.

There are data analysis tools that have some of the above features.

H2O Driverless AI (H2O.ai, 2023) is an AI platform for automatic machine learning. The automated machine learning function allows users to create machine learning models without knowledge of data analysis and its custom recipes helps users to customize their machine learning models. On the other hand, it doesn't support waveform data analysis and model deployment.

RapidMiner (RapidMiner, 2023) is a data science platform which enables no-code development. The Auto Model function enables users to machine learning models without special knowledge and many kinds of operators including waveform data processing helps users to customize machine learning models. It also can deploy machine learning model to other machines. However, a database connection is needed to diagnose data with the deployed model and it has no function to feedback diagnosis result to control. This makes it difficult to deploy and use the model in production sites.

Thus, while there are tools that satisfy some of features needed for data analysis in the manufacturing industry, there are no tools that can satisfy all of them. Therefore, we developed "MELSOFT MaiLab", a data science tool for the manufacturing industry.

2. OVERVIEW OF MELSOFT MAILAB

MELSOFT MaiLab supports all three phases necessary to improve production sites with data utilization, such as

predictive maintenance. The three phases are: collecting data, analyzing data and create machine learning model, and deploying machine learning model.

In the data collection phase, MELSOFT MaiLab supports the creation of data by reading csv files, merging data, automatically detecting and changing data types, etc.

In the analyzing data and create machine learning model phase, MELSOFT MaiLab can automatically analyzes data and create AI. In MaiLab, AI is a model that performs preprocessing and diagnosis on input data and outputs diagnostic results.

In the deploying machine learning model phase, MELSOFT MaiLab provides functions to create tasks from the AI, deploy tasks to field PCs, and monitor diagnostic results easily. In MaiLab, A task is a series of processes that collect data, perform AI diagnosis, and output the diagnosis results to output destinations.
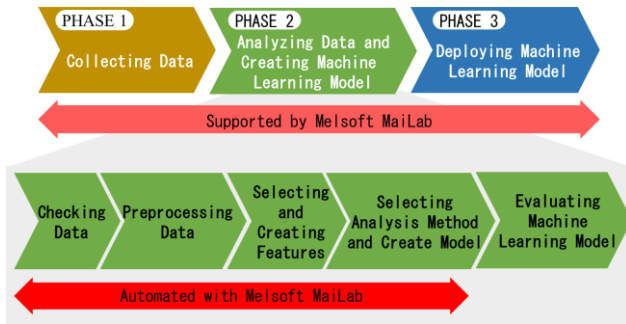

Figure 1 Phases for production site improvement with data

3. FEATURES OF MELSOFT MAILAB

In this section, we describe the main features of MELSOFT MaiLab.

3.1. Easy Analysis

One of the features for easy Analysis is "Automated Machine Learning", which enables anyone to easily analyze data and create diagnostic models.

Users can create the optimal AI to achieve the objective by simply answering questions about the purpose of analysis as shown in Figure 2. Then, MELSOFT MaiLab selects the necessary preprocessing and analysis methods based on the user's answers and automatically generates AI.

After creating the AI, MELSOFT MaiLab displays the accuracy of the AI as a score and comment as shown in Figure 3. This score is expressed as a value between 0 and 100, regardless of analysis methods, with the closer to 100, the higher the accuracy. Therefore, users can determine the approximate accuracy of a model without having to know the meaning of performance metrics used to evaluate AI.

For users with knowledge of machine learning, MELSOFT MaiLab also possible to display detailed evaluation results.
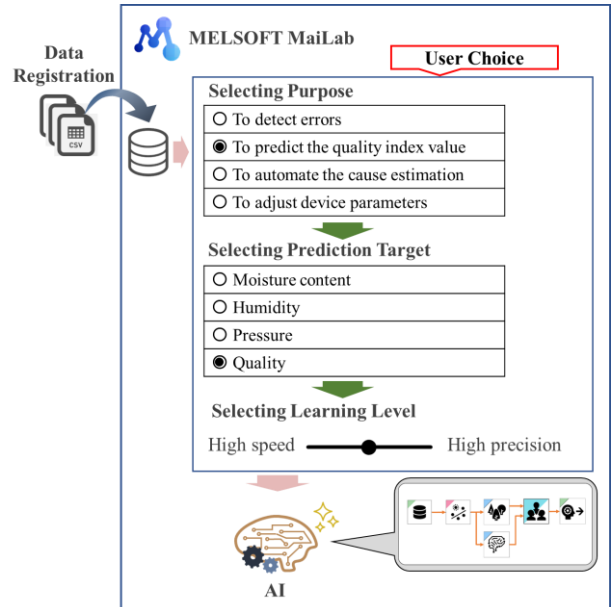

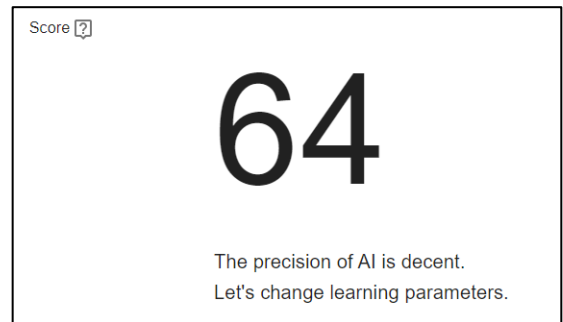Figure 2 Automatic learning operation procedure

Figure 3 Learning result page

3.2. Advanced preprocessing functions

Data preprocessing is critical to the accuracy of AI, and MELSOFT MaiLab automatically performs the following five preprocessing steps to optimize data as needed, as shown in Figure 4.

(1)   Wave processing

For waveform data that changes in time series, such as sensor measurement data, MELSOFT MaiLab generate sections and generate t features from the sections.

(2)   Missing value processing

MELSOFT MaiLab replace missing values with appropriate value.

(3)   Encoding

Data that cannot be learned in its original data format is encoded into a data format that can be learned while maintaining the characteristics of the data.

(4) Scaling

To ensure proper learning and to facilitate evaluation of learning results, data should be converted to an equivalent scale.
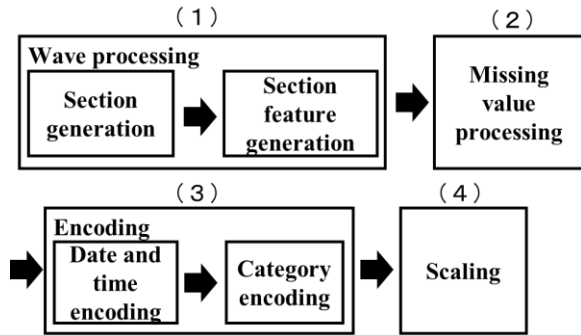

Figure 4 Preprocessing Flow

3.3. Effective and accurate learning

To improve the accuracy of the AI, MELSOFT MaiLab has following three features.

(1) Hyper parameter optimization

Hyper parameters are values that control the behavior of analysis methods. MELSOFT MaiLab searches for hyperparameters for each training data and optimizes the hyperparameters.

(2) Various learning methods

MELSOFT MaiLab offers many analysis methods to support various use cases.

For example, if users want to create a model to determine whether the current state is normal or abnormal using normal and abnormal data as training data, analytical methods such as random forest and deep learning can be used.

If users want to create a model that uses only normal state data as training data to determine how far away from normal the current state is, the MT method and autoencoder can be used.

If users want to create a model using waveform data to determine how different the waveform is from normal, a similar waveform recognition method can be used. This method outputs an indicator called a similarity score that indicates how similar the waveform is to the normal waveform at the time of diagnosis.

(3) Ensemble learning

Ensemble learning is a technique that combine multiple analysis methods to improve accuracy.

Prediction results from a single analysis method may contain bias depending on data and model.

Ensemble learning uses results of multiple analysis methods as shown in Figure 5, and it enables better prediction than single analysis method.
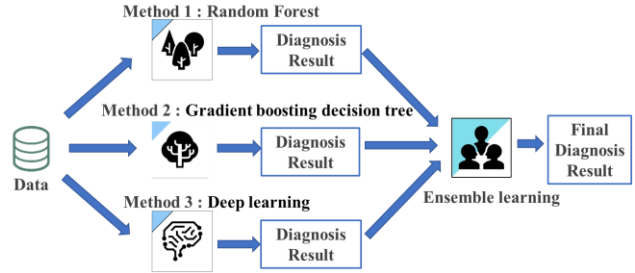

Figure 5 Image of Ensemble Learning

3.4. Flexible customization of AI

AI built in MELSOFT MaiLab is represented as a flow consisting of blocks and lines, as shown in Figure 6. The icons in the screen are functional blocks that package preprocessing and analysis methods. A user can edit the AI simply by placing blocks and connecting lines.
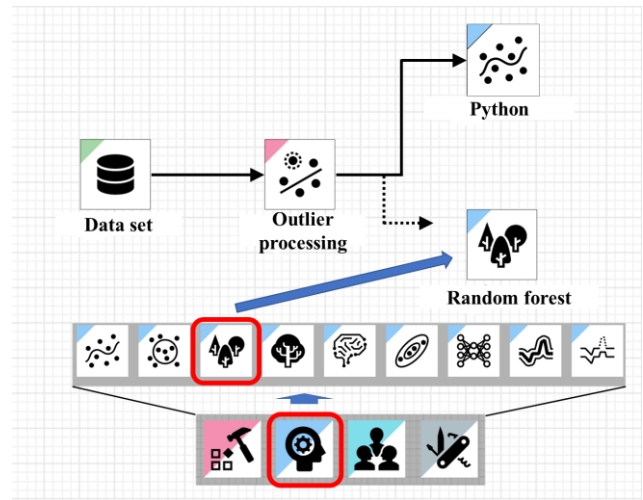

Figure 6 Editing AI

If necessary, users can refine the automatically created AI themselves. Users with knowledge of data analysis can also create AI from scratch.

Figure 7 Example of Functional Blocks

3.5. High Convenience in Diagnosis

MESLSOFT MaiLab manages the diagnostic process in units called tasks. A task is a group of processing from diagnosing collected data with an AI to outputting the diagnosis result. Input and output of task can be selected from Text file, OPC UA server connection, and Mitsubishi Electric FA Connector. When selecting "Mitsubishi Electric FA Connector" as output connection method, diagnostic results can be reflected in programmable logic controllers directly.

Created tasks are deployed to the diagnosis terminal and the diagnosis are performed on the diagnosis terminal. Diagnosis terminal is a PC on which MELSOFT MaiLab for diagnosis terminal is installed. Deployments of task to a diagnosis terminal are done over the network.

4. EXAMPLE OF UTILIZATION

In this section, we describe how MELSOFT MaiLab works with example. Note that the data used in this example is not the actual data of an equipment, but artificial data created by imitating the data of an equipment.

4.1. Description of example

This example assumes a use case to diagnose the maintenance timing of gears in an equipment.

Gears wear out with operation and need to be replaced before the equipment fails. In many cases, gears are replaced periodically based on operating hours. However, this approach may replace gears that can still be used.

If predictive maintenance using equipment data could be performed, it would reduce the number of gear replacements and prevent equipment failures.

4.2. Description of data

In this example, training will be conducted using normal state data of an equipment.

The training data consists of 93 csv files, each file representing one time normal operation of an equipment. Each csv file has 300 records and 7 variables including timestamps.

4.3. Creating Data set

MESLSOFT MaiLab manages imported data as a data set.

Users can add data to the data set by dragging and dropping csv files. MELSOFT MaiLab displays the contents of the imported data in the data Set view, as shown in Figure 8.
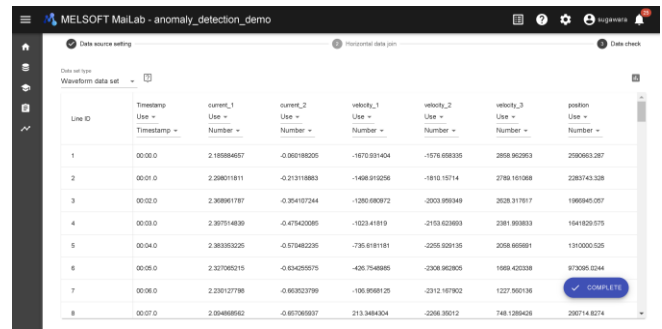

Figure 8 Data set view

4.4. Creating AI

As described in section 3.1, users can create the optimal AI by simply answering questions about the purpose of analysis.

In this example, the purpose is "To detect errors", and use normal values only, and don't use the shape of periodic waveforms, and use file switching as the section.
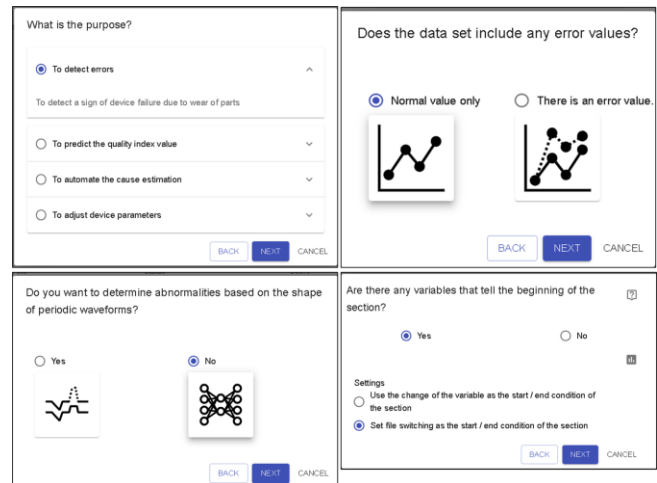

Figure 9 Questions when creating AI

In this example, MESLSOFT MaiLab creates an AI shown in Figure 10 based on answers to questions. This AI takes the

average value of each variable to create feature, performs scaling, and train an autoencoder.
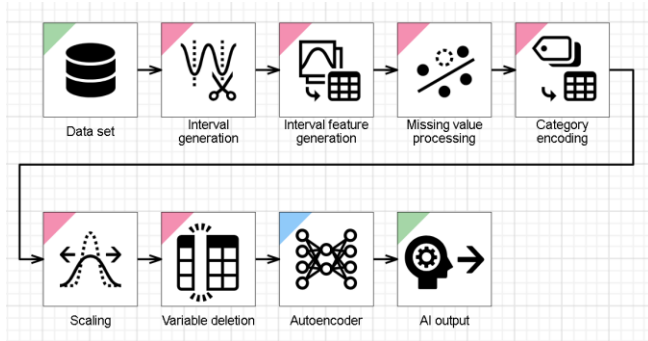

Figure 10 Generated AI

4.5. Diagnosis

We performed diagnosis using the task using the AI shown in Figure 10 and confirmed whether anomalies could be detected.

Figure 11 shows the result of monitoring the diagnosis results with the function of MELSOFT MaiLab. The vertical axis value means error level. It was confirmed that the error level increased when diagnosing data different from normal.
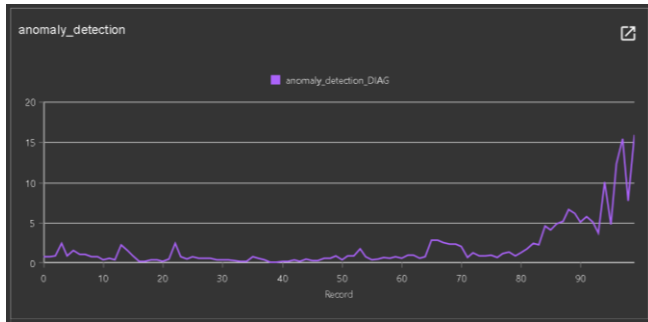

Figure 11 Diagnosis Result

5. CONCLUSION

In this paper, we describe the background of the development of MELSOFT MaiLab, its features, and examples of the utilization.

We will continue to contribute to solving problems and improving productivity at manufacturing sites by expanding new technologies and expanding the scope of application.

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