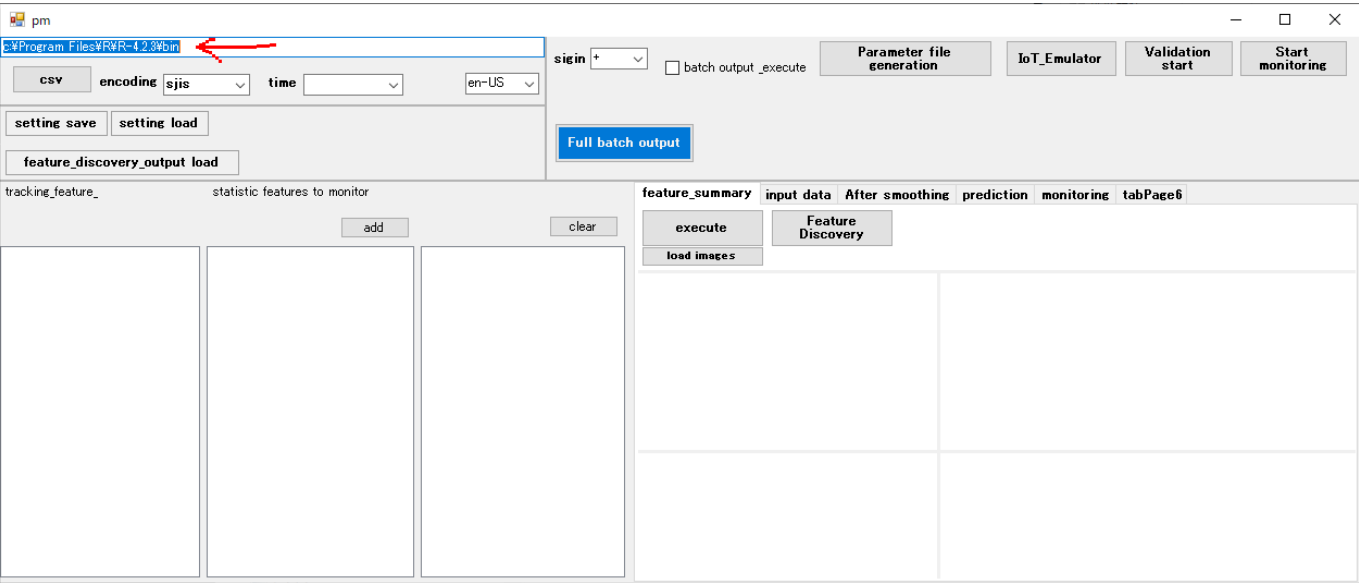


# pm.bat

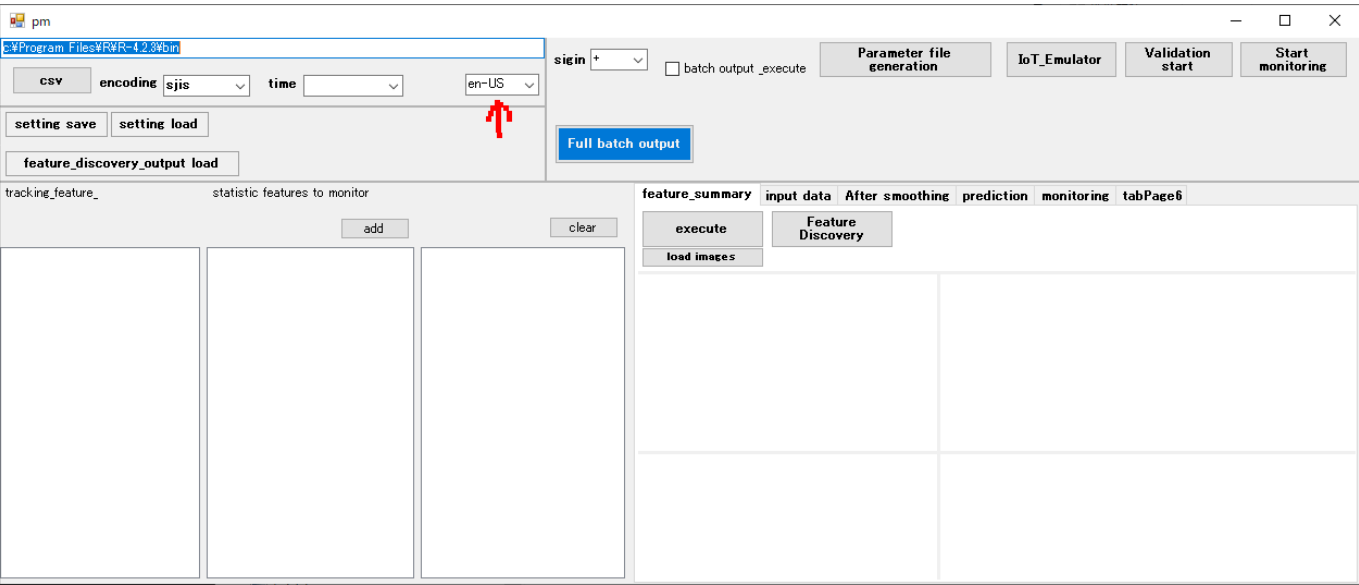
## Set the installation location for R



This only needs to be done once.

## Language Settings

You can choose between Japanese or English. After setting, restart to apply the specified language.



## File encoding settings

Currently, it is fixed to UTF-8, and all input CSV files are automatically converted to UTF-8. Also, all output files are output in UTF-8.

## Importing CSV Data

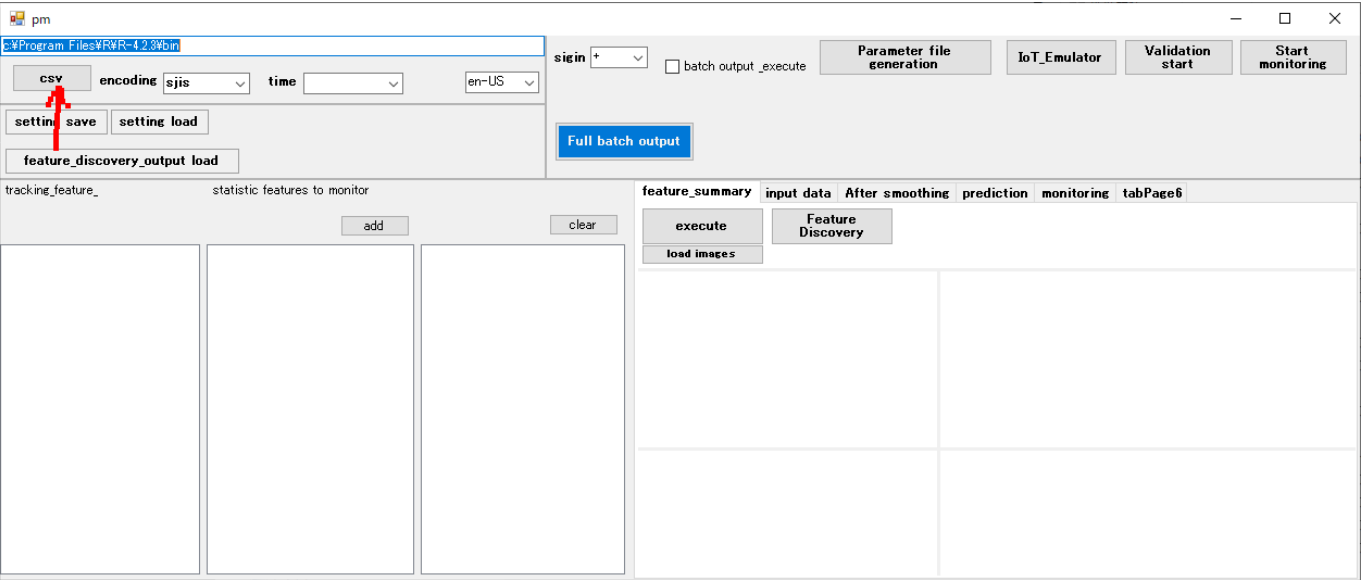
CSV data can be either accumulated data from periodic saving or consolidated CSV files. One or multiple files are acceptable. Place these CSV files under an appropriately named folder. Use the "CSV" button to access the

folder and select the first CSV file. Do not use \*\*, \*\* in the column names of csv data. Be especially careful because the R language automatically converts characters that cannot be used as variables into \*\*, \*\* in the column names of csv data.

















Automatically correct column names that do not conform to R's variable name rules. In this case, the following rules apply

- Whitespace (space) → "." converted to ".".
- Example: "column name" → "column.name"
- Special characters (-, +, ?, ! etc.) → "." converted to
- Example: "column-name" → "column.name"
- Names starting with a number → append "X"
- Example: "123data" → "X123data"
- Duplicate column names → ". Append "." to make it unique
- Example: c("A", "A") → c("A", "A.1")

Please replace the column name with . in advance, replace the column name with \_ etc. to prevent conversion to .



Select the first CSV file.

 01st-day-vibration-2013_03_07 01_57_46....	2024/03/28 6:51	Microsoft Excel CS...	20,788 KB
 02nd-day-vibration-2013_03_08 01_57_46....	2024/03/28 6:51	Microsoft Excel CS...	20,795 KB
 03rd-day-vibration-2013_03_09 01_57_46....	2024/03/28 6:51	Microsoft Excel CS...	20,799 KB
 04th-day-vibration-2013_03_10 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,799 KB
 05th-day-vibration-2013_03_11 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,798 KB
 06th-day-vibration-2013_03_12 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,790 KB
 07th-day-vibration-2013_03_13 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,798 KB
 08th-day-vibration-2013_03_14 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,792 KB
 09th-day-vibration-2013_03_15 01_57_46....	2024/03/28 6:52	Microsoft Excel CS...	20,798 KB
 10th-day-vibration-2013_03_16 01_57_46....	2024/03/28 6:53	Microsoft Excel CS...	20,795 KB
 11th-day-vibration-2013_03_17 01_57_46....	2024/03/28 6:53	Microsoft Excel CS...	20,798 KB
 12th-day-vibration-2013_03_18 01_57_46....	2024/03/28 6:53	Microsoft Excel CS...	20,801 KB
 13th-day-vibration-2013_03_19 01_57_46....	2024/03/28 6:53	Microsoft Excel CS...	20,798 KB
 14th-day-vibration-2013_03_20 01_57_46....	2024/03/28 6:53	Microsoft Excel CS...	20,785 KB
 15th-day-vibration-2013_03_21 01_57_46....	2024/03/28 6:54	Microsoft Excel CS...	20,802 KB
 16th-day-vibration-2013_03_22 01_57_46....	2024/03/28 6:54	Microsoft Excel CS...	20,800 KB

## Timestamp Parameter Settings

When CSV data is loaded, each item and a list of investigable features are automatically set.

01st-day-vibration-2013\_03\_07 01\_57\_46.000

c:\Program Files\FWR-4.2.3\bin

csv

encoding sjis

time

en-US

setting save

setting load

feature\_discovery\_output load

signin +

☐ batch output \_execute

Parameter file generation

IoT\_Emulator

Validation start

Start monitoring

Full batch output

tracking\_feature\_

statistic features to monitor

add

clear

datetime vibration

mean  
sd  
var  
skewness  
kurtosis  
peak2peak  
RMS  
range  
OrestFactor  
ShapeFactor  
ImpulseFactor  
MarginFactor  
logEnergy  
spectrum  
spectral\_mean  
spectral\_std  
spectral\_skewness  
spectral\_kurtosis  
mahalanobis

feature\_summary

input data

After smoothing

prediction

monitoring

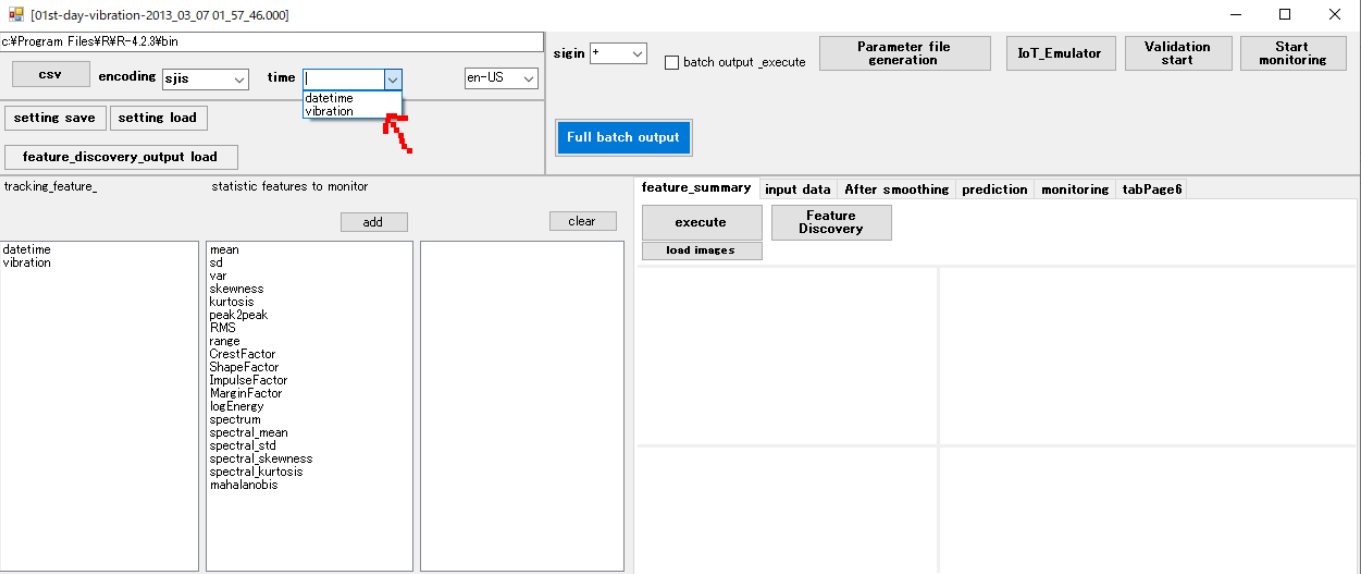
tabPage6

execute

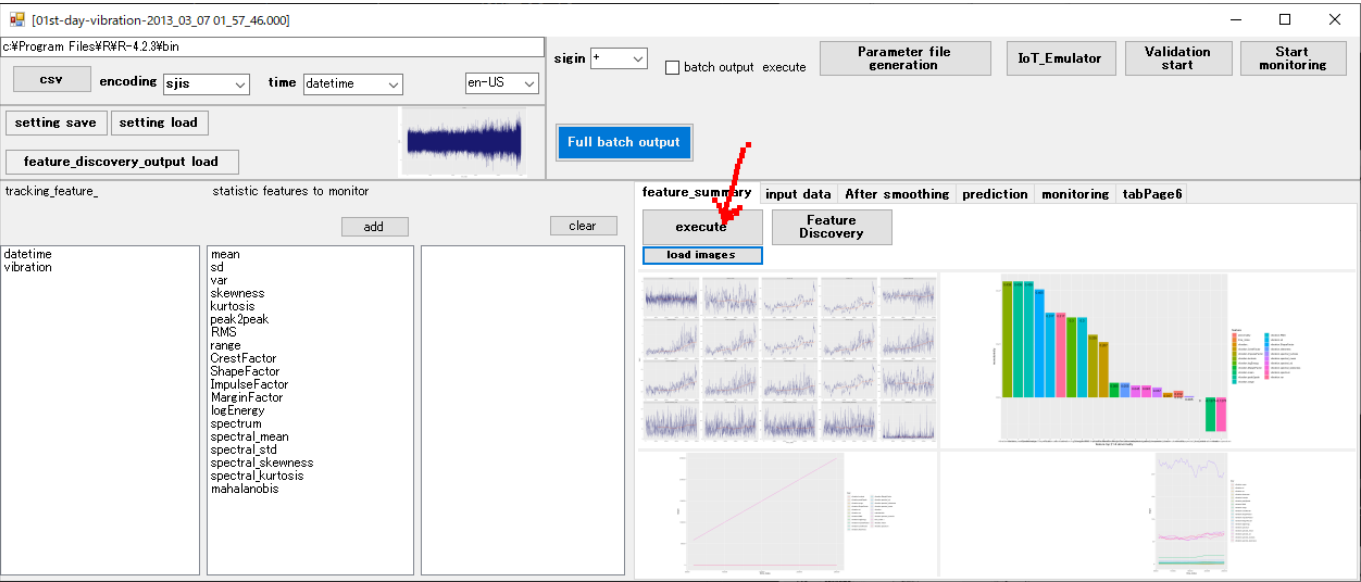
load images

Feature Discovery

First, select and specify the item representing the timestamp.



Summary of Features



xxxx\_feature\_summary\_visualization.bat ("xxxx" is determined from the name of the imported CSV file.)

Generates a batch for visualizing the summary of features for each data item.

**batch output & execute** If the checkbox is ON, batch generation and execution are performed. This process takes time as it is done for all items.

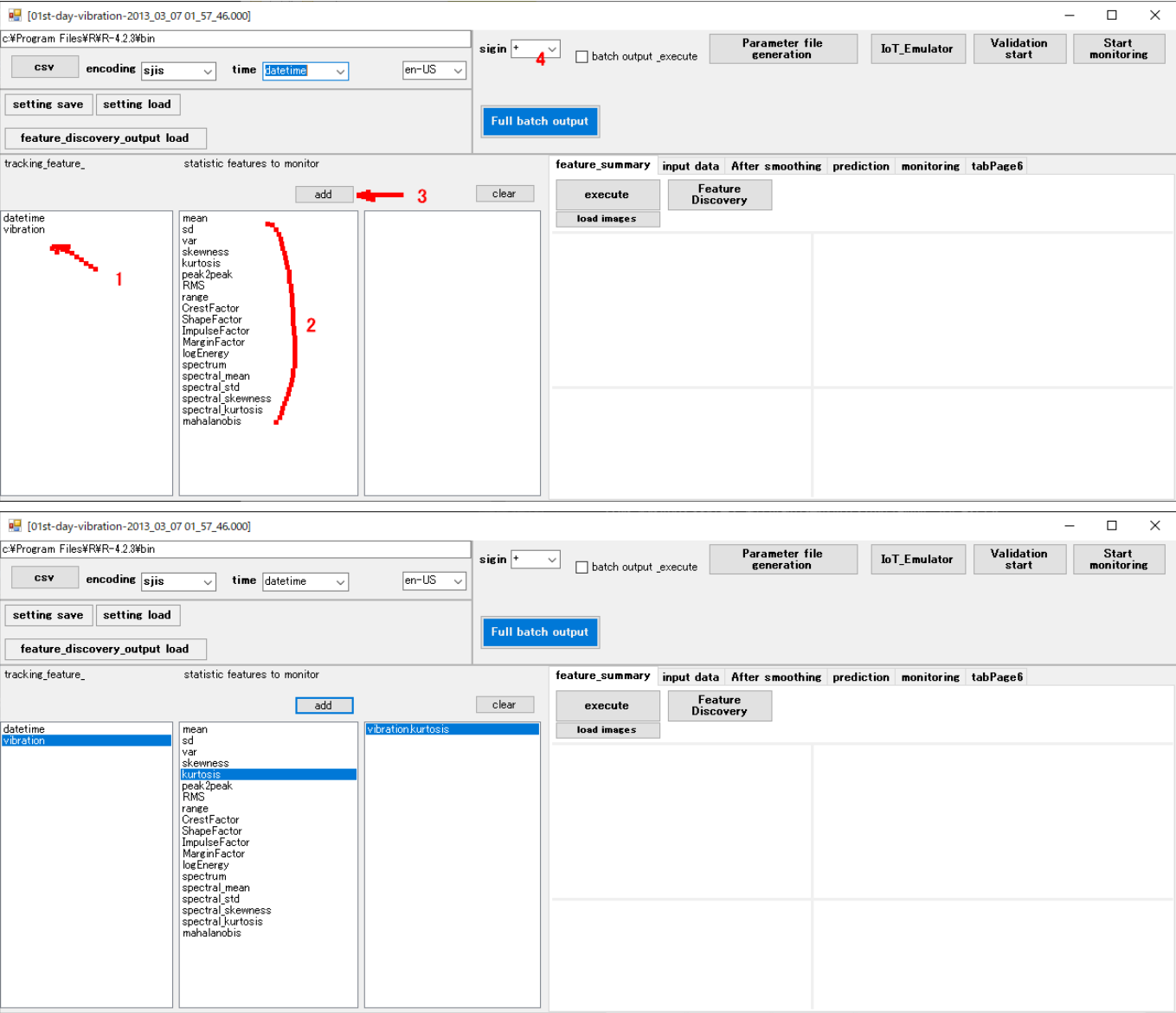
Parameter Settings for Estimating Remaining Useful Life (RUL)

You can set parameters either manually or semi-automatically. You can also adjust specific parameters manually after semi-automatic setting.

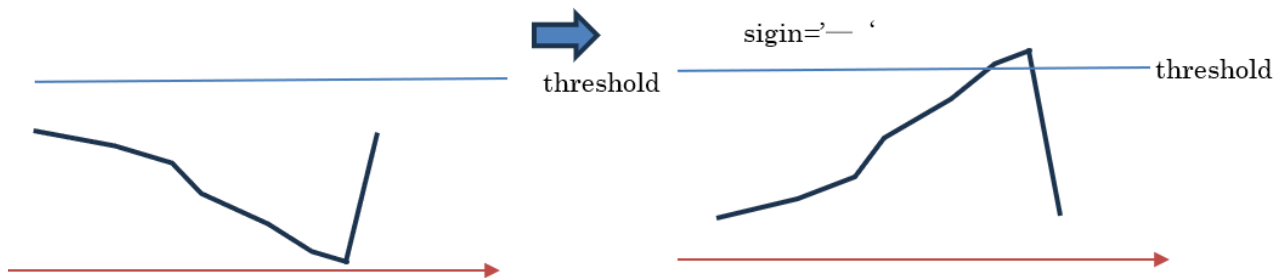
Various Settings

Feature Selection

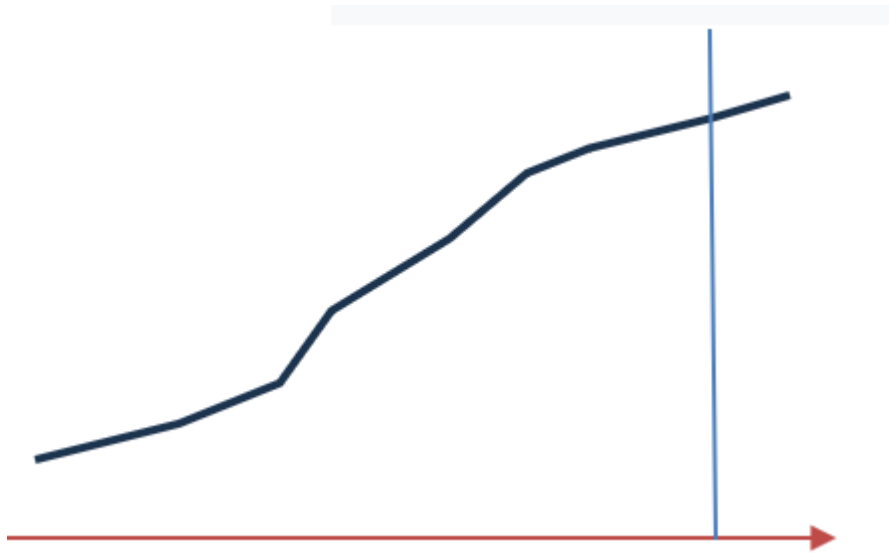
No setup is required for semi-automatic configuration. Select the items and features for tracking RUL and press the **add** button.



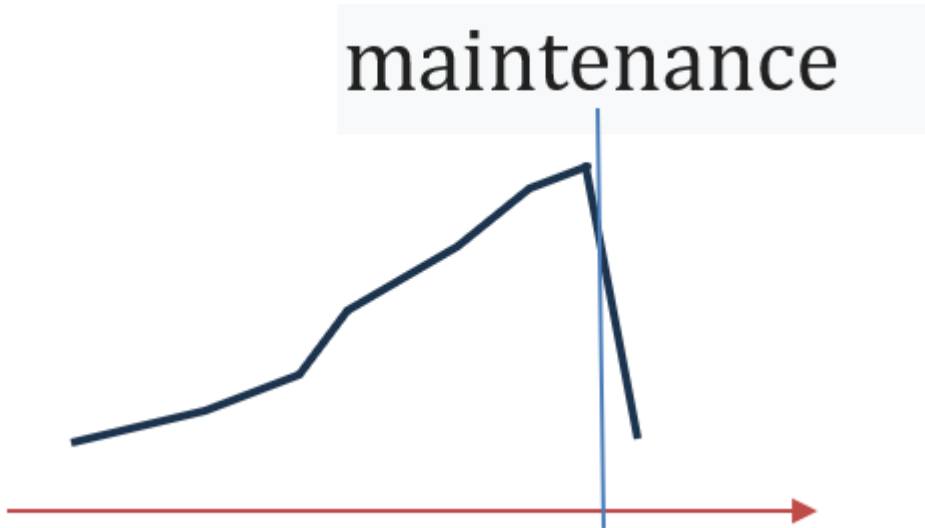
- **sign** Specify whether to reverse the sign of the feature.



Features need to increase over time to exceed the threshold as the lifespan decreases.



If this feature represents RUL, it will likely show a sharp drop after maintenance, making it critical for decision-making.



Two items and features must be set for tracking RUL. Additional settings will not be tracked.

[01st-day-vibration-2013\_03\_07 01\_57\_46.000]  
c:\Program Files\R\R-4.2.3\bin

csv encoding sjis time datetime en-US

setting save setting load

feature\_discovery\_output load

Full batch output

sign + batch output \_execute

Parameter file generation

IoT\_Emulator

Validation start

Start monitoring

tracking\_feature\_ statistic features to monitor

add clear

datetime  
vibration

mean  
sd  
var  
skewness  
kurtosis  
peak2peak  
RMS  
range  
CrestFactor  
ShapeFactor  
ImpulseFactor  
MarginFactor  
logEnergy  
spectrum  
spectral\_mean  
spectral\_std  
spectral\_skewness  
spectral\_kurtosis  
mahalanobis

vibration.kurtosis  
vibration.ImpulseFactor

feature\_summary input data After smoothing prediction monitoring tabPage6

max\_prediction\_length 800

forecast\_time\_unit day

prediction model

☐ use\_auto\_arima ☒ use\_arima ☐ use\_ets ☐ use\_plophet

failure\_time\_init 1000\*max\_prediction\_length\*unit\_of\_record

Also, **sign** and other parameters are shared. The second listed feature is tracked as reference data. In the later **Forecast Execution (Validation)** step, thresholds will be adjusted automatically.

## Input Data Settings

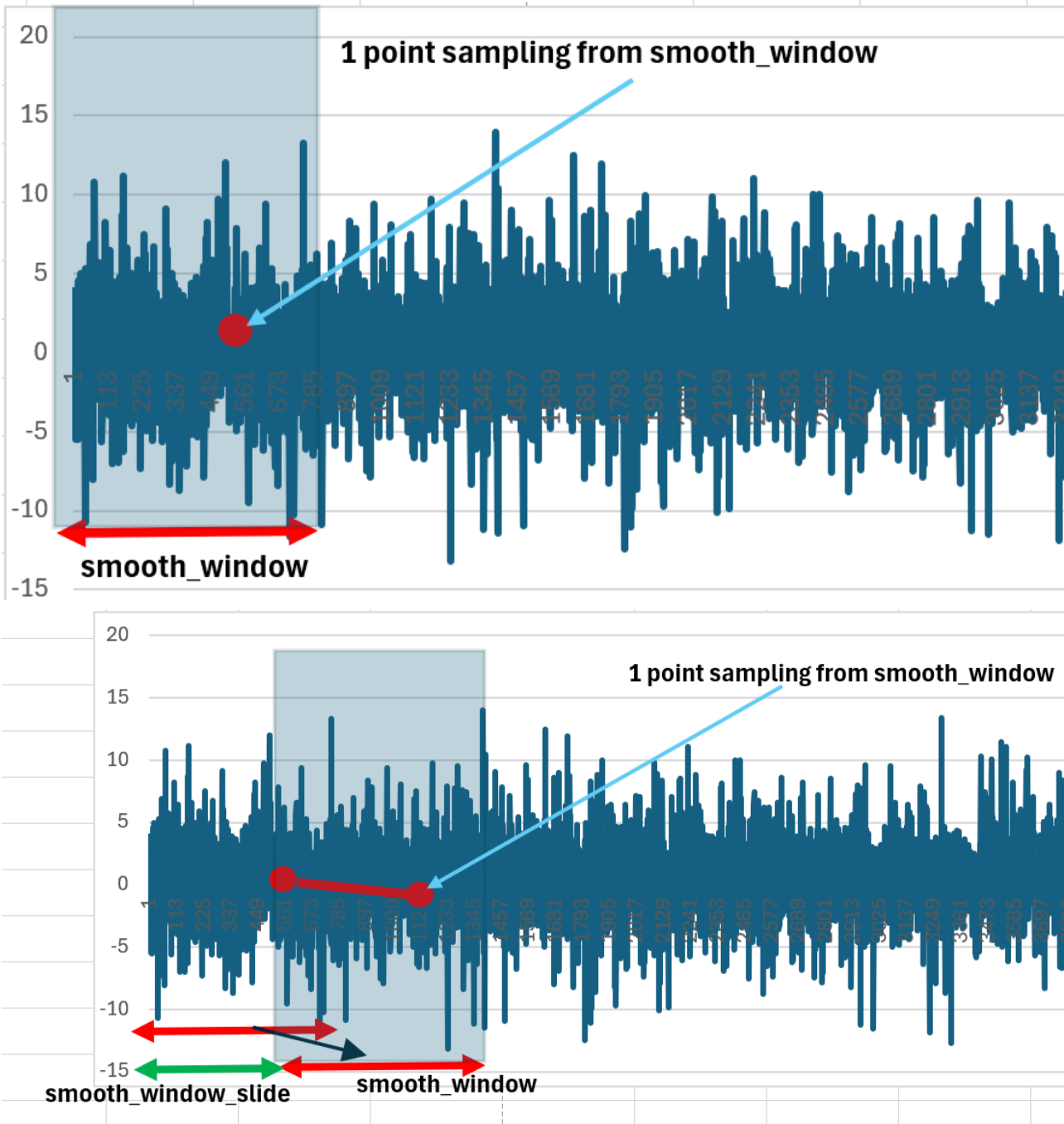
Specify the time unit of the data, the approximate amount of observational data generated each time, the amount used for training, and the maximum amount to retain, including historical data. If the maximum retention is exceeded, the oldest data is automatically deleted.

The screenshot shows the 'Input Data Settings' window. At the top, there's a file path field with the value 'c:\Program Files\R\R-4.2.3\bin'. Below it, there are dropdowns for 'encoding' (sjis), 'time' (datetime), and 'en-US'. There's a 'sign' dropdown set to '+', a 'batch output \_execute' checkbox, and buttons for 'Parameter file generation', 'IoT Emulator', 'Validation start', and 'Start monitoring'. A 'Full batch output' button is also present. Below these, there are buttons for 'setting save', 'setting load', and 'feature\_discovery\_output load'. A small waveform graph is visible. The main area is divided into two panels: 'tracking\_feature\_' and 'statistic features to monitor'. The 'tracking\_feature\_' panel has a list of features including 'datetime', 'vibration', 'mean', 'sd', 'var', 'skewness', 'kurtosis', 'peak2peak', 'RMS', 'range', 'CrestFactor', 'ShapeFactor', 'ImpulseFactor', 'MarginFactor', 'logEnergy', 'spectrum', 'spectral\_mean', 'spectral\_std', 'spectral\_skewness', 'spectral\_kurtosis', and 'mahalanobis'. The 'statistic features to monitor' panel has an 'add' button and a 'clear' button. The right panel shows various settings: 'unit\_of\_time' (sec), 'unit\_of\_record' ((1/585936)\*60\*60\*24), 'one\_input' (24\*60\*60), 'max\_train\_span' (11\*30\*24\*60\*60), and 'max\_retained\_length' (3\*30\*24\*60\*60). There are checkboxes for 'use\_lowess' and 'use\_spline'. The 'smooth\_window' and 'smooth\_window\_slide' fields are highlighted with a red box, both set to 0. The 'feature\_smooth\_window' field is set to 0.

The parts highlighted in red can be set automatically. Typically, this parameter is fine at 0. If the input data is huge, sampling can be done based on **smooth\_window** and **smooth\_window\_slide** settings.

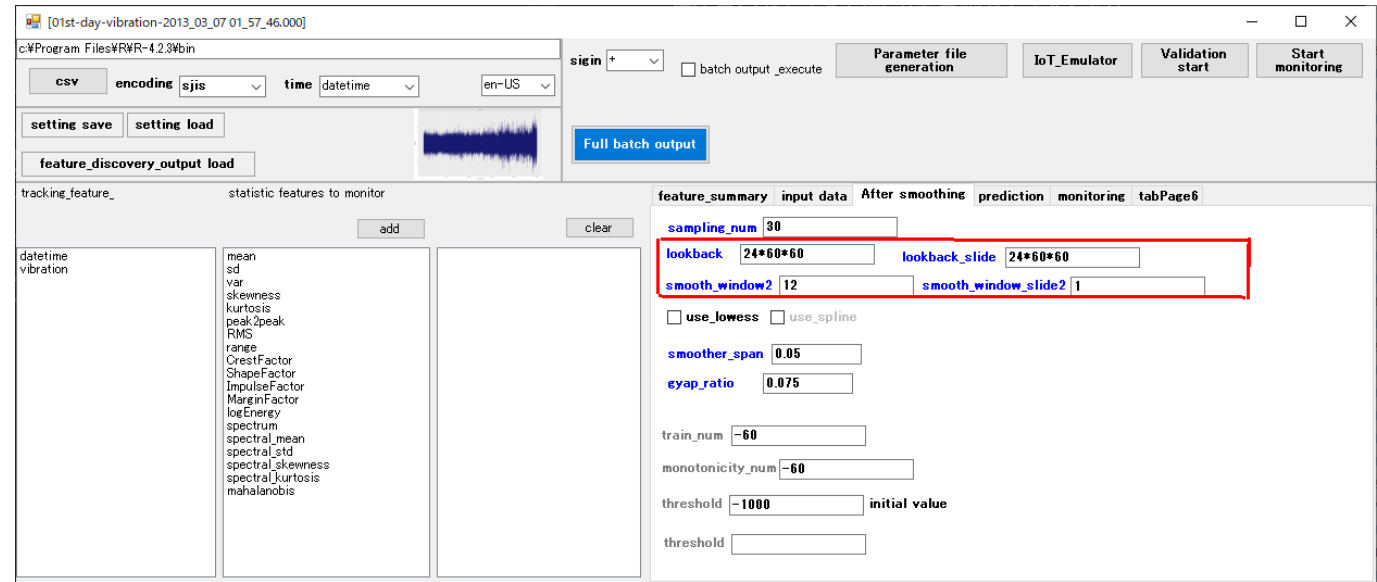
- **unit\_of\_time** Time unit of the data.
- **unit\_of\_record** Time interval between rows.
- **one\_input** Amount of CSV data provided each time. This is the row count of CSV files provided during operation. CSV files are automatically split based on this setting and generated in the files folder. These files are copied to the Untreated folder, processed one file at a time, and moved from Untreated to the Processed folder during operation.
- **max\_train\_span** Amount used for training (needed for threshold estimation and Mahalanobis distance calculation). If data accumulation exceeds this amount, threshold estimation stops, and the Mahalanobis distance model is generated using data up to this point.
- **max\_retained\_length** Maximum retention of historical data. Set it significantly larger than max\_train\_span.
- **smooth\_window** Specifies the window size for sampling input data.

- **smooth\_window\_slide** Specifies the movement of the sampling window for input data.



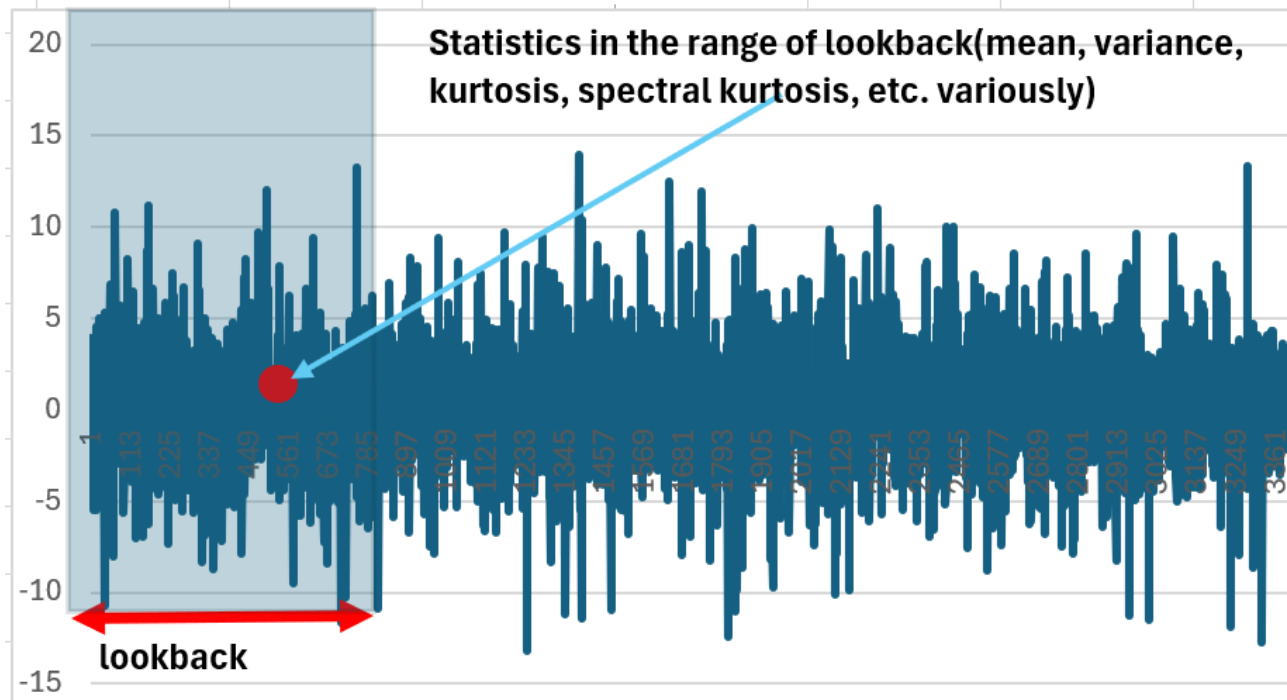
Feature Tracking Settings



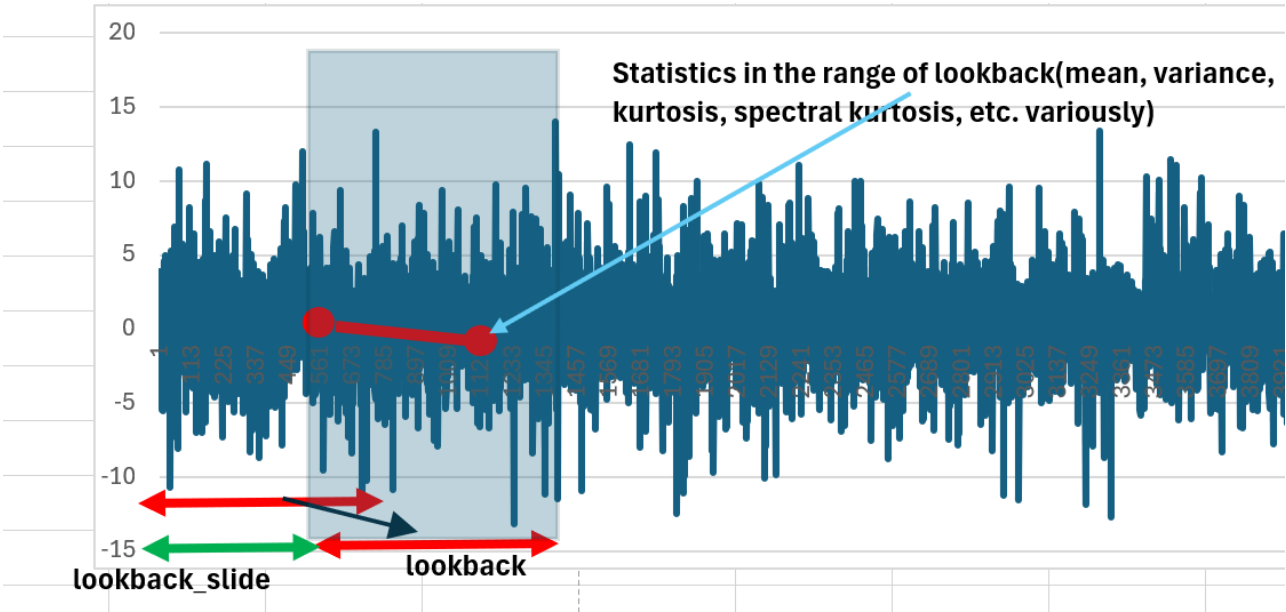


The parts highlighted in red can be set automatically.

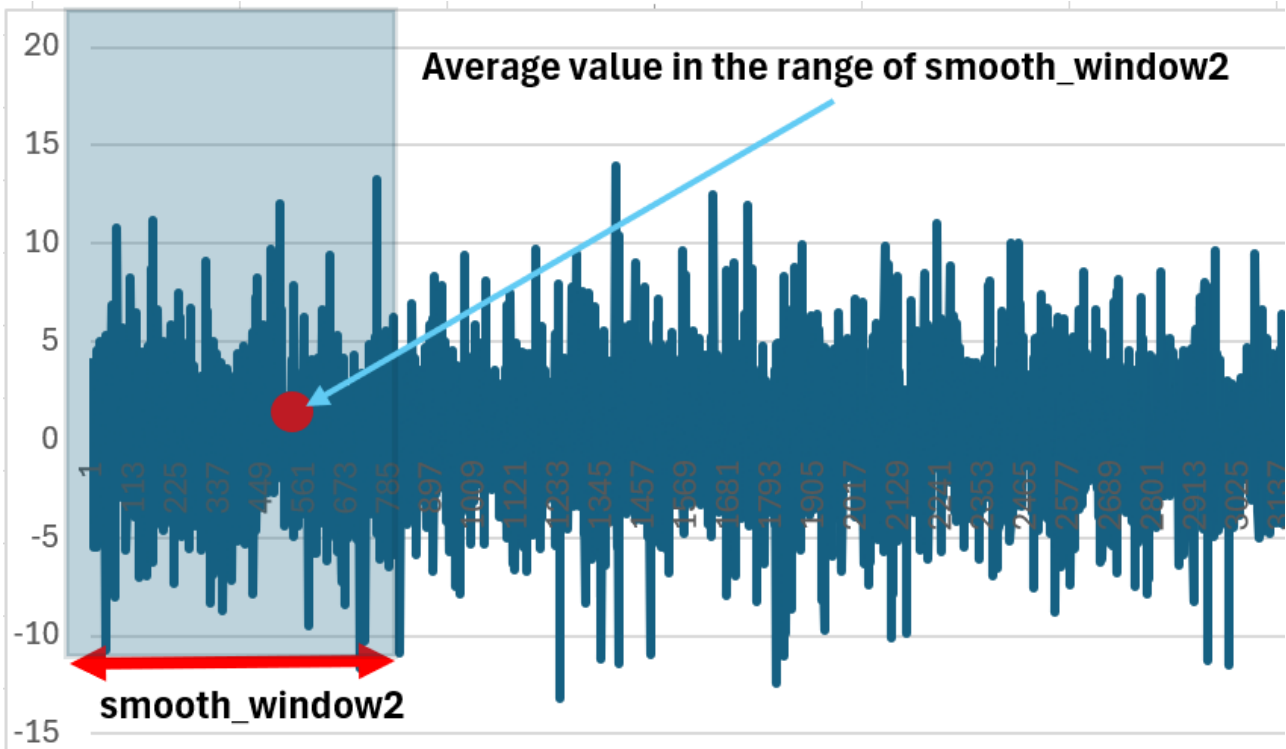
- **sampling\_num** Specify the number of samples to fit when creating a prediction line without referencing all historical data.
- **lookback** Specify the window size for creating statistical feature data from input data.



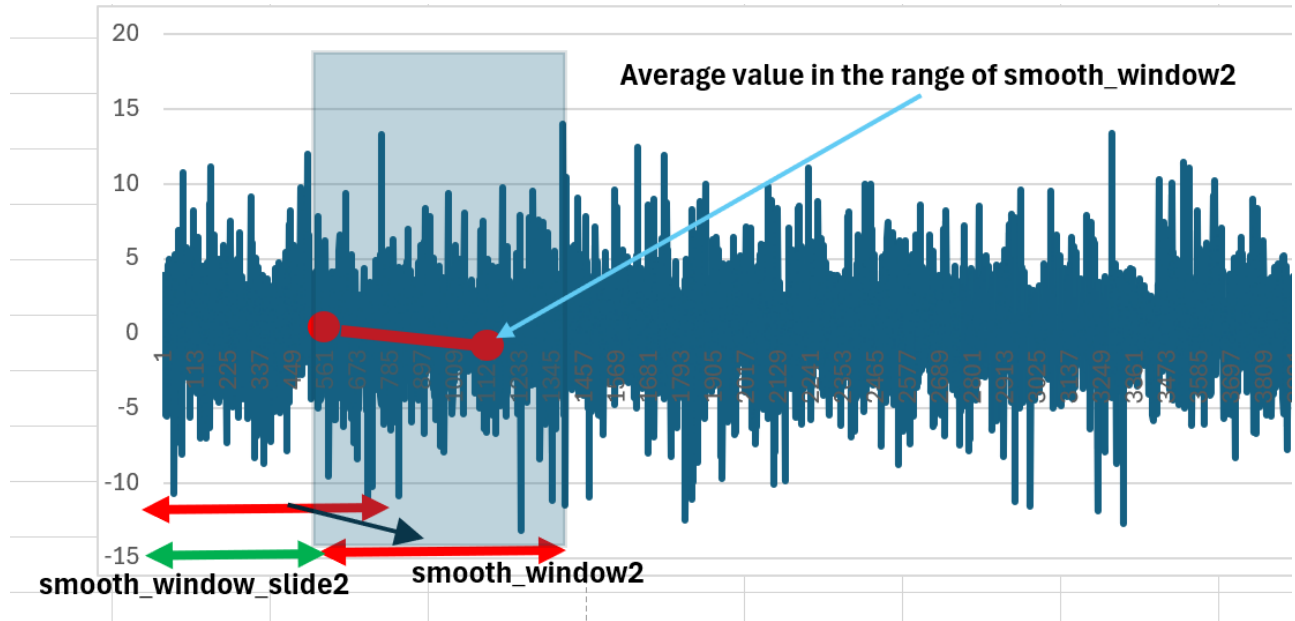
- **lookback\_slide** Specify the window movement amount for creating statistical feature data from input data.



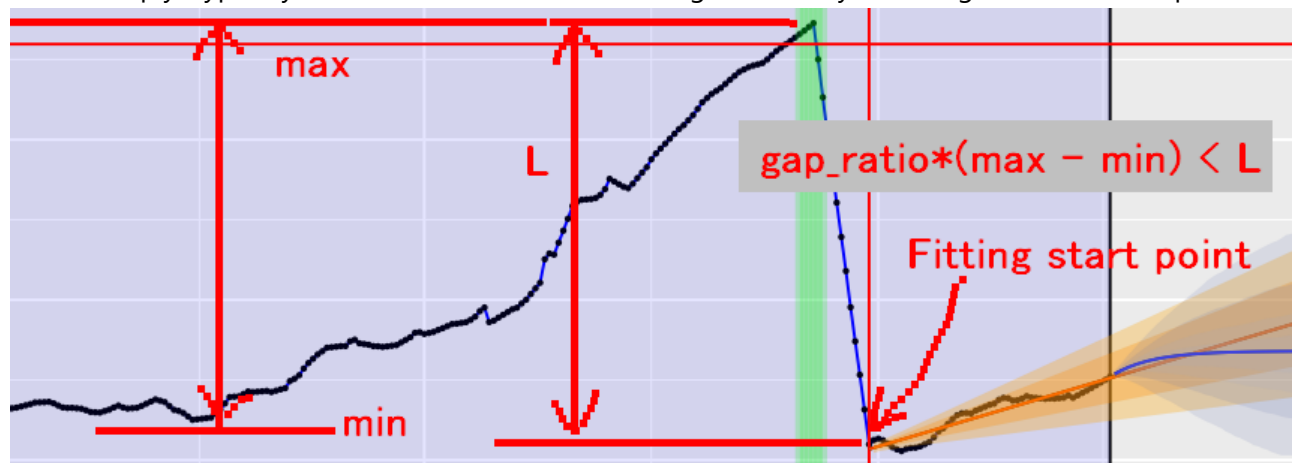
- **smooth\_window2** Specify the window size for smoothing features.



- **smooth\_window\_slide2** Specify the movement of the smoothing window for features.



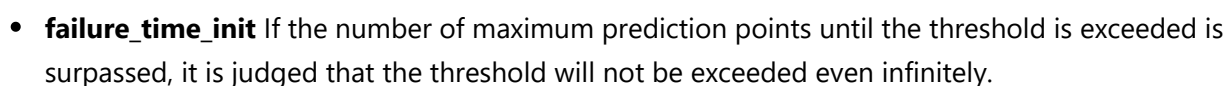
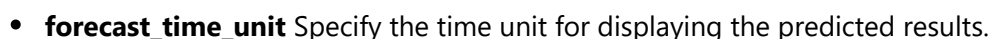
- **smoother\_span** Smooth the point sequence before fitting the input data. Smaller values retain the original fluctuations; larger values make it smoother.
- **gap\_ratio** Reset the fitting start point to the position of a sudden change when input data trends rise or fall sharply. Typically, after maintenance, trends change drastically, so fitting starts from this point.

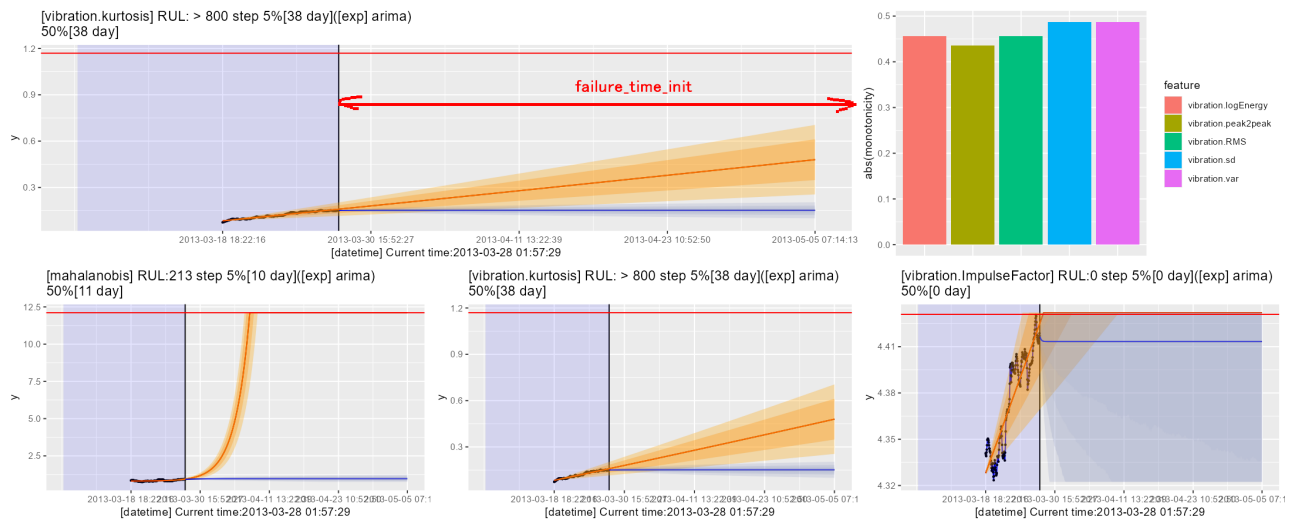


- **train\_num** Specify the amount of past data used to create a prediction line. Negative values use all past data. Positive values truncate past data and use only the specified number of points to create the prediction line.
- **monotonicity\_num** Specify the amount of past data used for monotonicity checks. Negative values use all past data, while positive values truncate past data and use only the specified number of points.
- **threshold initial value** Automatically adjust the threshold until the total input data exceeds **max\_train\_span**.
- **threshold** Specify a value as the threshold if automatic adjustment is not performed. This only applies to the first listed feature.

## Prediction Conditions Settings

- **max\_prediction\_length** Specify the number of future points to predict from the last observed point.



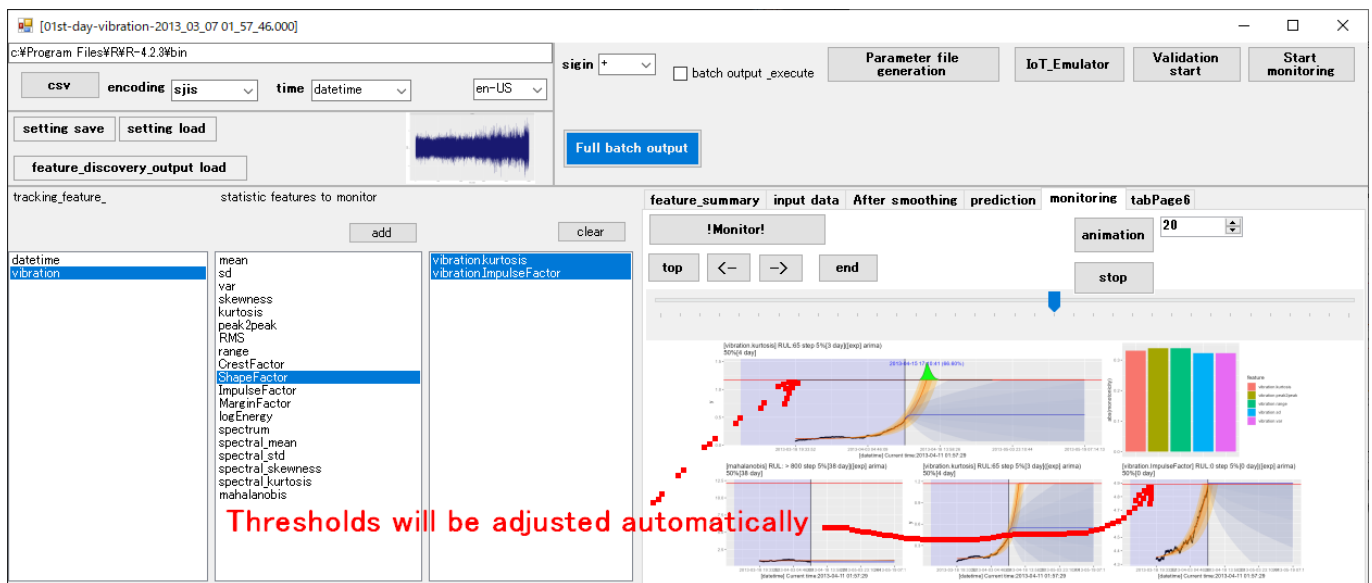
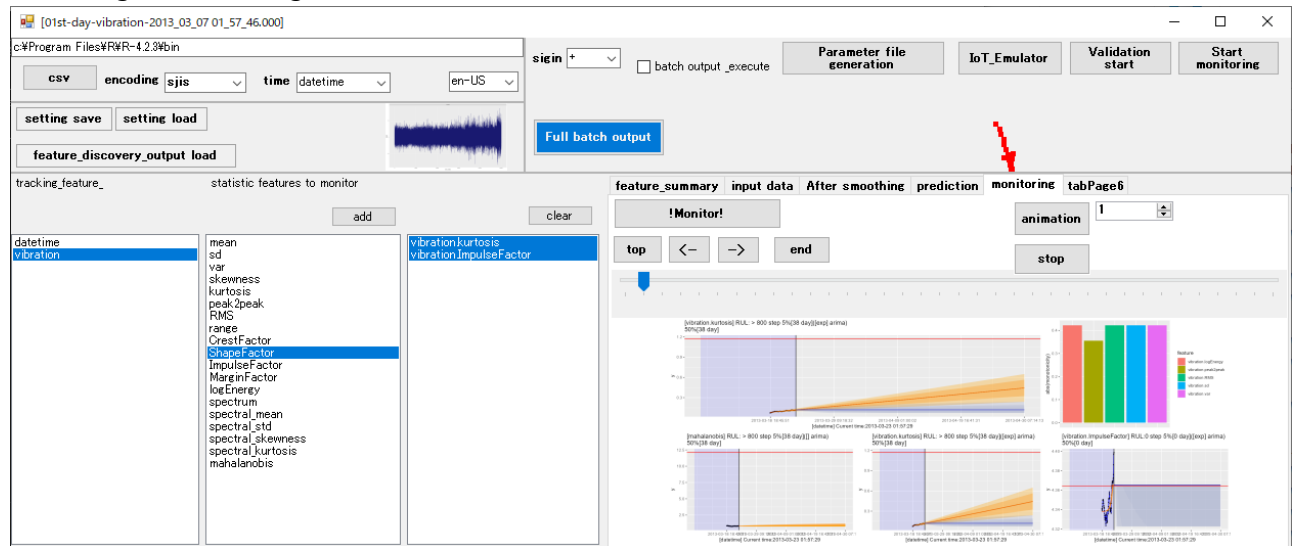


## Batch Generation

The screenshot shows the Batch Generation software interface. The top bar includes a file path, a sign dropdown, a batch output checkbox, and buttons for Parameter file generation, IoT\_Emulator, Validation start, and Start monitoring. The main area has tabs for feature\_summary, input data, After smoothing, prediction, monitoring, and tabPage6. The prediction tab is active, showing max\_prediction\_length (800), forecast\_time\_unit (day), and prediction model options (use\_auto\_arima, use\_arima, use\_ets, use\_plophet). The failure\_time\_init is set to 1000\*max\_prediction\_length\*unit\_of\_record. The bottom section shows tracking\_features and statistic features to monitor.

- [1] Generate Parameter File xxxx\_parameters.r ("xxxx" is determined from the name of the imported CSV file.)
- [2] Generate Data Emulation Batch xxxx\_IoT\_Emulator.bat ("xxxx" is determined from the name of the imported CSV file.) Emulates transfer to the folder (**work\Untreated**) for processing CSV files.
- [3] Perform Prediction (Validation) xxxx\_test.bat ("xxxx" is determined from the name of the imported CSV file.) Execute the batch and open the **monitoring** tab to visualize the prediction simulation

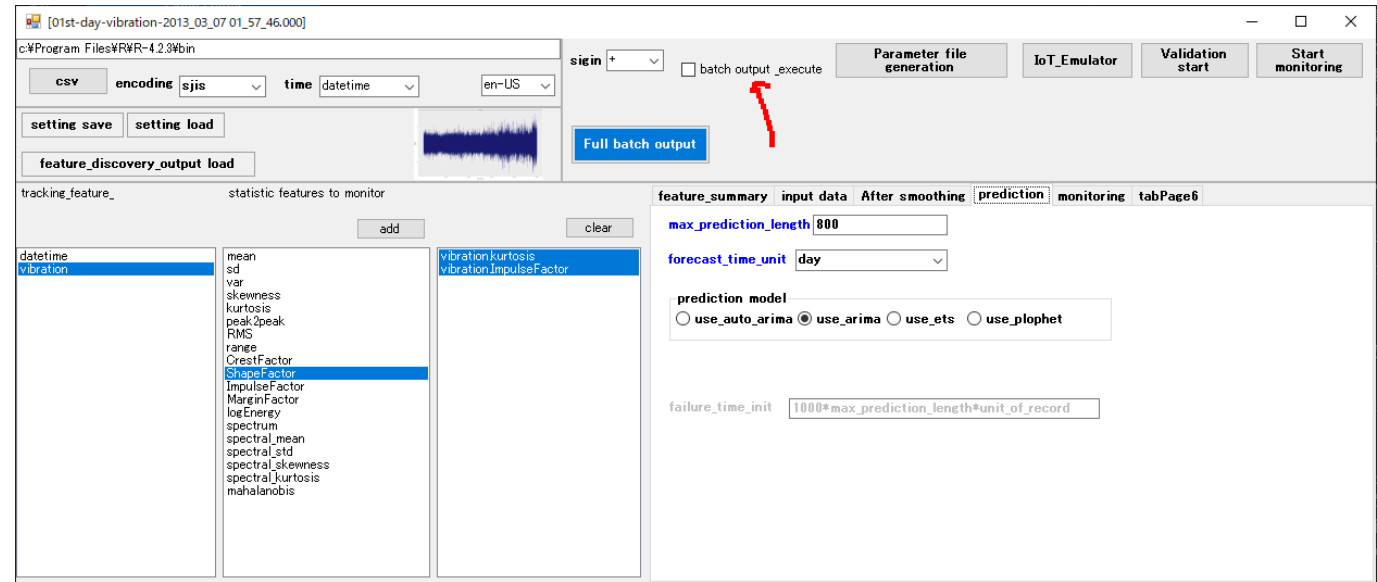
according to the settings.



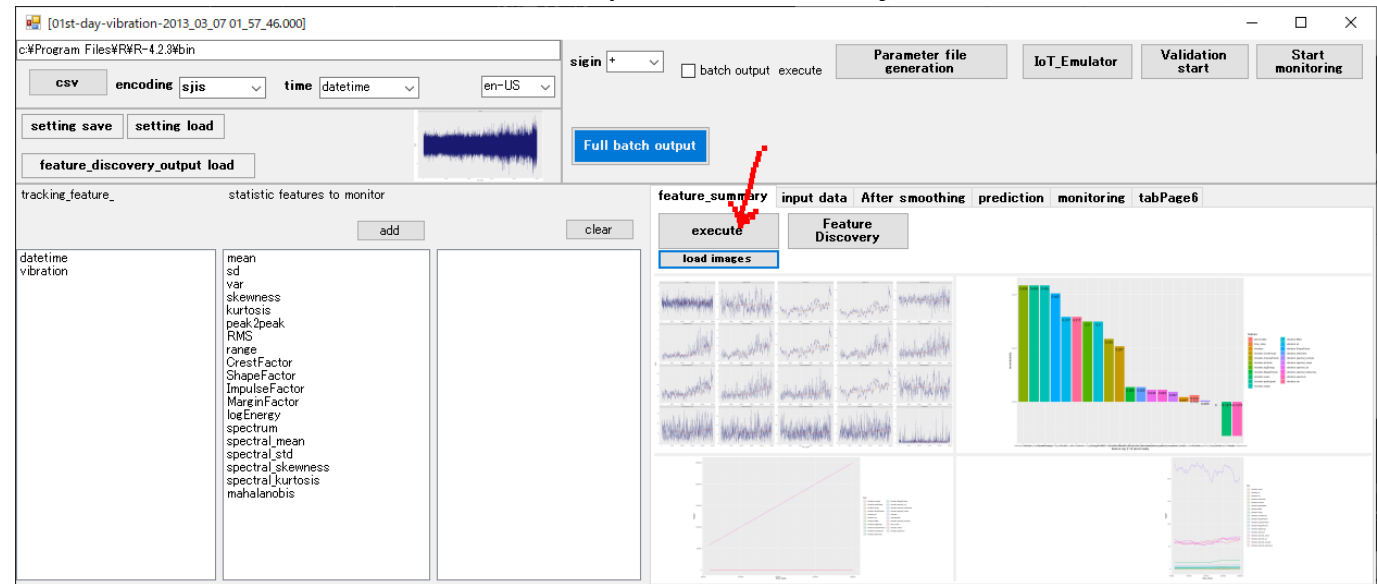
Appropriate thresholds are set during this execution. **Batches must be executed in the order 1, 2, 3.** During this validation execution, parameters are adjusted, and a file "**work/xxxx\_feature\_param.csv**" is generated and recorded.

- [4] Execute Operation xxxx\_execute.bat ("xxxx" is determined from the name of the imported CSV file.) Generate a batch for actual operation. Once operation starts, the folder (**work\Untreated**) for processing CSV files is periodically accessed, and files are processed if present. Files are split and processed according to the **one\_input** setting. The **Full batch output** button allows batch output of all files at once. However, even if the **batch output & execute** checkbox is ON, the batch is not executed.

## Batch Execution

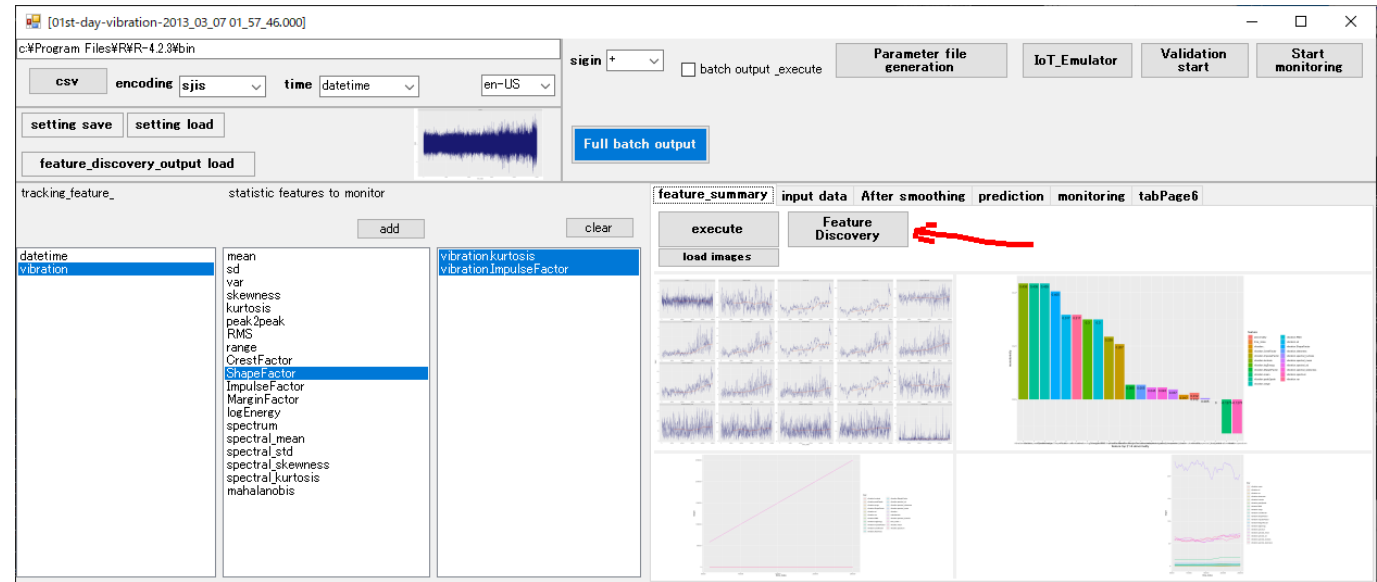


If the **batch output & execute** checkbox is ON, batch generation and execution are performed. After batch generation, individual batches can also be executed from the command prompt. The batch files are output, and they can be executed from the command prompt. Regardless of the method, **Batch Generation** steps 1 and 2 must be executed beforehand. Additionally, if **Feature Summary**



is checked, batch generation and execution are performed if the **batch output & execute** checkbox is ON.

Parameter Auto-Discovery (Semi-Automatic Parameter Setting)

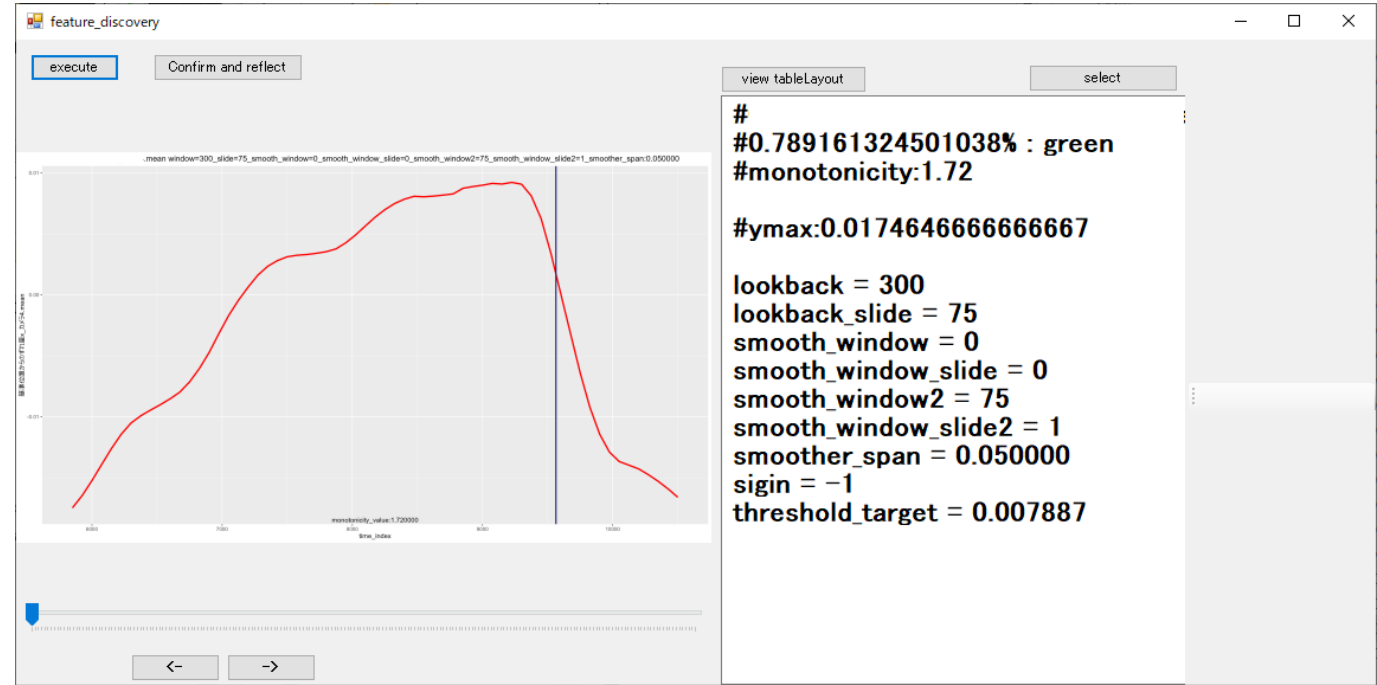


xxxx\_feature\_discovery.bat ("xxxx" is determined from the name of the imported CSV file.) Generate a batch for parameter auto-discovery. If the **batch output & execute** checkbox is ON, batch generation and execution are performed. This batch starts parameter auto-discovery when executed. The **Timestamp Parameter Settings** step must be completed in advance.

The parameters explored include **smooth\_window**, **smooth\_window\_slide**, **lookback**, **lookback\_slide**, **smooth\_window2**, **smooth\_window\_slide2**, **threshold**, and **sign**.

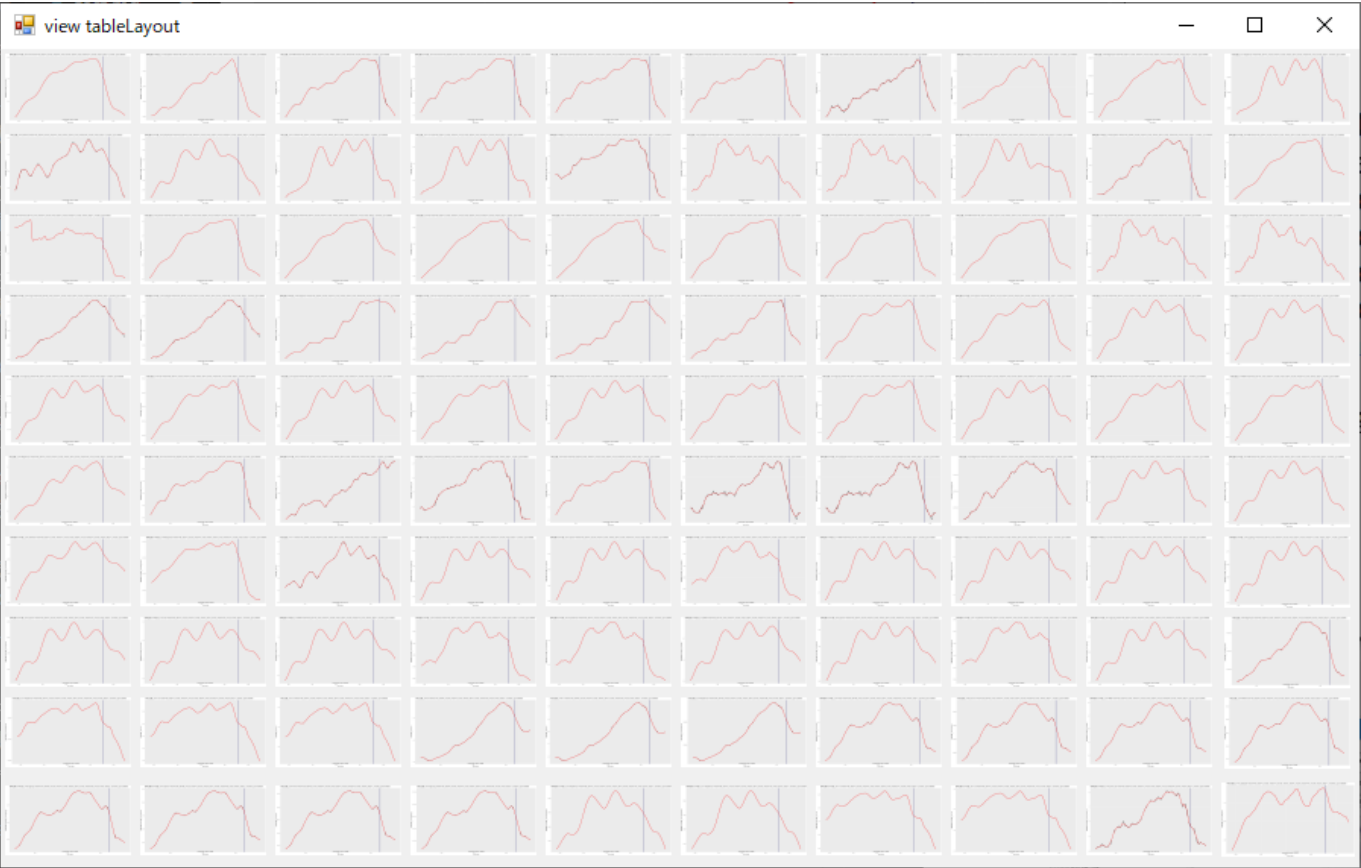
During this exploration, all files in the folder specified during **Importing CSV Data** are combined, and the entire observation period is targeted for exploration.

When batch execution ends, the most suitable parameter settings and feature graphs are displayed.

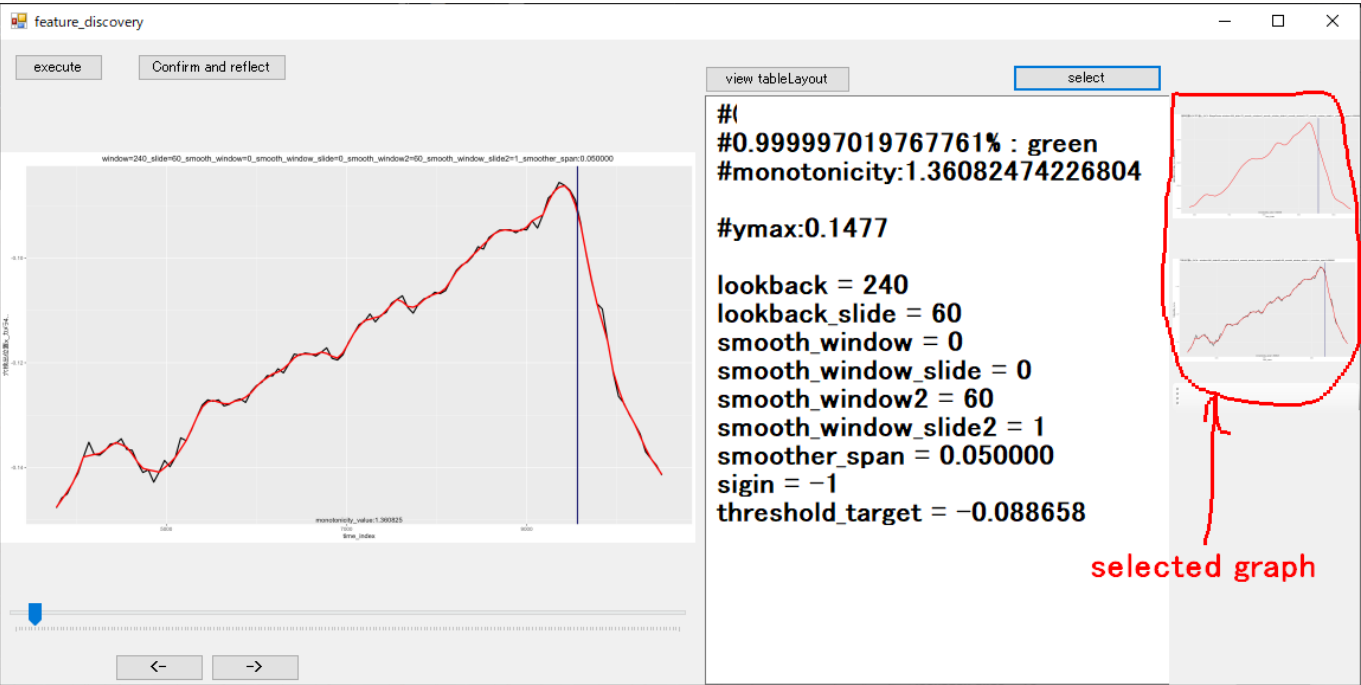




Press the **view tableLayout** button to display all candidate feature graphs deemed suitable.



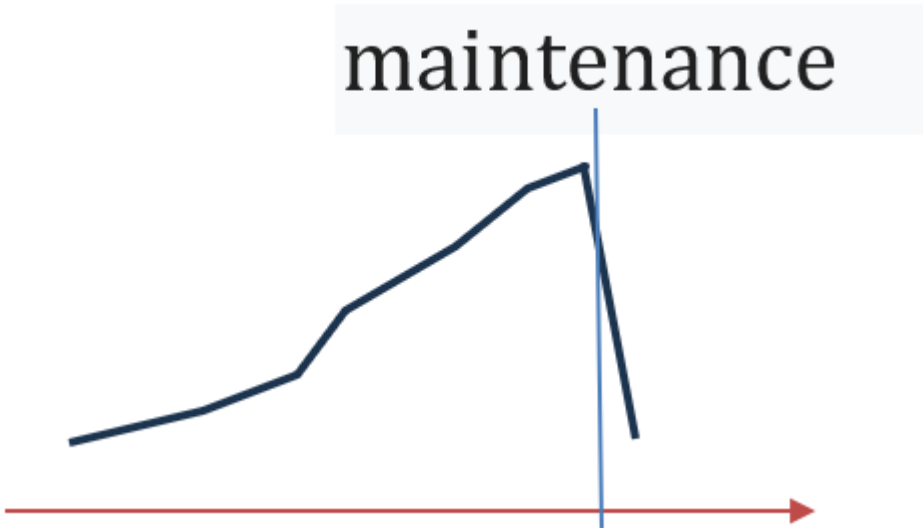
From this list, select appropriate feature graphs or use the trackbar to display suitable feature graphs and confirm the selection with the **select** button. Up to two features can be selected.



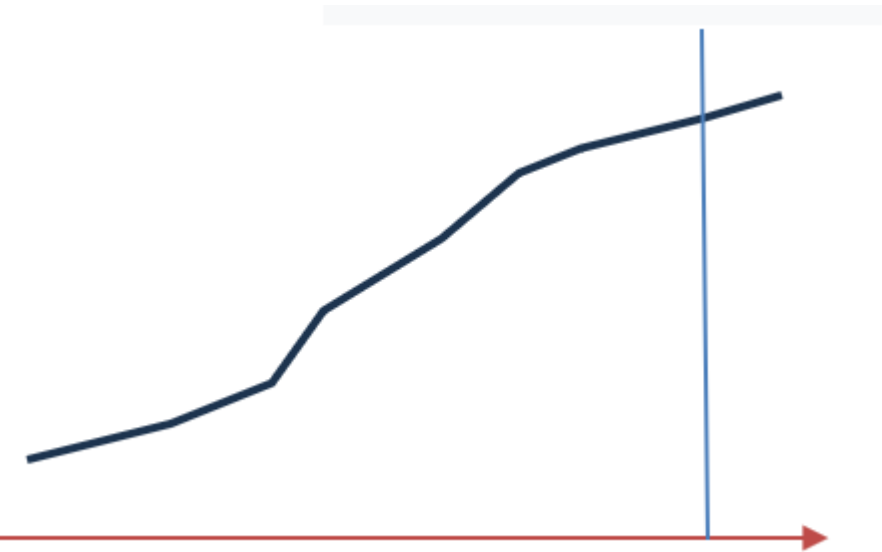
Double-click a selected graph to deselect it. For tracking RUL, the topmost selected graph is used as the primary feature, while the second graph is used as a supplemental feature. Be sure to select two features.

## About Selecting Features and CSV Data Items

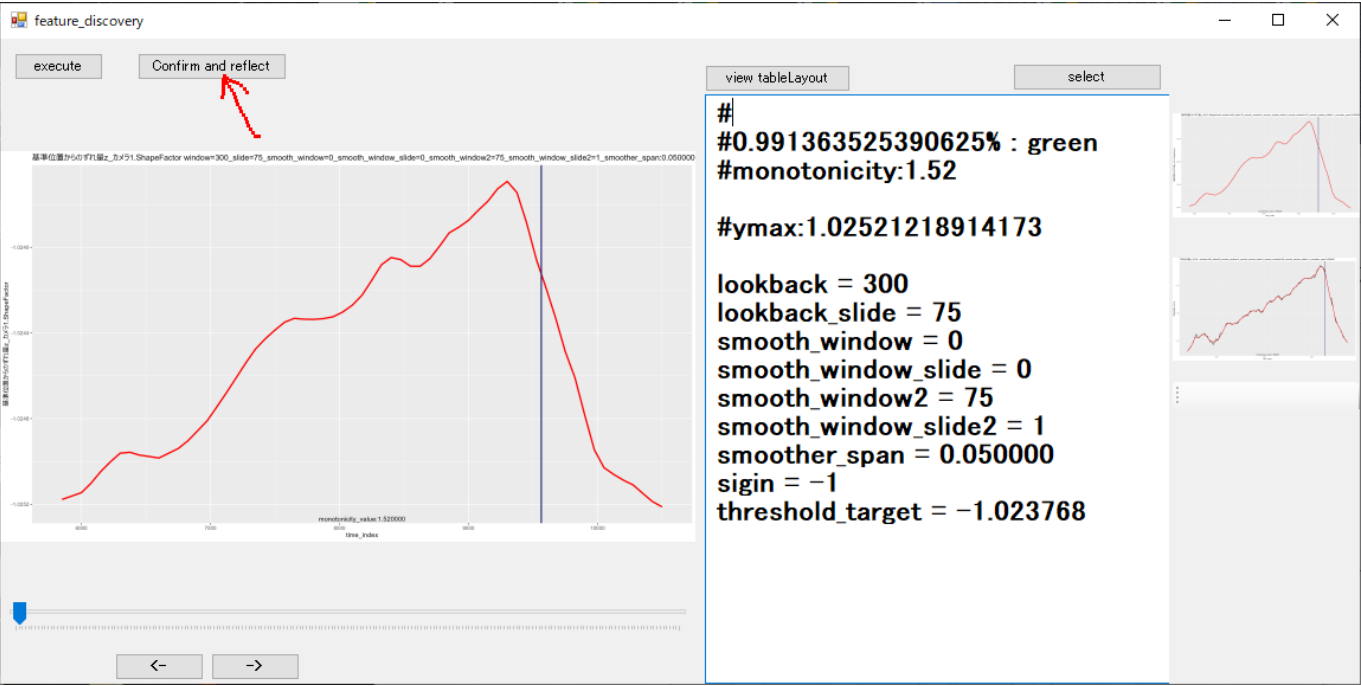
Features for tracking RUL must have an upward trend and exhibit a rapid decrease after maintenance.



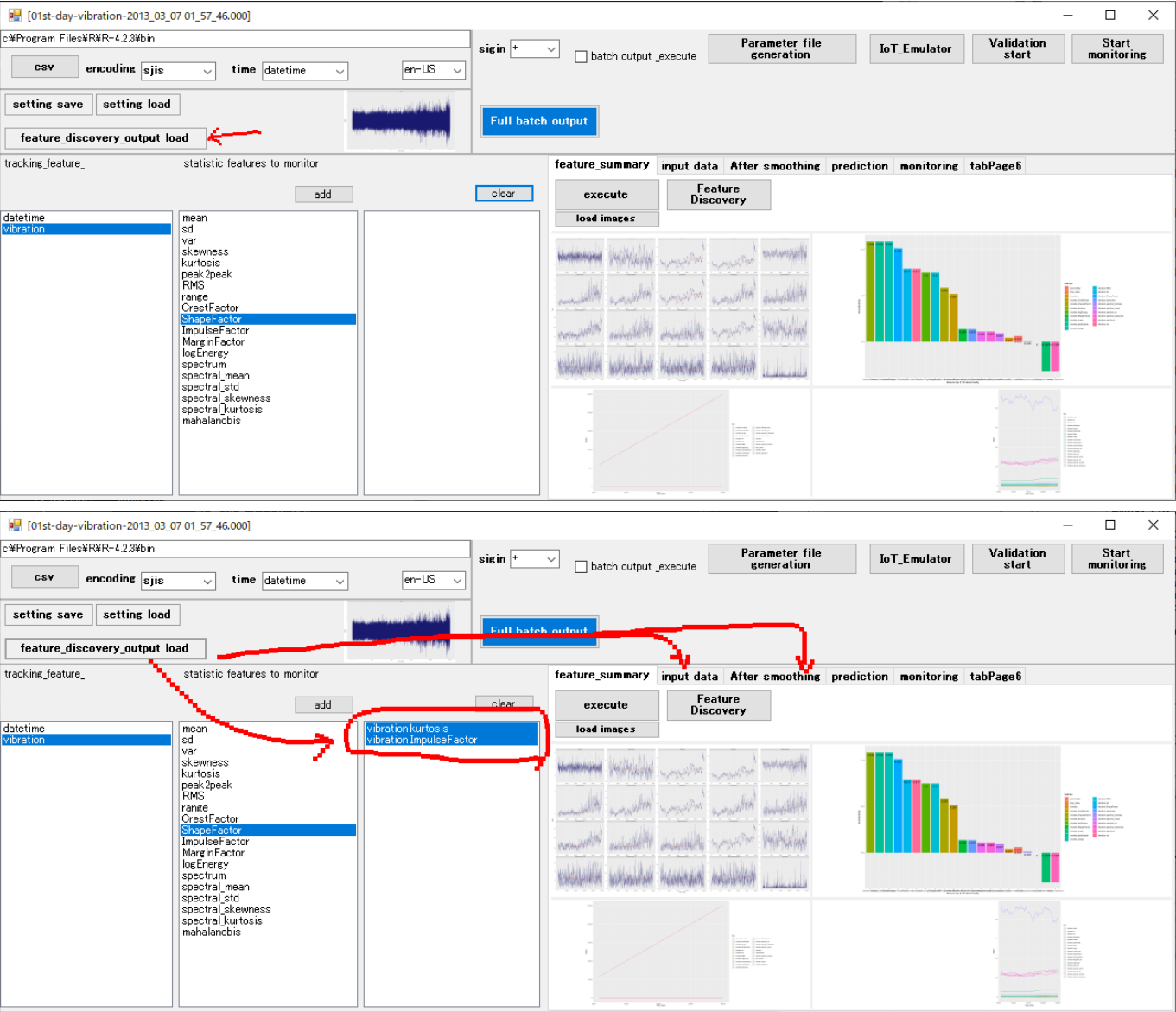
The entire observation period is targeted, but if a column named **maintenance** (with a value of 1 during maintenance periods) exists, the data from the start to the next maintenance and the subsequent maintenance position are extracted to check if they meet the tendencies of features tracking RUL. If no **maintenance** column exists, the data is assumed to start at the beginning and end just before the termination point as if maintenance was performed there. The tendency to meet RUL tracking feature cr...



Confirm with the **confirm and reflect** button.



Next, press the **feature\_discovery\_output load** button to set all the parameters and selected features from exploration and selection.



## Operation Execution

Using the parameter settings generated in **Forecast Execution (Validation)**

"**work/xxxx\_feature\_param.csv**", RUL is tracked during operation. Once started, the folder (**work\Untreated**) for processing CSV files is periodically accessed, and files are processed if present.

---

## Appendix

---

### Time Domain Features

#### Mean

- **Characteristics:** Represents the central tendency of the vibration signal.
- **Advantages:** Helps track baseline shifts or long-term level changes, though it is less sensitive to impulsive events.

#### Standard Deviation (Std)

- **Characteristics:** Quantifies the dispersion or spread of the signal values.
- **Advantages:** Increases in variability may indicate abnormal behavior or the onset of degradation.

#### Skewness

- **Characteristics:** Measures the asymmetry of the signal's distribution.
- **Advantages:** Changes in symmetry can signal early fault symptoms, as the distribution may shift when abnormal events occur.

#### Kurtosis

- **Characteristics:** Assesses the "peakedness" or heaviness of the tails in the signal's distribution.
- **Advantages:** High kurtosis values often highlight sharp, impulsive peaks typical in fault conditions. In this example, kurtosis is identified as a key indicator.

#### Peak-to-Peak

- **Characteristics:** The difference between the maximum and minimum signal values.
- **Advantages:** Captures the overall amplitude variation, making it sensitive to sudden shocks or spikes.

#### RMS (Root Mean Square)

- **Characteristics:** Represents the effective value or energy content of the vibration signal.
- **Advantages:** Provides an overall measure of vibration energy, which can increase as degradation progresses.

#### Crest Factor

- **Characteristics:** The ratio of the maximum amplitude to the RMS value.
- **Advantages:** Emphasizes the impact of sudden peaks relative to the overall energy, serving as an indicator of impulsiveness.

## Shape Factor

- **Characteristics:** The ratio of the RMS value to the mean absolute value.
- **Advantages:** Reflects the waveform shape, helping distinguish between normal and abnormal signal forms.

## Impulse Factor

- **Characteristics:** The ratio of the maximum value to the mean absolute value.
- **Advantages:** Highlights the presence of extreme peaks, which are often associated with early fault symptoms.

## Margin Factor

- **Characteristics:** The ratio of the maximum value to the square of the mean absolute value.
- **Advantages:** Further accentuates the effect of outliers or sudden bursts in the signal, enhancing sensitive fault detection.

## Energy

- **Characteristics:** The sum of the squared signal values.
- **Advantages:** Measures the total energy in the vibration signal, which can increase as the component begins to deteriorate.

---

## Frequency Domain Features (Based on Spectral Kurtosis)

### SKMean

- **Characteristics:** The average value of the spectral kurtosis across different frequency bands.
- **Advantages:** Provides an overall measure of impulsiveness in the frequency domain, revealing degradation trends over a range of frequencies.

### SKStd

- **Characteristics:** The standard deviation of the spectral kurtosis values.
- **Advantages:** Captures variability in impulsiveness across frequencies, highlighting localized abnormal behavior.

### SKSkewness

- **Characteristics:** Evaluates the asymmetry of the spectral kurtosis distribution.
- **Advantages:** A skewed distribution may indicate that certain frequency components are disproportionately affected, serving as an early warning sign.

### SKKurtosis

- **Characteristics:** Measures the peakedness of the spectral kurtosis distribution.
- **Advantages:** Enhances detection of outlier frequency components that are often associated with incipient faults.

## Overall Benefits

- **Comprehensive Signal Analysis:**

By extracting both time-domain and frequency-domain features, the approach provides a multi-faceted view of the signal, capturing gradual changes (e.g., baseline shifts or energy increases) as well as sudden, impulsive events.

- **Enhanced Fault Detection:**

Features such as kurtosis, crest factor, and spectral kurtosis are particularly sensitive to impulsive changes and serve as early indicators of bearing degradation.

- **Robust Health Indicator:**

The combination and fusion of these features (using techniques like PCA) yield a more reliable health indicator, which is essential for predicting the remaining useful life (RUL) of the component.

<https://mathworks.com/help/predmaint/ug/wind-turbine-high-speed-bearing-prognosis.html>