RUL Prediction of Oscillation Dataset using Hjorth's Parameters

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Contents

Proposal Summary (1)

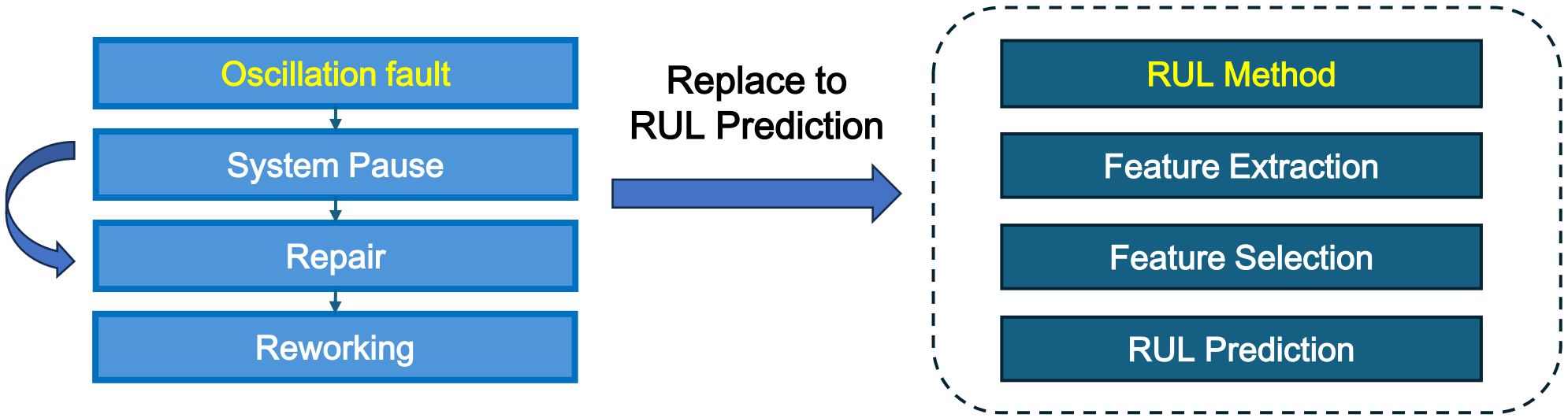


Figure. 1 Previous Method to Improved Method (RUL)

Proposal Summary (2)

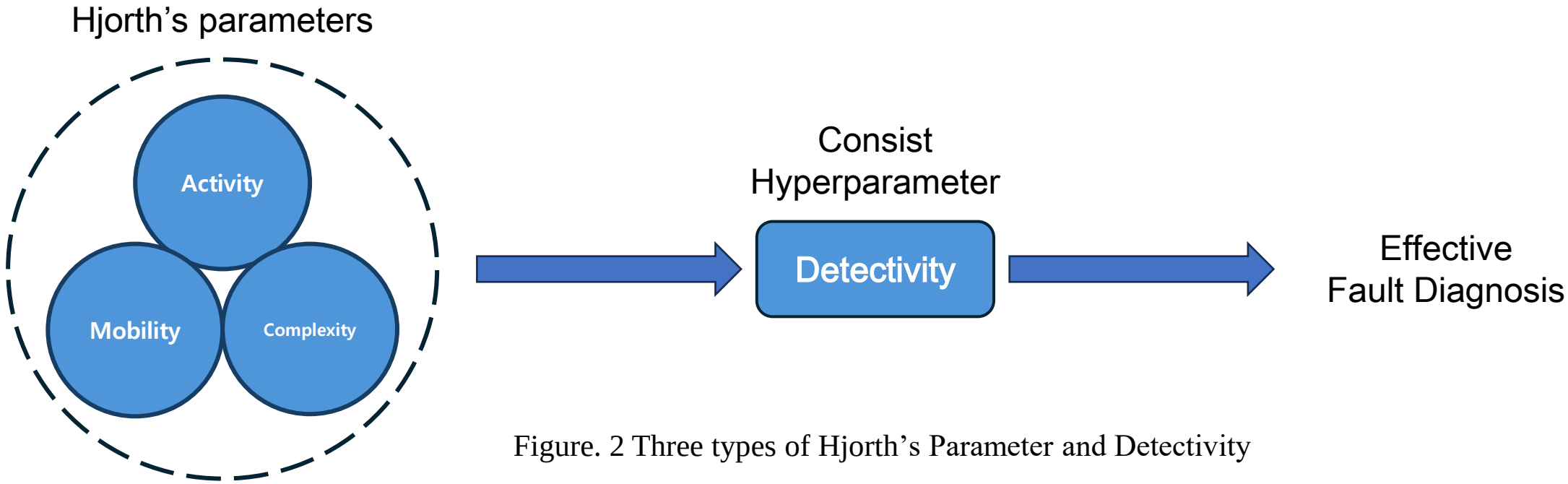


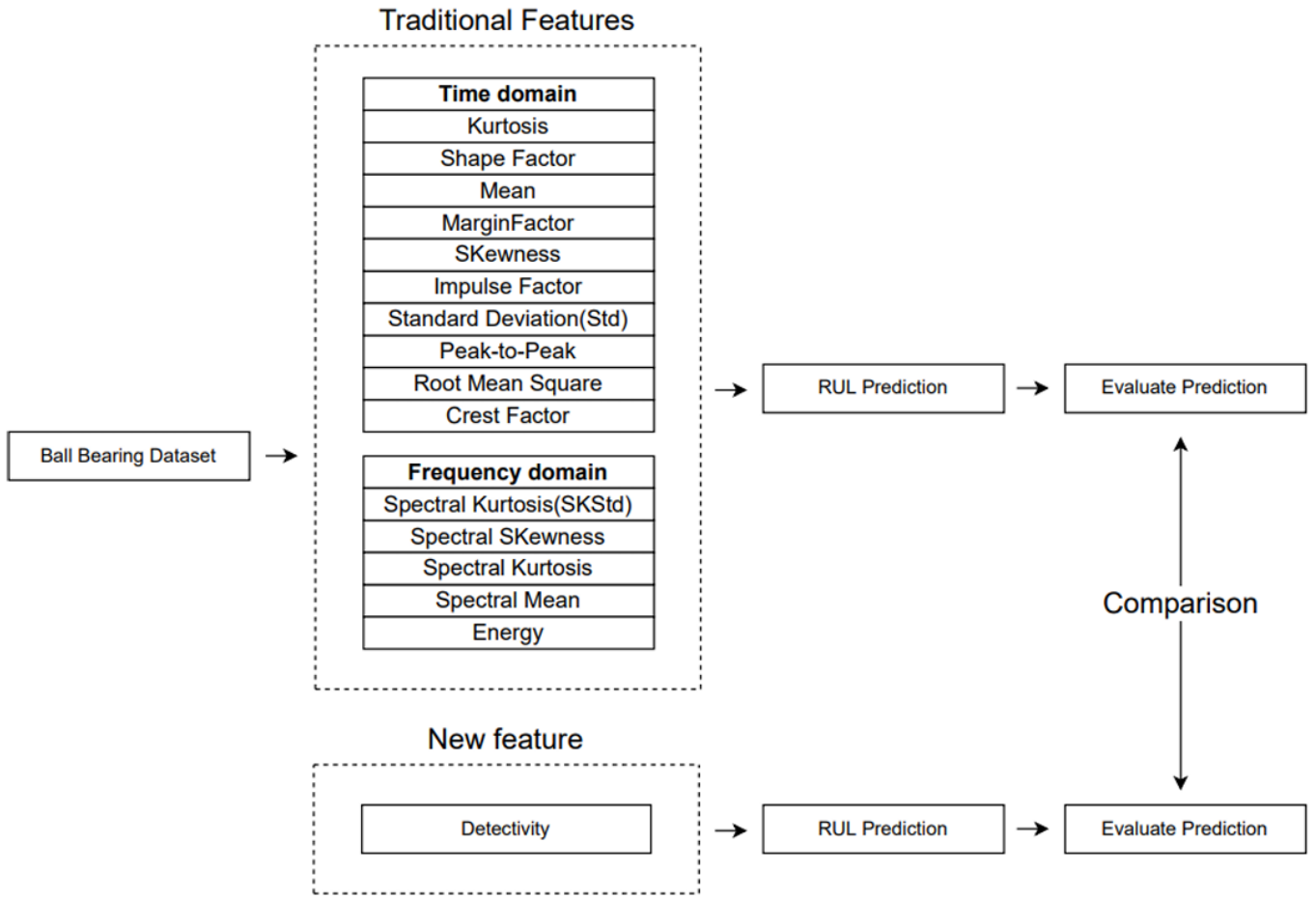
Figure. 2 Three types of Hjorth's Parameter and Detectivity

- $Activity_i(x) = \sigma^2(signal_i[n])$
- $Mobility_i(x) = \sqrt{\frac{Activity_i(\dot{x})}{Activity_i(x)}}$
- $Complexity_i(x) = \frac{Mobility_i(\dot{x})}{Mobility_i(x)}$

- $Act_{ref},\ Mob_{ref},\ Com_{ref} = Average(Act),\ Average(Mob),\ Average(Com)$
- $Act_{dB},\ Mob_{dB},\ Com_{dB} = 10\log_{10}\frac{Act}{Act_{ref}},\ 10\log_{10}\frac{Mob}{Mob_{ref}},\ 10\log_{10}\frac{Com}{Com_{ref}}$
- $Detectivity = Act_{dB} - Mob_{dB} + Com_{dB}$

Proposal Summary (3)

[1] Cocconcelli, M., Strozzi, M., Camargo Molano, J. C., & Rubini, R. (2022). Detectivity: A combination of Hjorth's parameters for condition monitoring of ball bearings. Mechanical Systems and Signal Processing, 164, 108247. https://doi.org/10.1016/j.ymssp.2021.108247



We will extract dominant traditional features to compare traditional RUL prediction with new RUL prediction by using new parameter named detectivity

Figure. 3 Flow Chart of Overall Project

Datasets

[2] Link 1: GitHub - mathworks/WindTurbineHighSpeedBearingPrognosis-Data: Data set for Wind Turbine High-Speed Bearing Prognosis example in Predictive Maintenance Toolbox

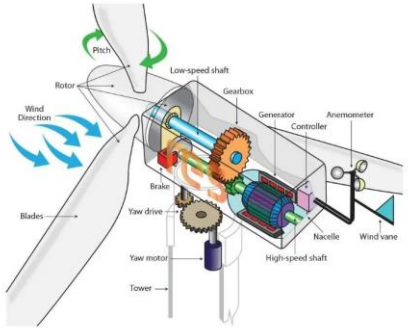


Figure. 4 Wind Turbine

Dataset

Hardware: 20-tooth pinion gear / 2 [MW]

Sampling frequency: 97.66 [kHz]

Sampling time: 6 [s/day]

Data number: 585,936 data of each 50 files

Sampling period: 50 [day]

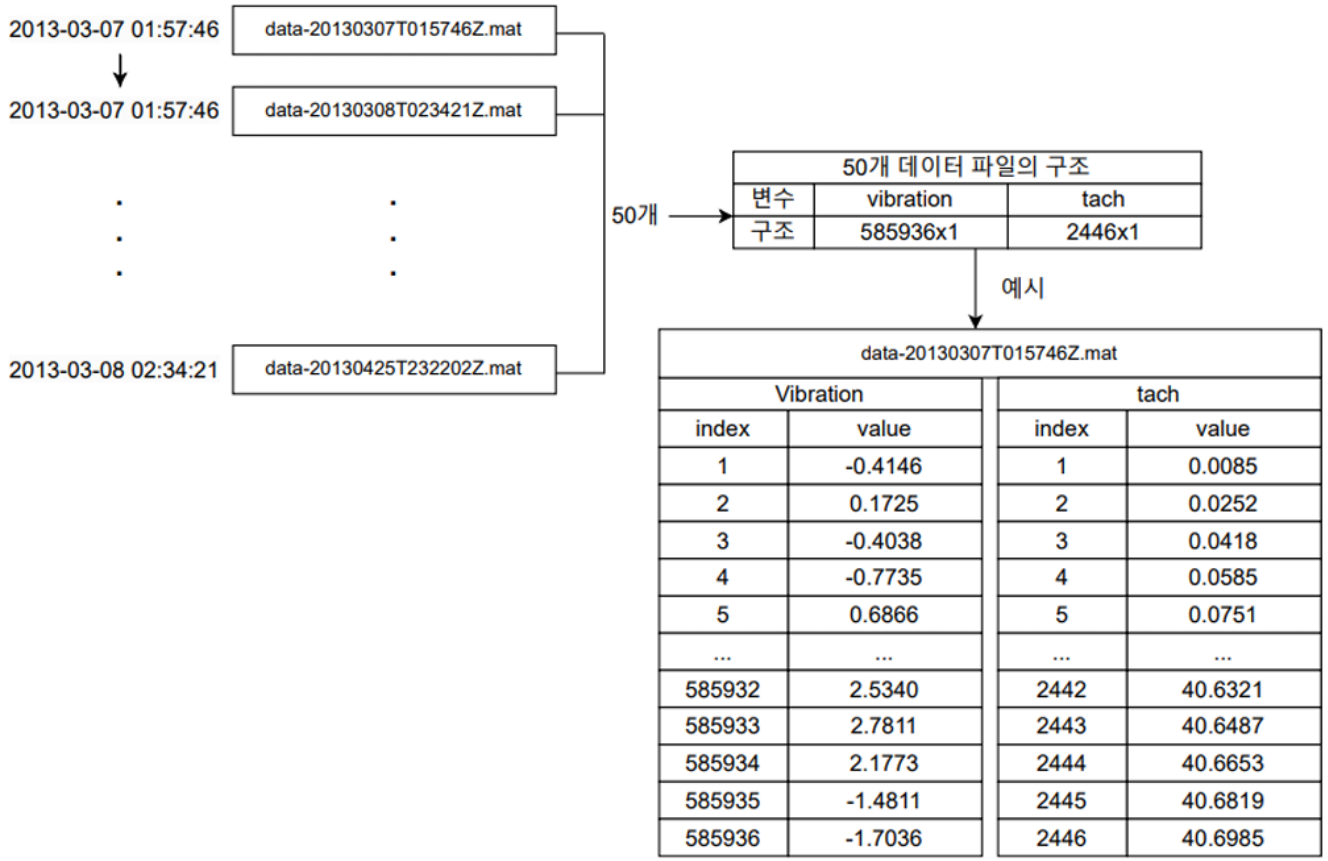
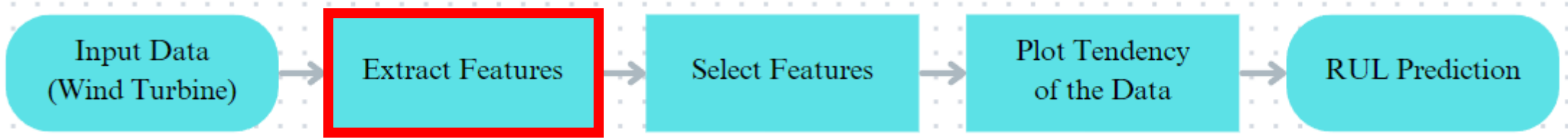


Figure. 5 Structure of Wind Turbine Dataset

Data Analysis 1 (Compare RUL Methods: General Method)



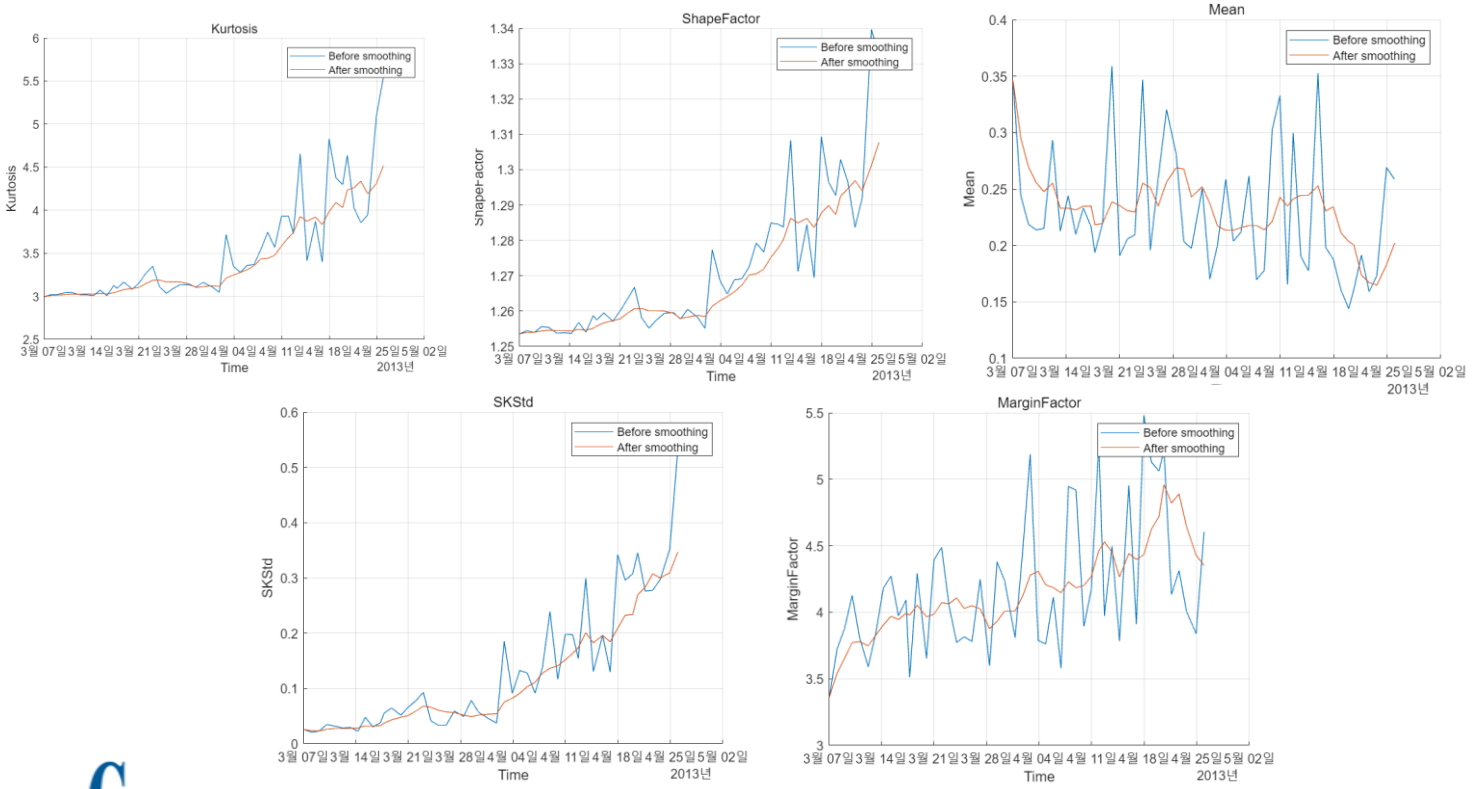


Figure. 6 Plot Traditional Features (Smoothed)

Time domain
Kurtosis
Shape Factor
Mean
MarginFactor
SKewness
Impulse Factor
Standard Deviation(Std)
Peak-to-Peak
Root Mean Square
Crest Factor

Frequency domain
Spectral Kurtosis(SKStd)
Spectral SKewness
Spectral Kurtosis
Spectral Mean
Energy

Figure. 7 Traditional Feature List

Smoothing Option:

Moving Average Filter

(Window Size = 5)

Data Analysis 1 (Compare RUL Methods: General Method)

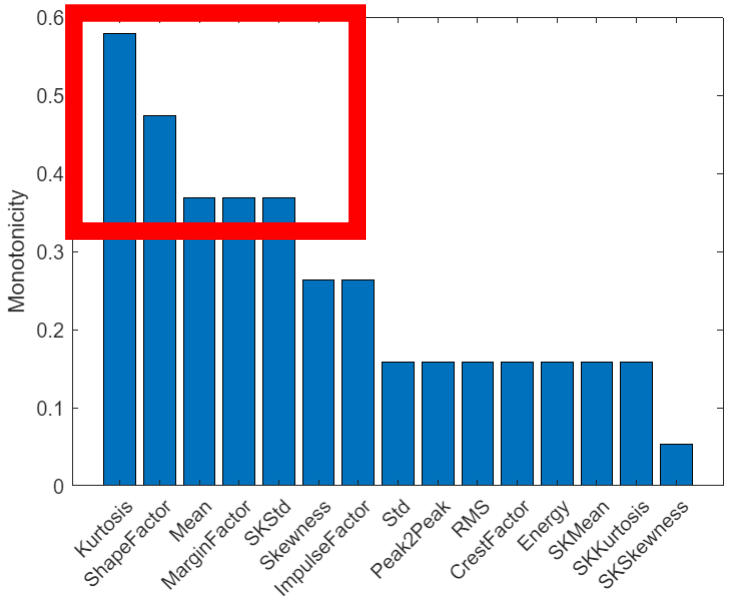


Figure. 6 Monotonicity of the Data

Traditional Features: Kurtosis, Shape Factor, Mean, Margin Factor…

Select Criteria: Monotonicity > 0.3 (30 [%])

Selected Data: Kurtosis, Shape Factor, Mean, Margin Factor, SKStd

Data Analysis 1 (Compare RUL Methods: General Method)

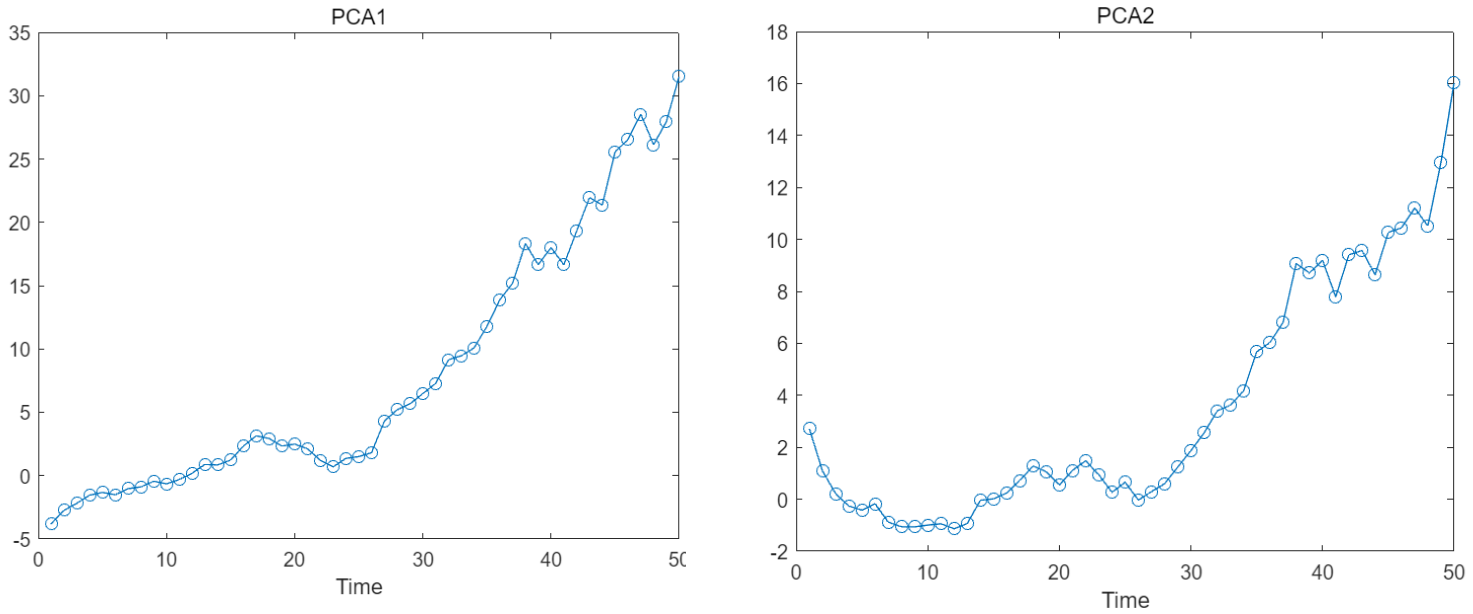
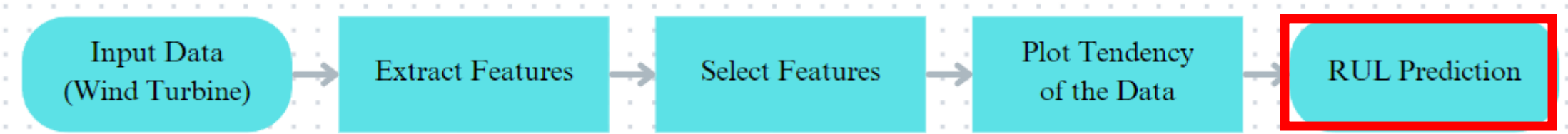


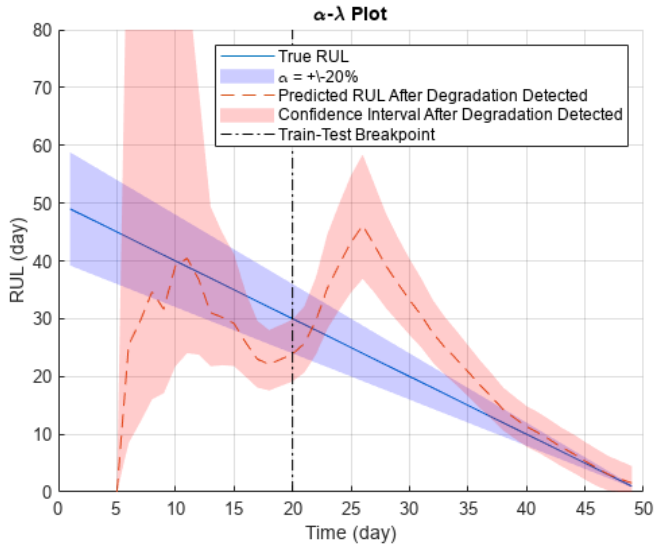
Figure. 8 Plot Tendency of the Data (Consist of 5 Selected Features)

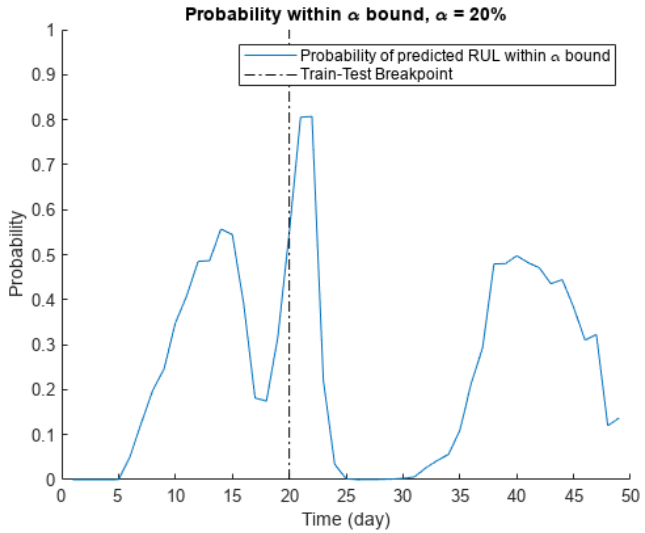
After selecting five features, we extracted PCA value to reduce the channel of features and organize all features into one feature.

We selected PCA1. because PCA1 shows higher monotonicity than PCA2.

Data Analysis 1 (Compare RUL Methods: General Method)





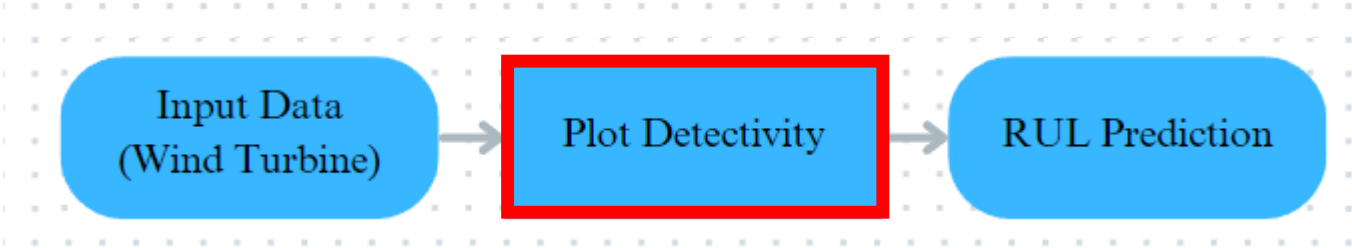


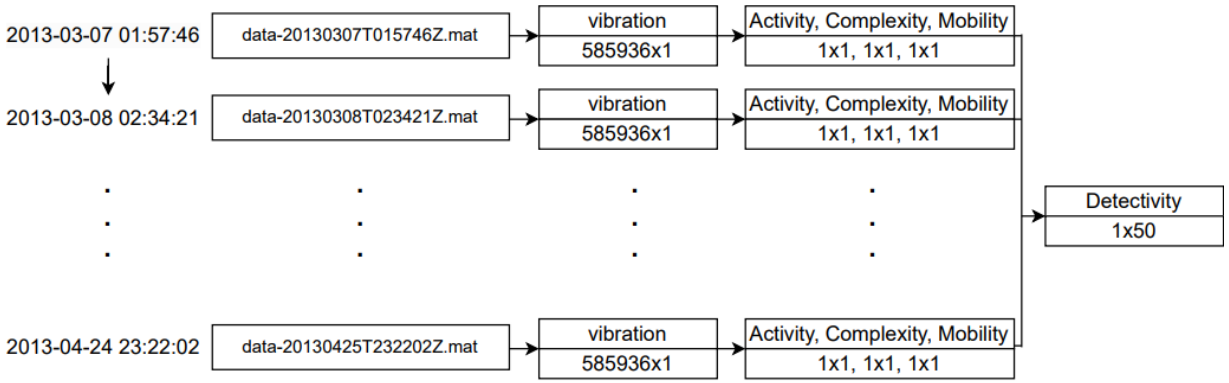
Probability means how near the true RUL between predicted RUL lines.

Around the breakpoint, probability is max.

Figure. 9 Plot RUL Prediction using PCA data

Data Analysis 1 (Compare RUL Methods: Detectivity Method)





Detectivity Dataset								
1	2	3	4	...	47	48	49	50
-0.3775	-0.6092	-0.4759	-0.8803	...	0.1405	0.6789	2.6225	1.9205

Figure. 10 Detectivity Extract

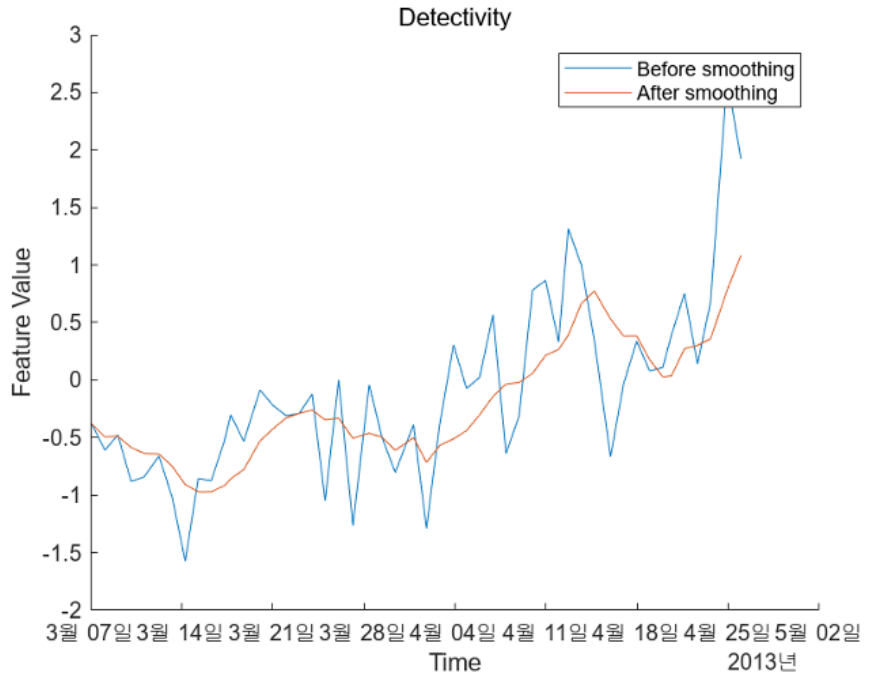
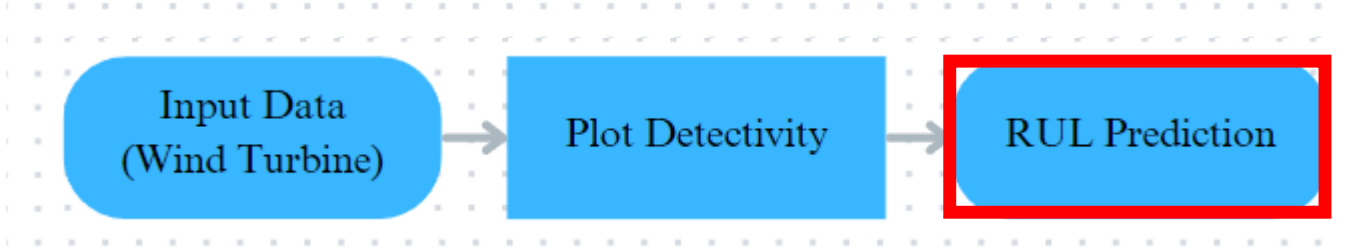
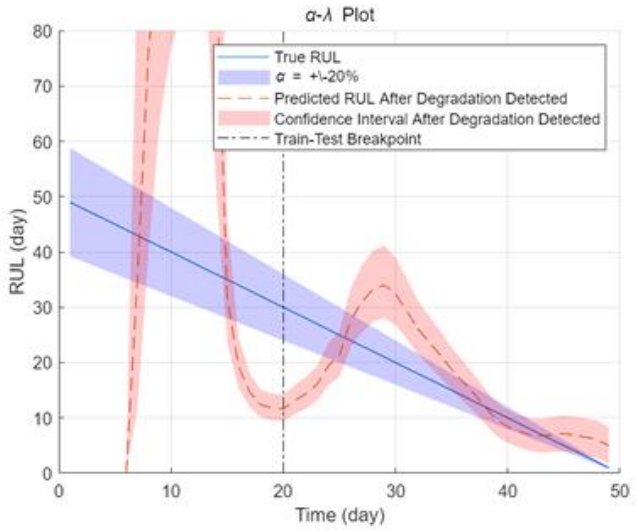
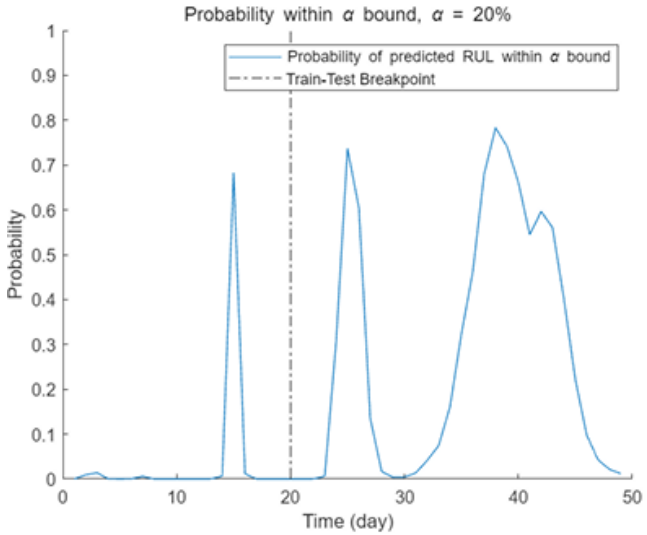


Figure. 11 Detectivity Plot (Moving Average Filter, Window Size = 5)

Data Analysis 1 (Compare RUL Methods: Detectivity Method)







Probability means how near the true RUL between predicted RUL lines.

Around the breakpoint, probability is max.

Figure. 12 Plot RUL Prediction using Detectivity hyperparameter

Discussion (Compare RUL Methods)

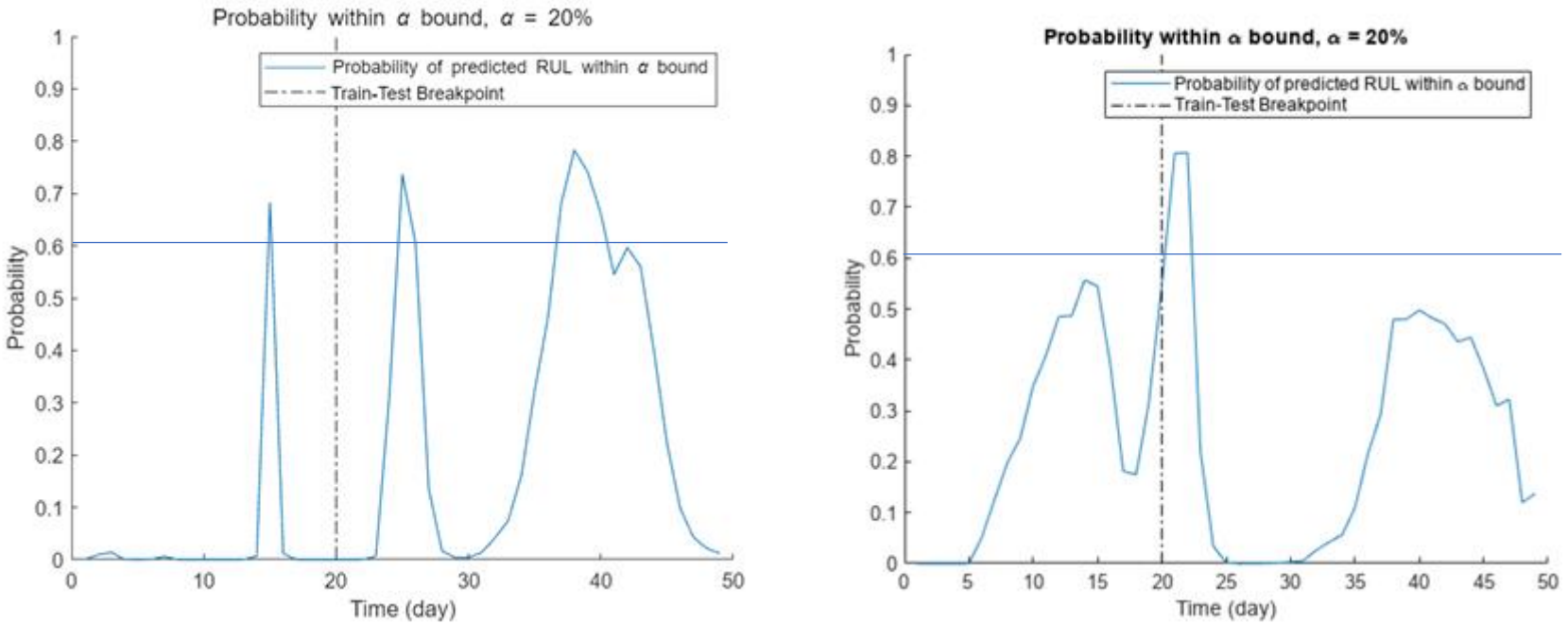


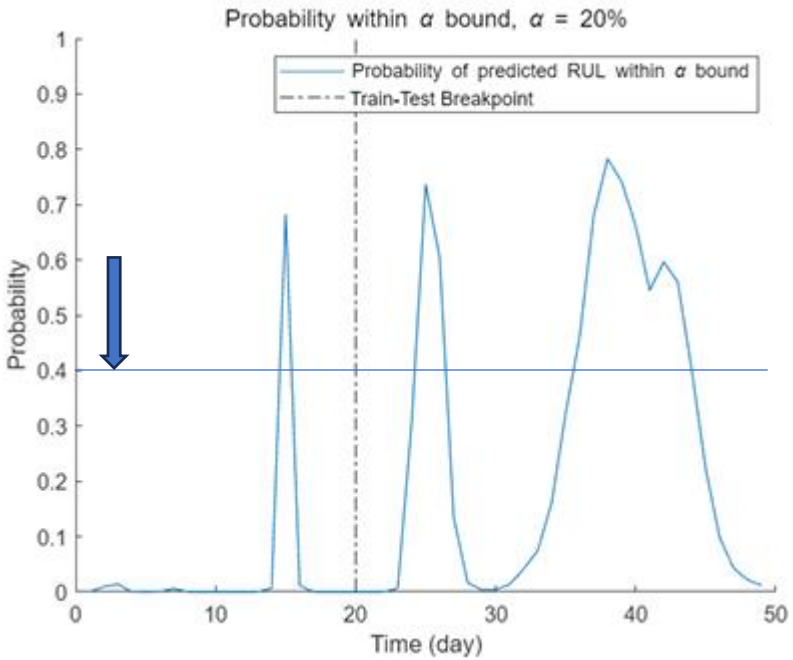
Figure. 13 Compare Probability of RUL Prediction (Left: Detectivity, Right: Traditional Features)

We evaluated the validity of the criteria: probability 0.6 (60 [%])

The RUL is only valid before the time of failure.

In this term, RUL using Detectivity can be evaluated as having the effect of improving failure prediction performance.

Discussion (Compare RUL Methods, Improvement Points)



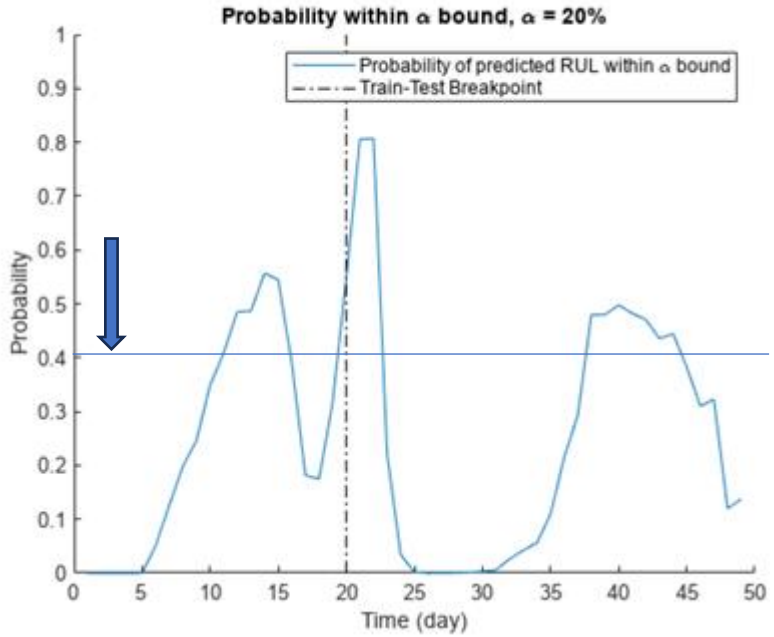


Figure. 14 Compare Probability of RUL Prediction Including Changed Criteria (Left: Detectivity, Right: Traditional Features)

RUL prediction using Detectivity is valid for probability 0.6 (60 [%]).

However, if the standard is lowered to 0.4 (40 [%]), the performance is poor in detecting failures early.

Discussion (Compare RUL Methods, Improvement Points)

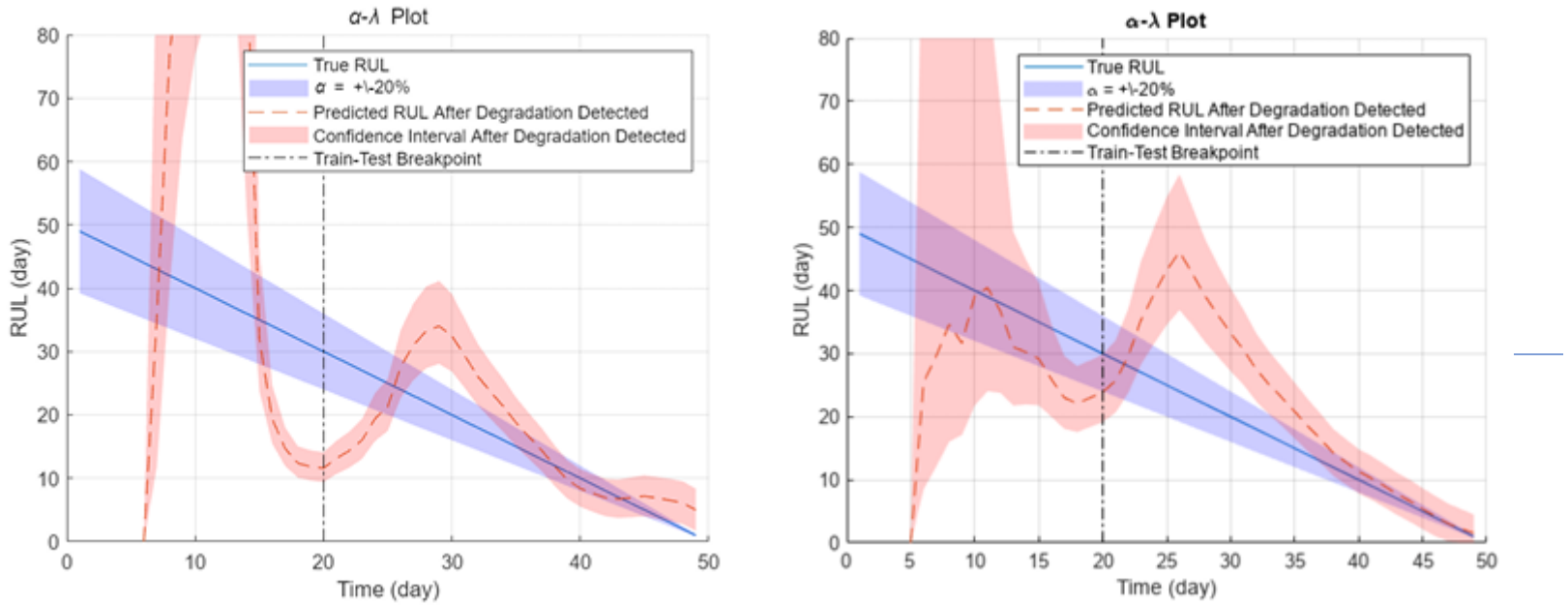


Figure. 15 α-λ plot (Left: Detectivity, Right: Traditional Features)

We predicted two causes of the problem.

First, it is the appropriateness of true RUL. Detectivity is a hyperparameter obtained by processing raw data into a [dB] scale. The settings of equivalent true RUL may be one of the reasons for performance degradation.

Discussion (Compare RUL Methods, Improvement Points)

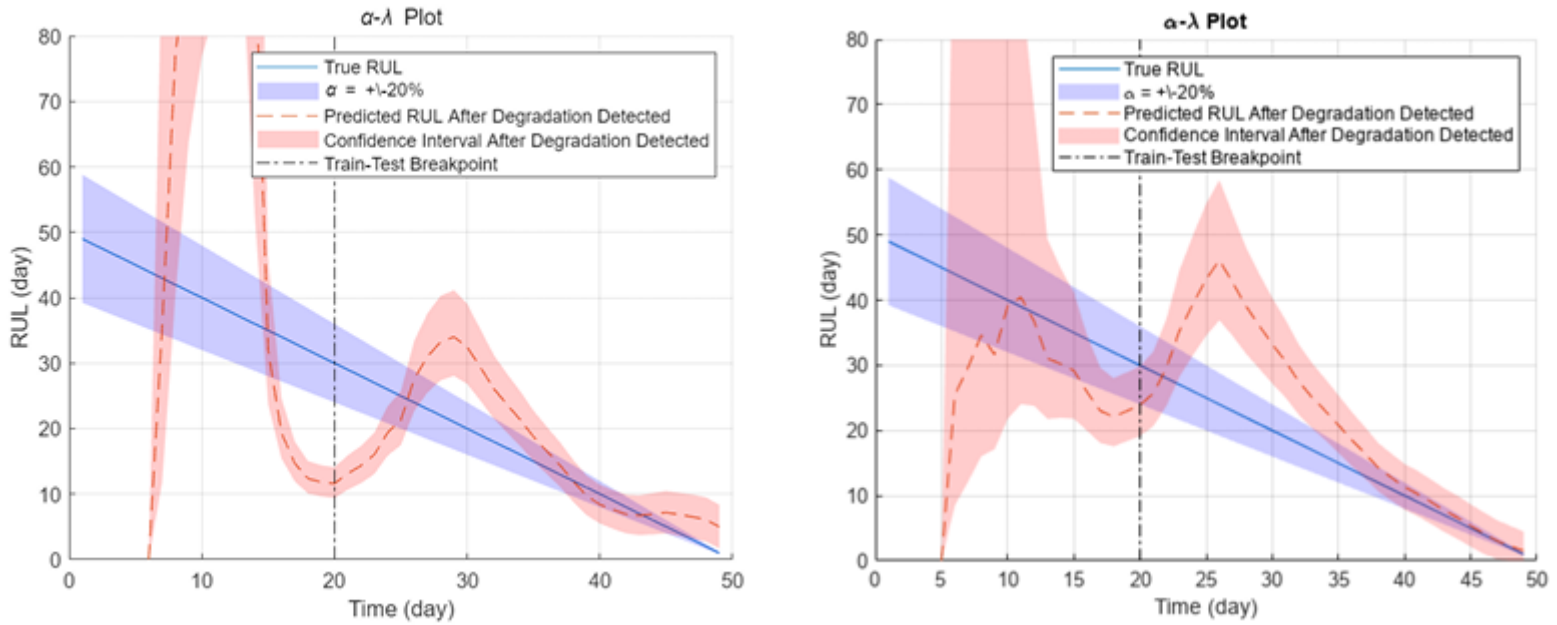


Figure. 16 α-λ plot (Left: Detectivity, Right: Traditional Features, Same as Figure. 15)

The second reason is the large variability of the predictive RUL.

Perceived RUL showed various trends every time whenever α-λ plot was performed.

The true RUL was set to a fixed graph beforehand. So, there is a need for improvement in the predicted RUL.

Conclusion

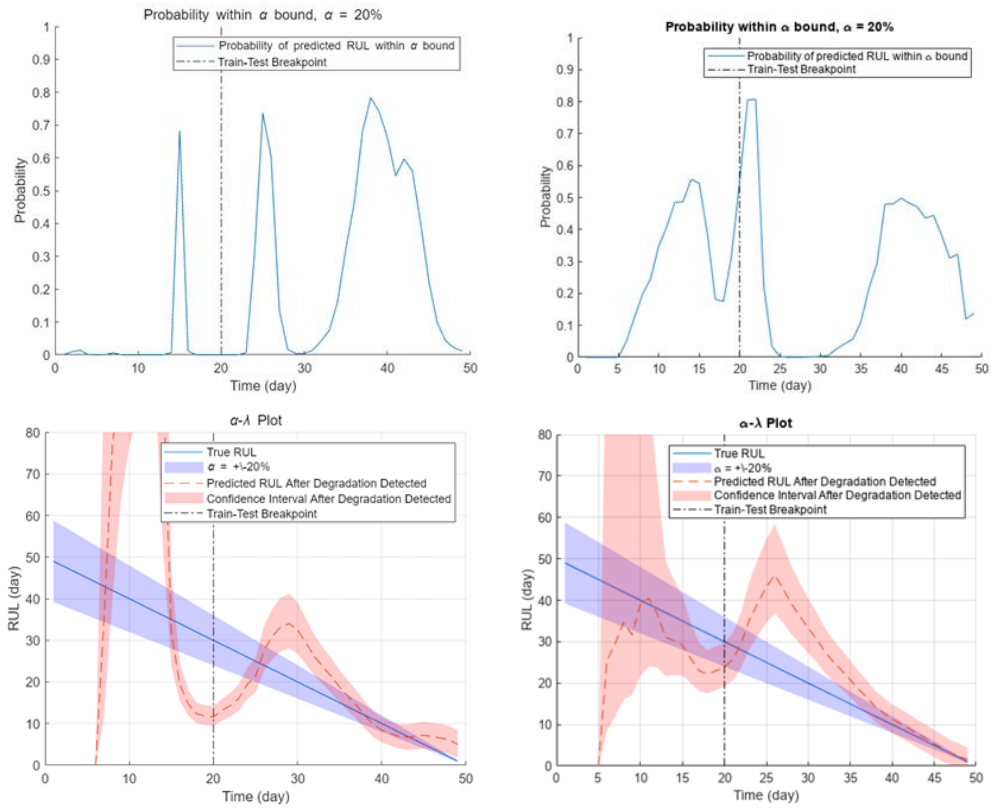


Figure. 17 Probability of RUL Prediction (Left: Detectivity, Right: Traditional Features)

We conducted RUL using Detectivity, to save time for feature extraction and produce effects similar traditional feature extraction method.

It is possible to evaluate indicator improvement by high probability criteria, but it was difficult to evaluate it by relatively low criteria. (60 [%], 40 [%])

We will further investigate the case of improving the surface performance through RUL prediction parameter adjustment such as true RUL and RUL evaluation for indicators on the [dB] scale.

Appendix

[1] Cocconcelli, M., Strozzi, M., Cavagliato Camargo Molano, J., & Rubini, R. (2022). Detectivity: A combination of Hjorth's parameters for condition monitoring of ball bearings. Mechanical Systems and Signal Processing, 164, 108247. https://doi.org/10.1016/j.ymssp.2021.108247

[2] Saxena, A., Celaya, J., Balaban, E., Goebel, K., Saha, B., Saha, S., & Schwabacher, M. (2008). Metrics for evaluating performance of prognostic techniques. 2008 International Conference on Prognostics and Health Management (PHM), 1-8. https://doi.org/10.1109/PHM.2008.4711436