The key research on fault diagnosis of locomotive transmission devices

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Background

Background

Maintenance of locomotive：

- **Repair maintenance**： maintenance is carried out after fault has occurred, also known as accident repair or failure.
- **Preventive maintenance:** repair and replacement before the failure of the components, also known as planned repair.

Background

Current fault diagnosis and prediction method for traction devices:

01 Traditional artificial diagnosis methods

Artificial detection, empirical processing.

02 Diagnosis method based on expert database and neural network

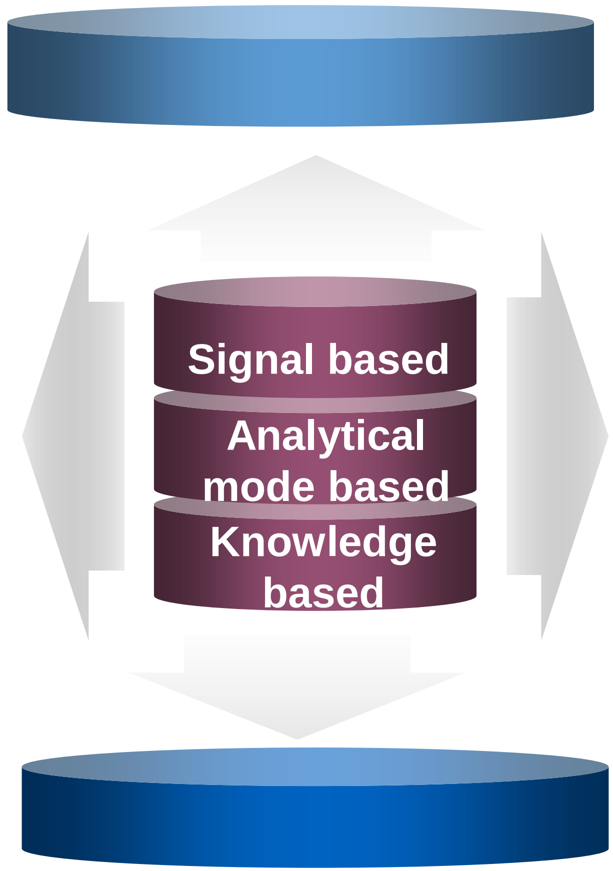
Fault diagnosis of equipment is carried out by means of neural network, fault tree and expert database.

Background

- Research status

In China

Shanghai Jiaotong University;
Sichuan University;
Tsinghua University.



In other country

Case Western Reserve University;
Michigan state university;
General Electric Research Institute.

Research significance

1

Make the maintenance plan according to the condition of the target. Realize the state repair, save costs, realize the maximum use of resources.

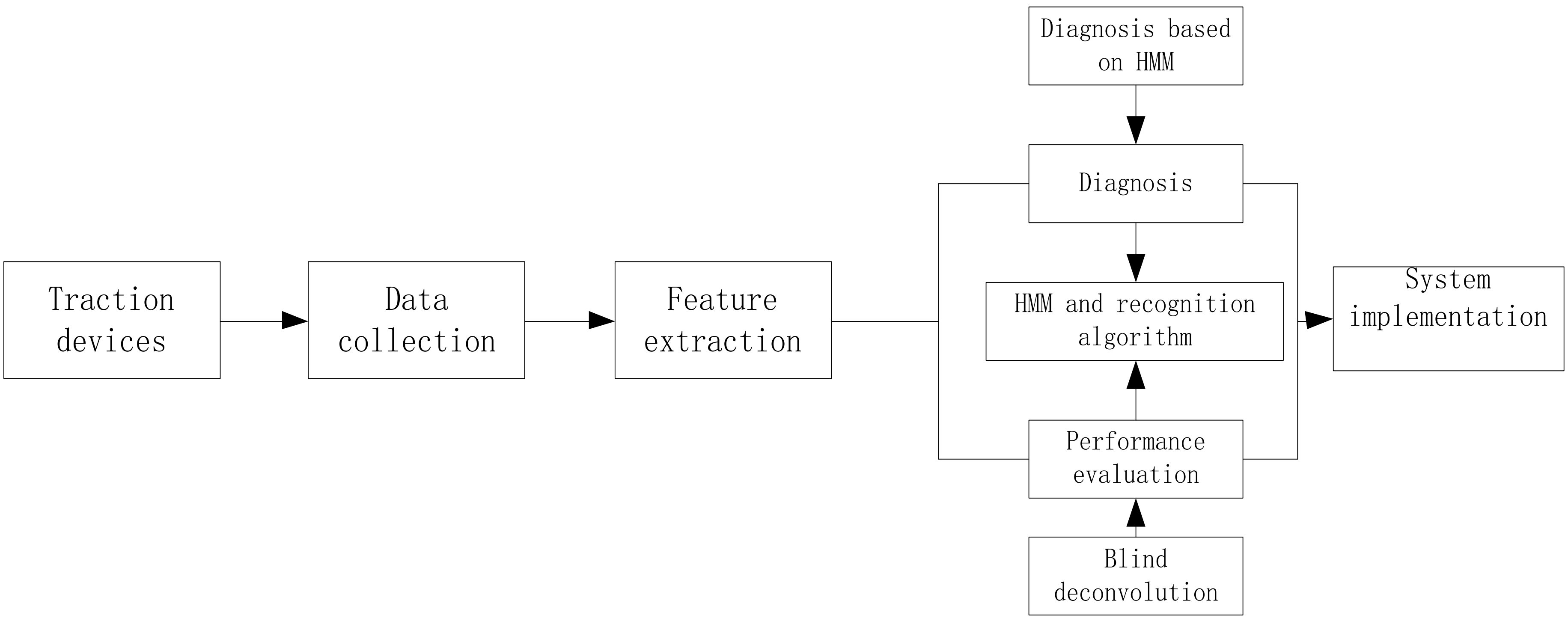
2

Machine learning is an important research field of artificial intelligence after expert system. It has the ability to deal with big data which is not available in previous research methods;

3

Accurate and effective diagnosis and prediction of the status of transport equipment can prevent real-time accidents and serious damage.

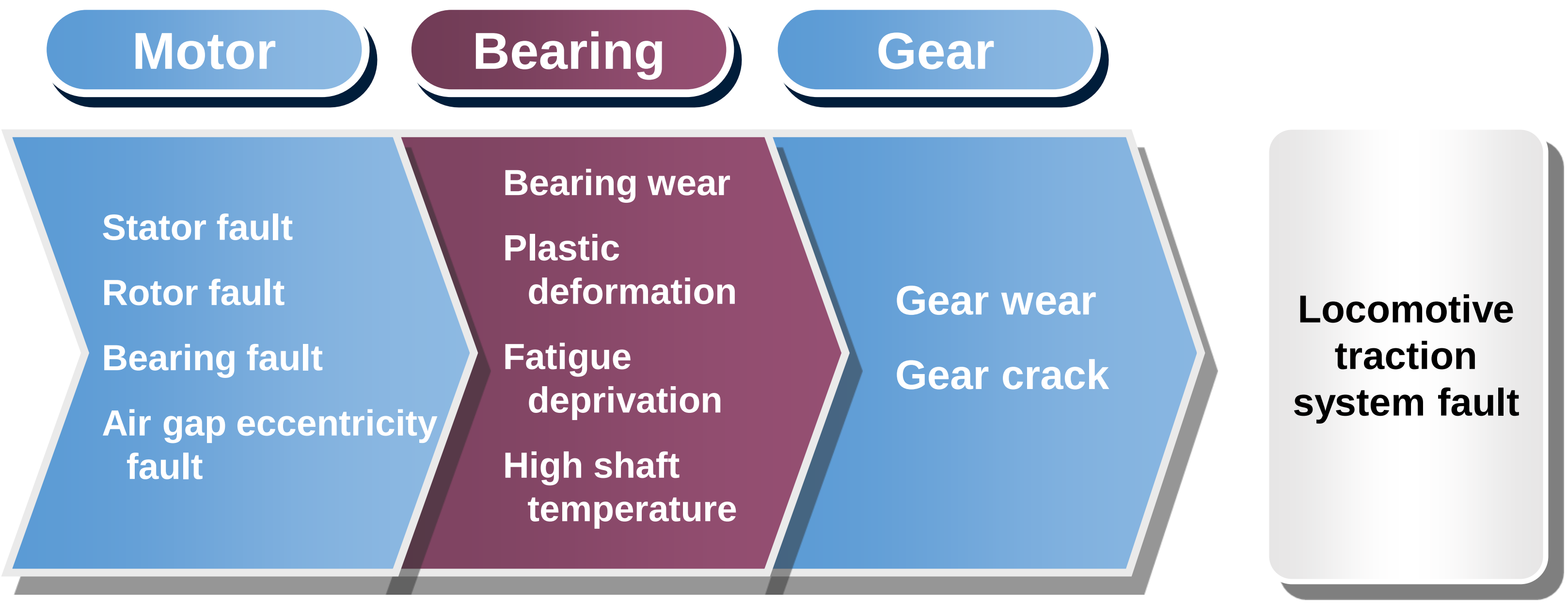
Research Plan



Structure chart

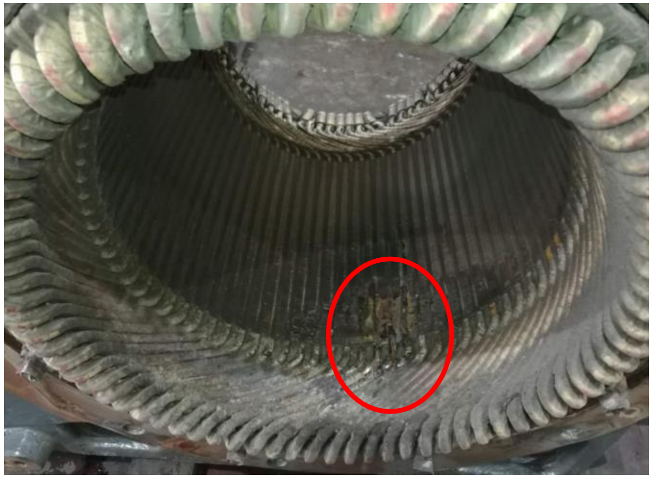
Research Object

Research Object

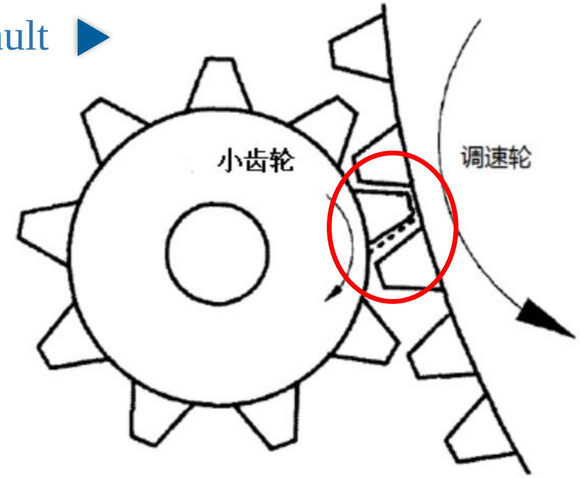


Research Object

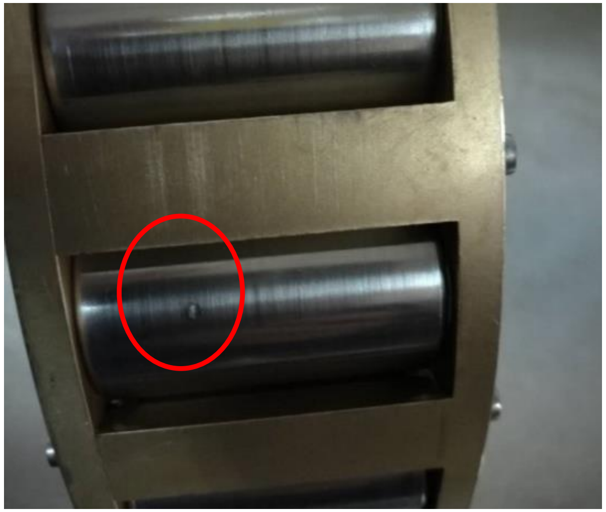
Motor fault

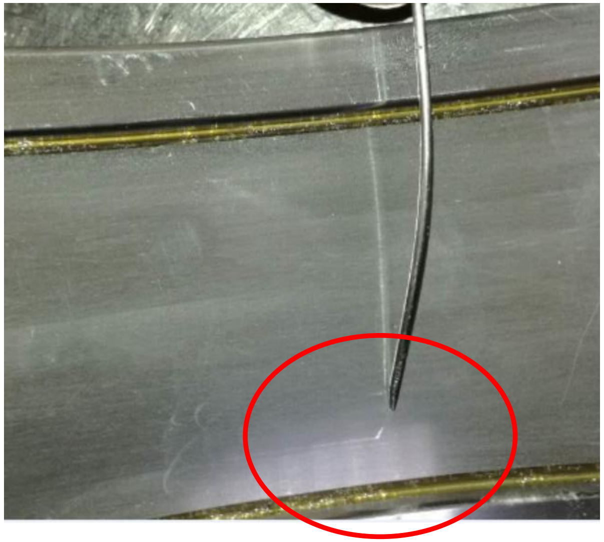


Gear fault



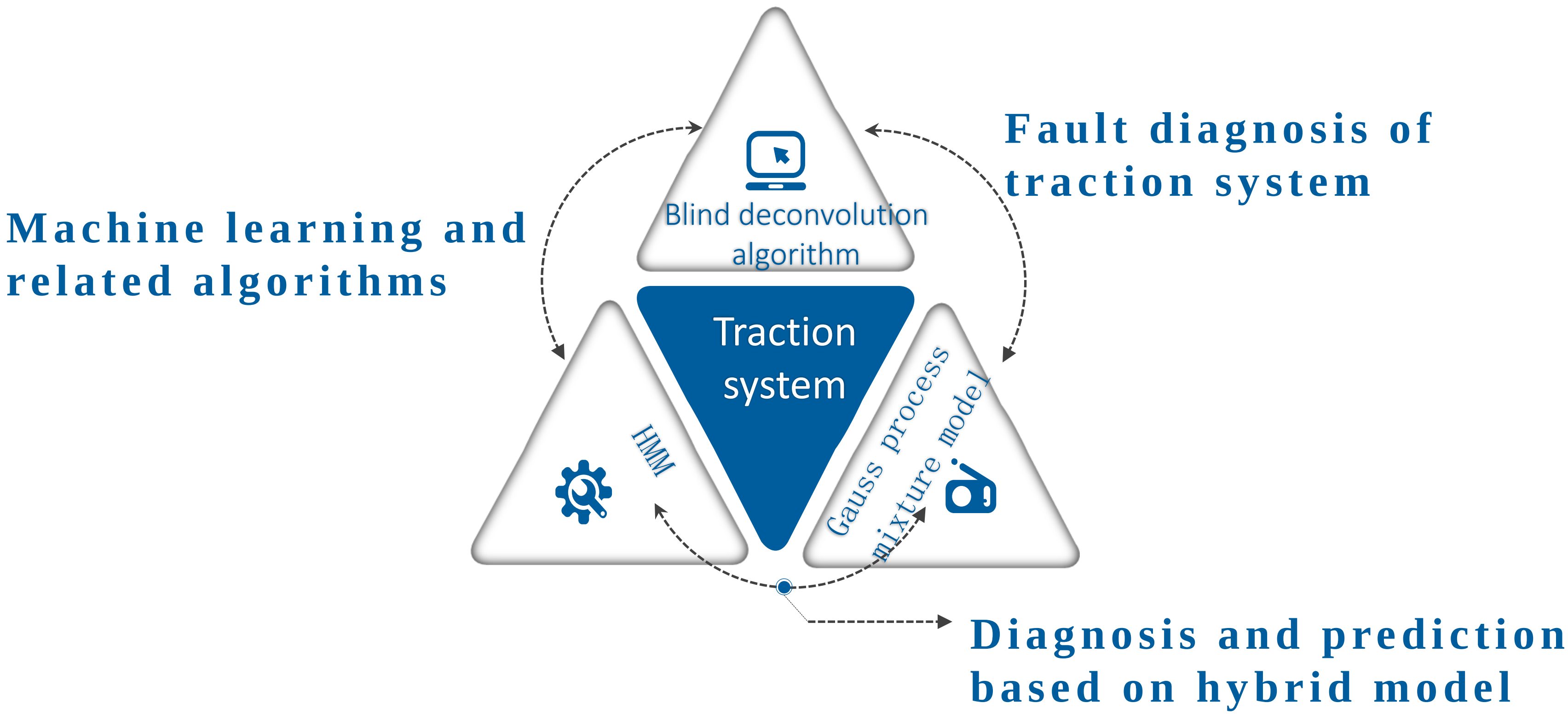
Bearing fault



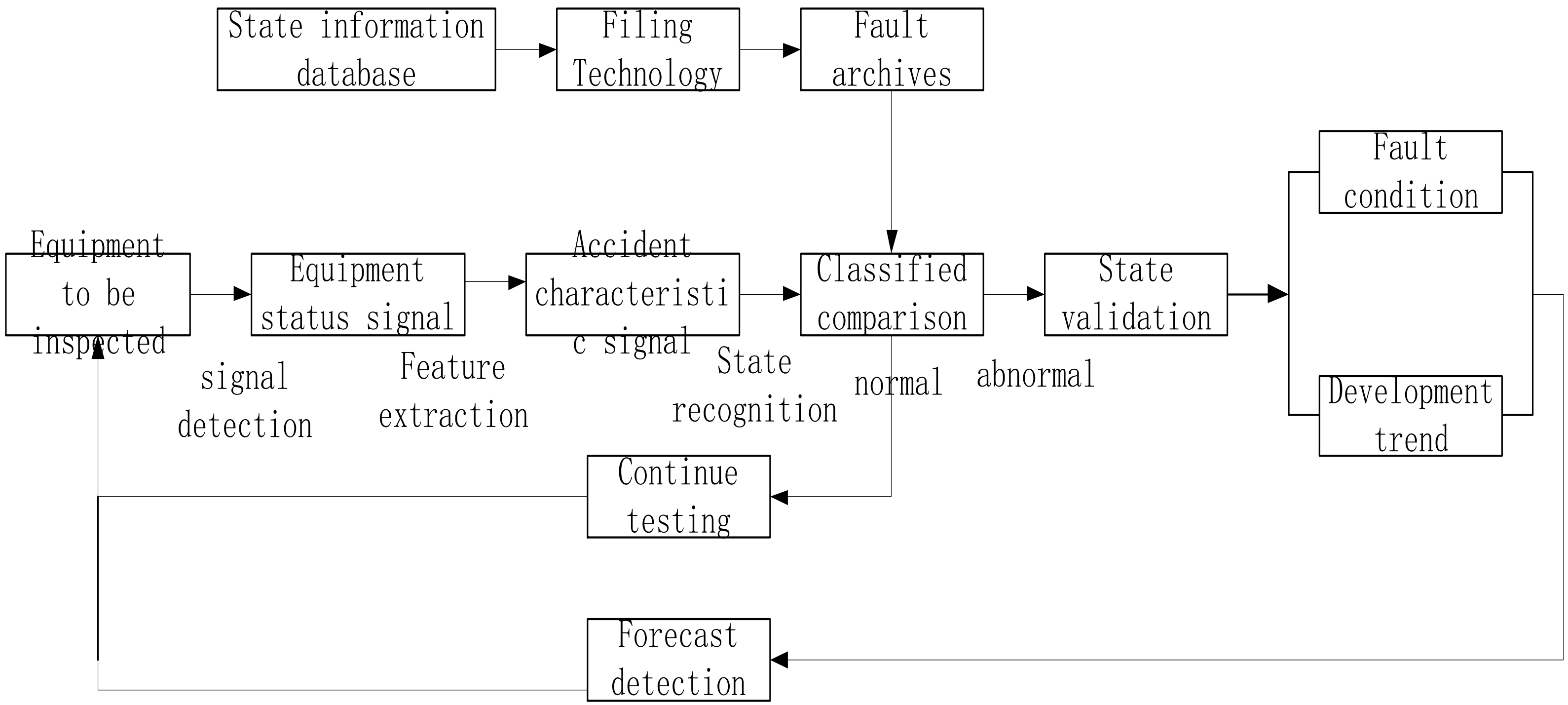


Research content and method

Research contents and methods



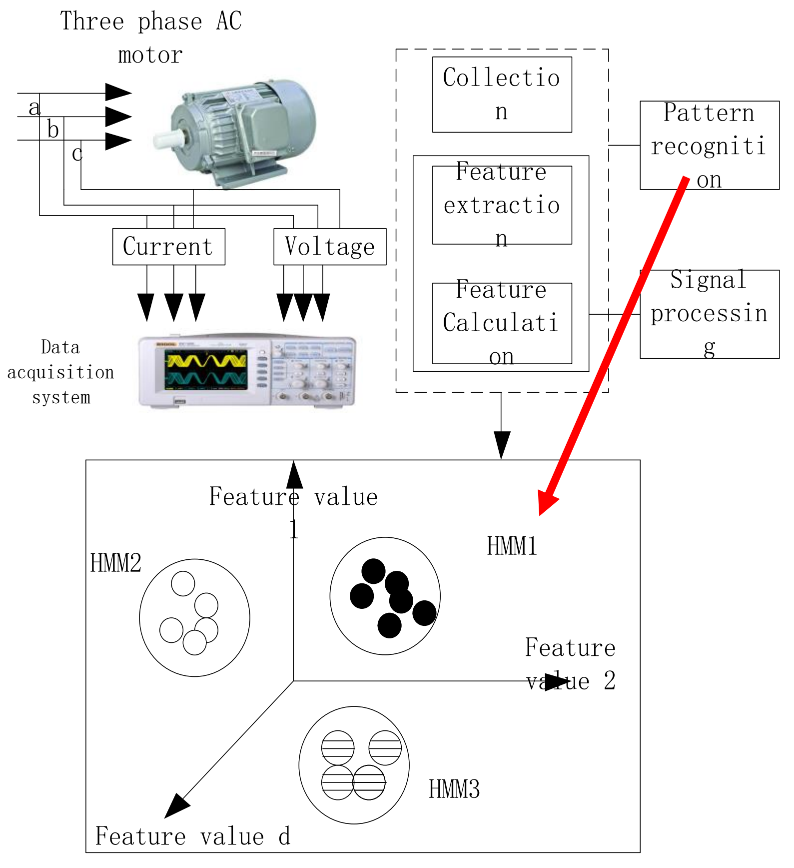
Research Content

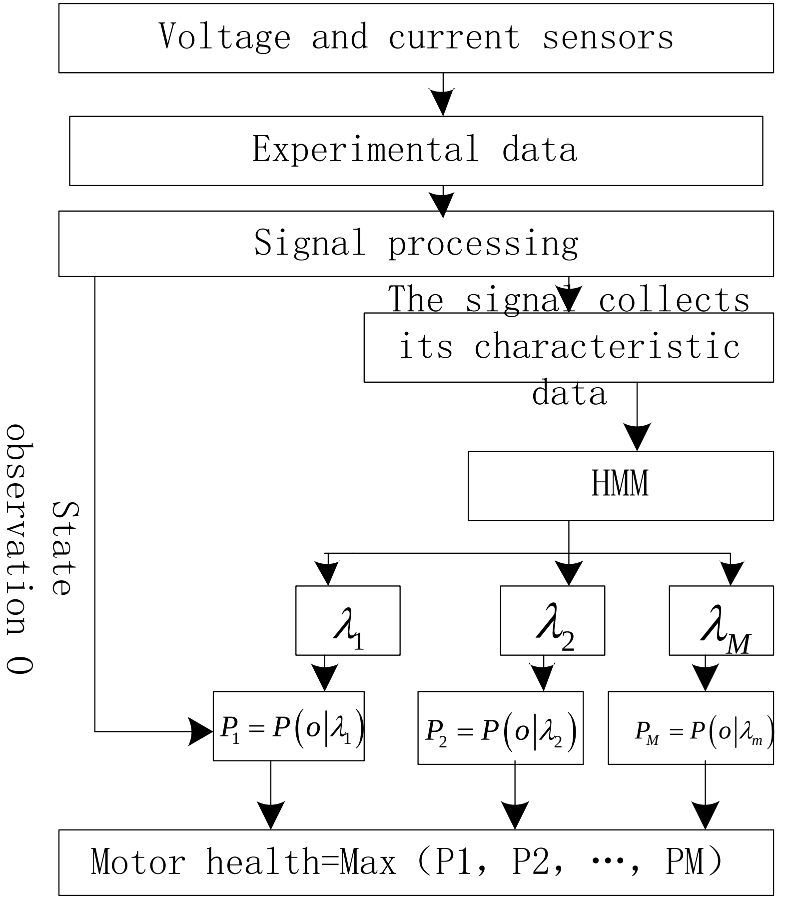


1. Fault diagnosis and prediction of motor based on Hidden Markov model and pattern recognition;
2. A new denoising algorithm for locomotive gear vibration signals is presented and a mathematical model is established;
3. In order to solve the problem that the inherent nature of the equipment degradation data is difficult to be used in the standard Gauss process regression, a prediction algorithm based on Hidden Markov Gauss process is proposed.

Machine learning for motor fault diagnosis

- Application of HMM:

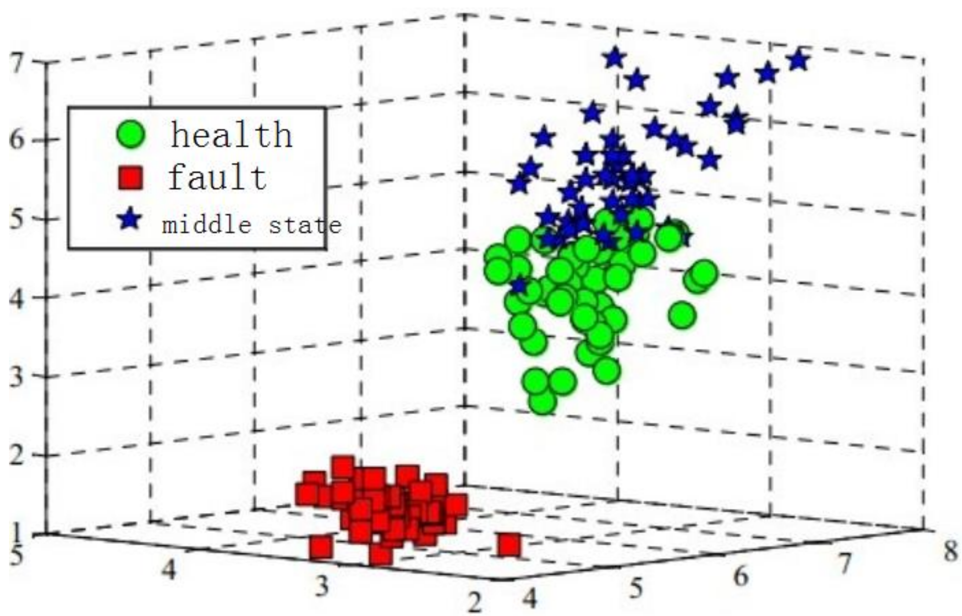




Motor fault diagnosis

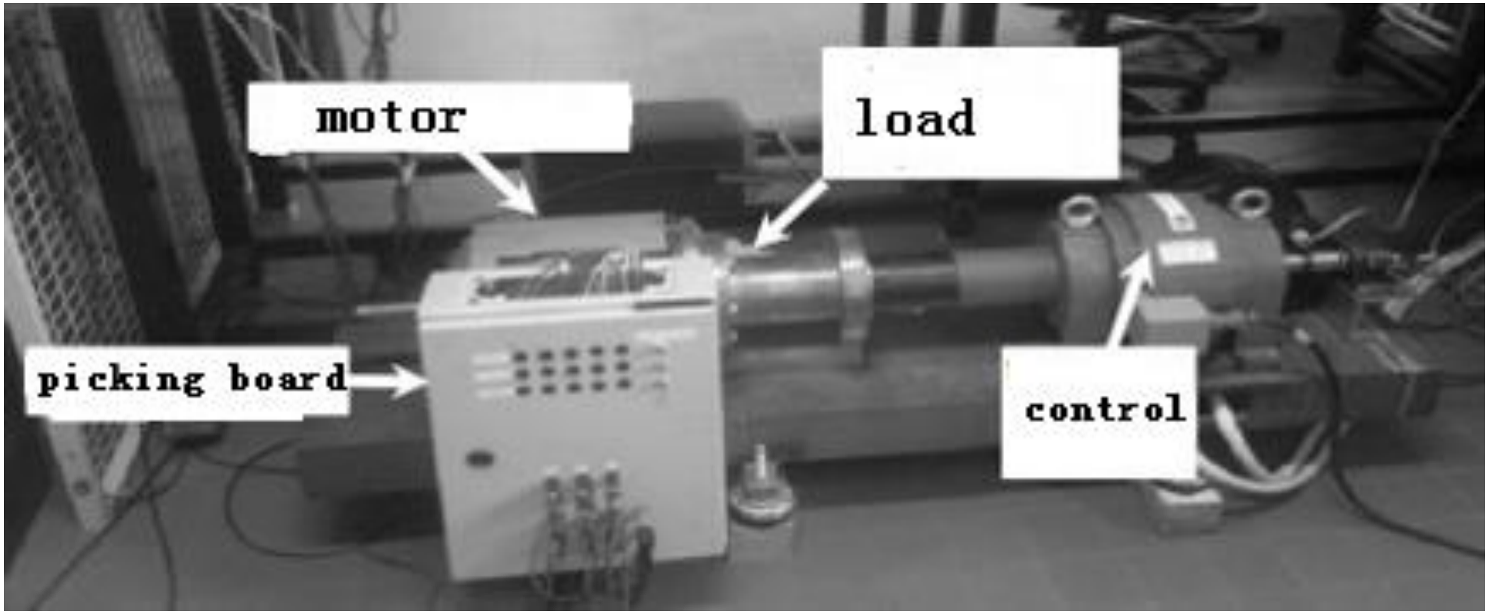
- Experimental accuracy analysis:

$$T_C(\%) = 100 \times \frac{2}{h(h-1)} \times \sum_{(i,j)\in(1,\ldots,h)^2} \epsilon_{ij} \qquad \epsilon_{ij} = \begin{cases} 0, c(O_i) = c(O_j) \\ 1, c(O_i) = c(O_j) \end{cases}$$



Motor fault diagnosis

- Experimental verification:



Motor fault diagnosis

Comparison of different diagnostic methods

Comparison of accuracy between multilayer feedforward networks and HMF

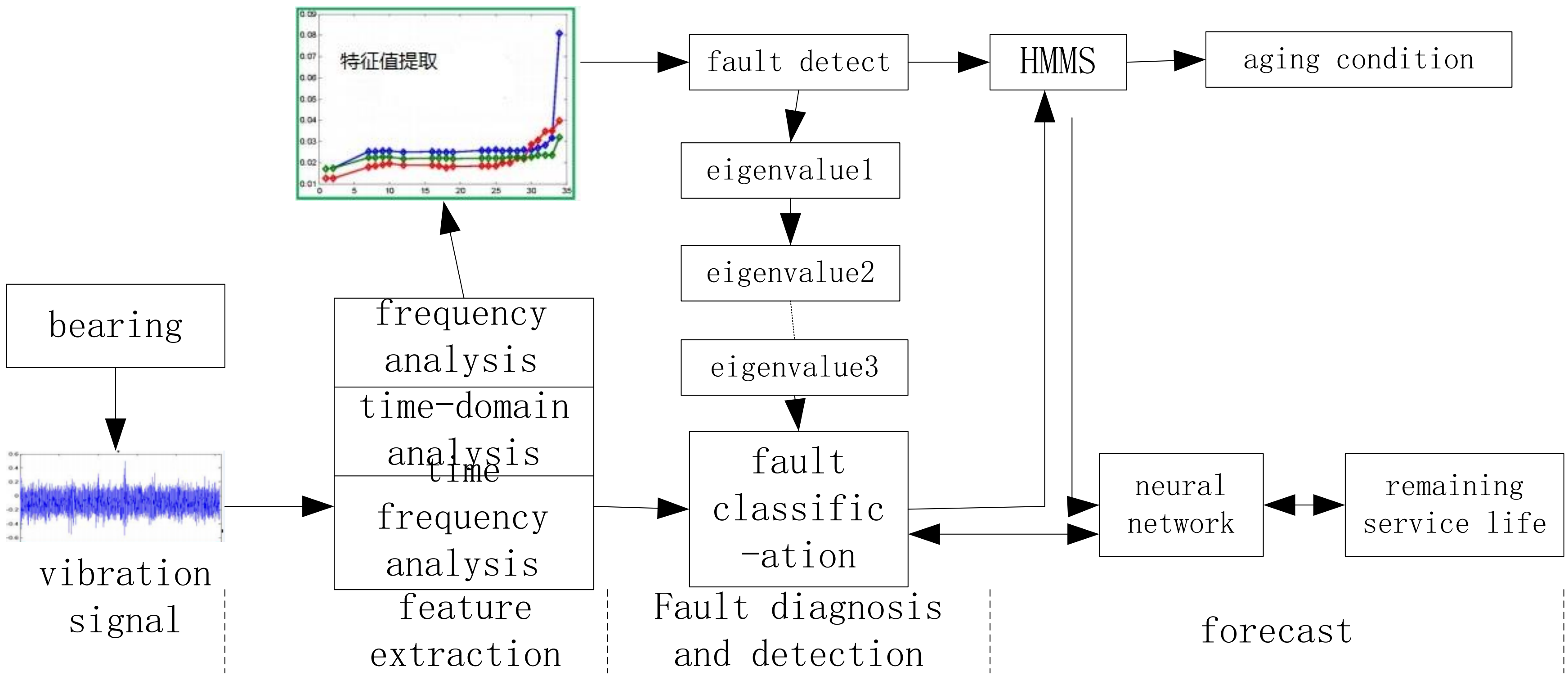
algorithm	Optimum system parameters	accuracy
HMM	three clusters	100%
Multilayer feedforward networks	ten neurons	96.9%

The classification of different fault conditions

working condition	MLFF	HMM
	classification	classification
normal	32/32	32/32
Rotor bar breaking	29/32	32/32
bearing fault	31/32	32/32

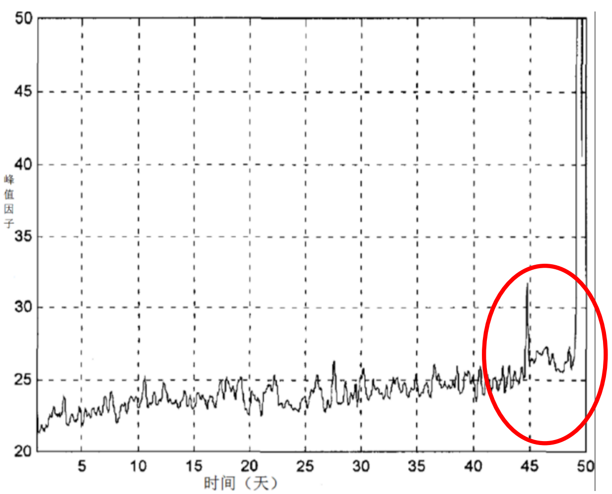
Motor bearing life prediction

- Motor bearing life prediction：

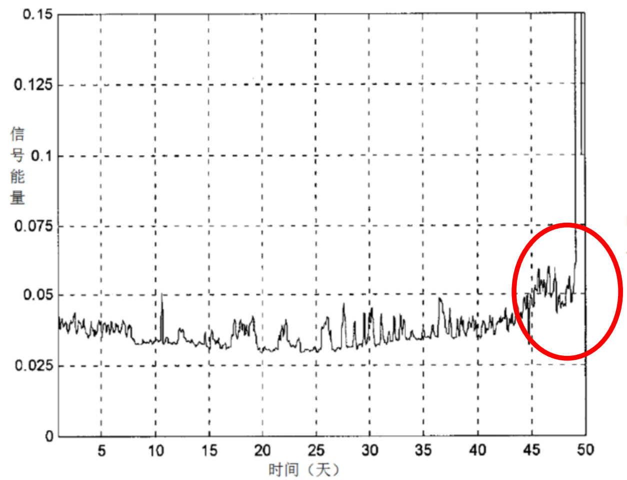


Motor bearing life prediction

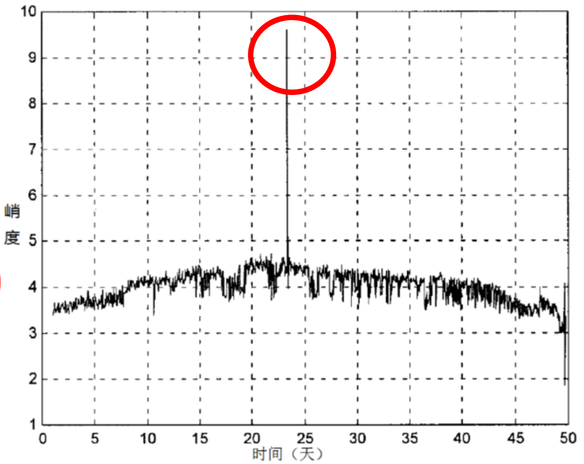
■ Analysis of bearing signal characteristics：



peak factor



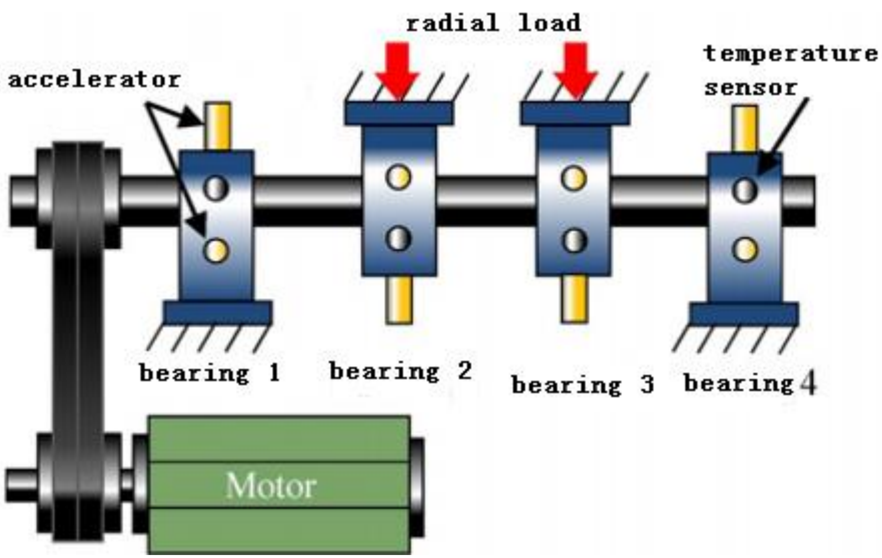
signal energy

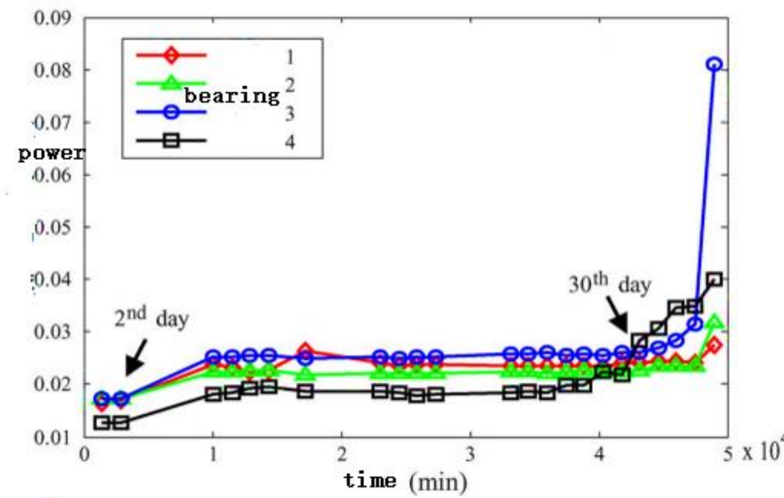


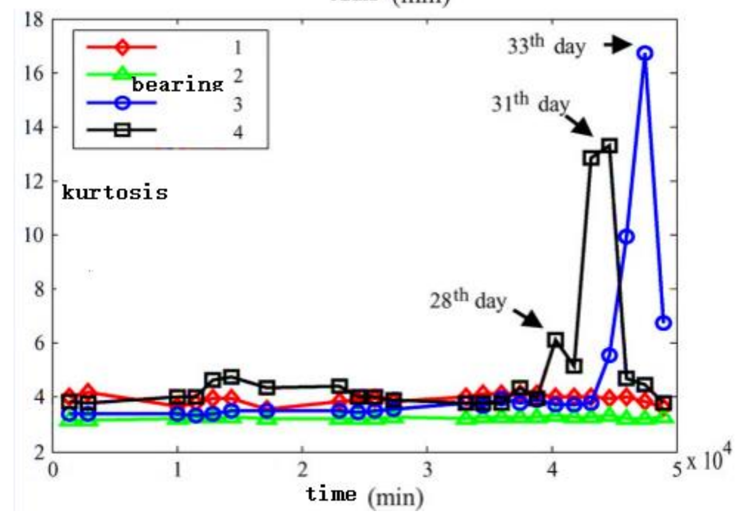
kurtosis

Motor bearing life prediction

- Experiment and comparison of characteristic value ：

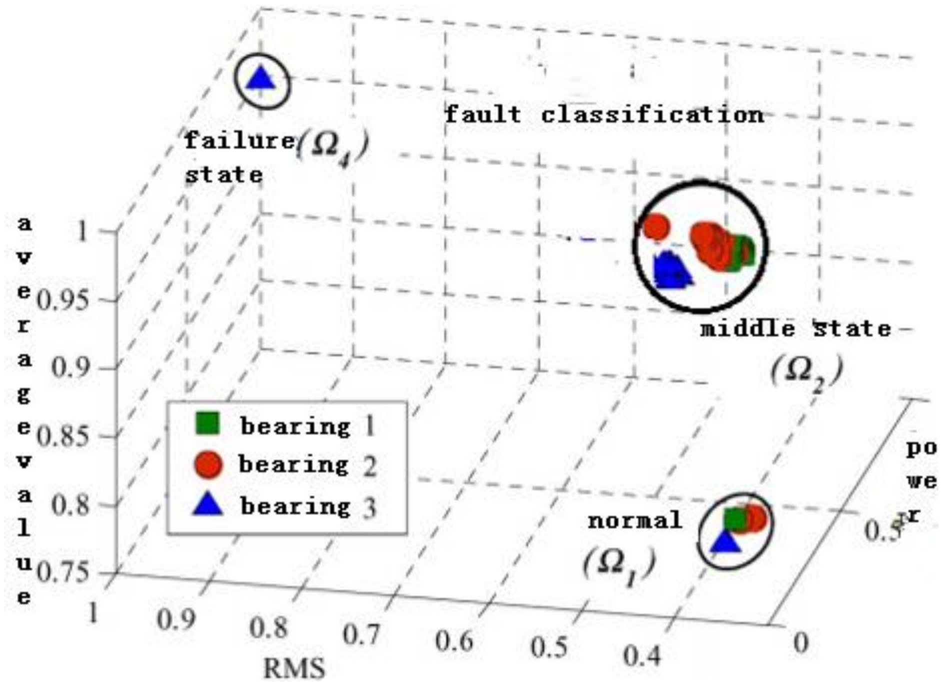






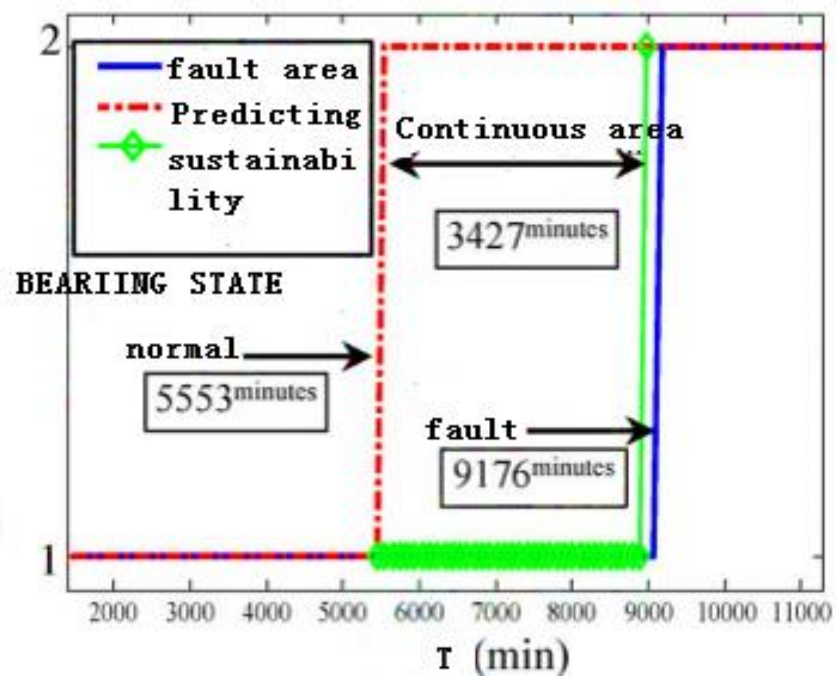
Motor bearing life prediction

- The data of fault classification：

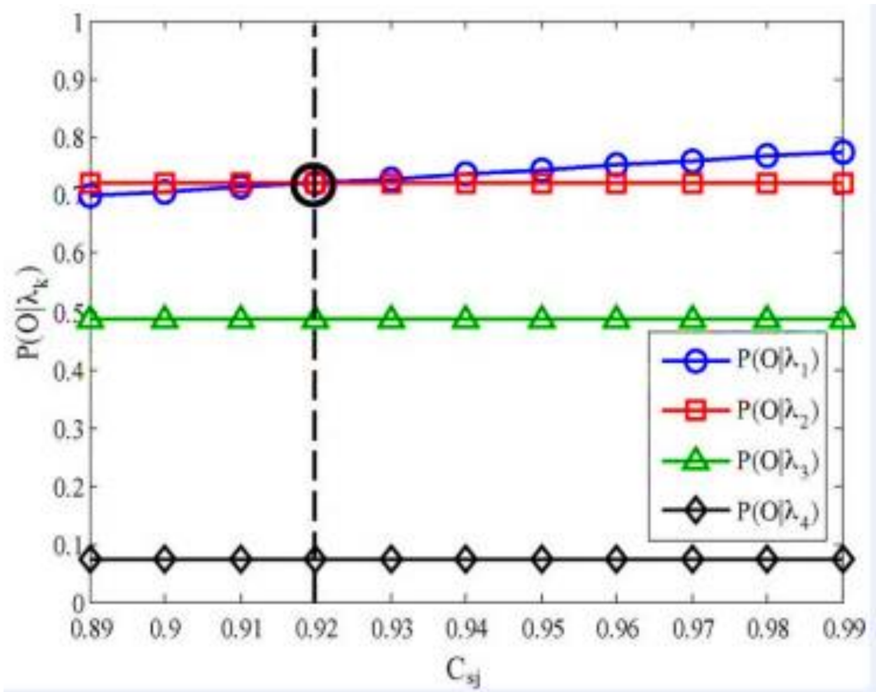


Motor bearing life prediction

- experimental result：



State monitoring and life prediction of bearing

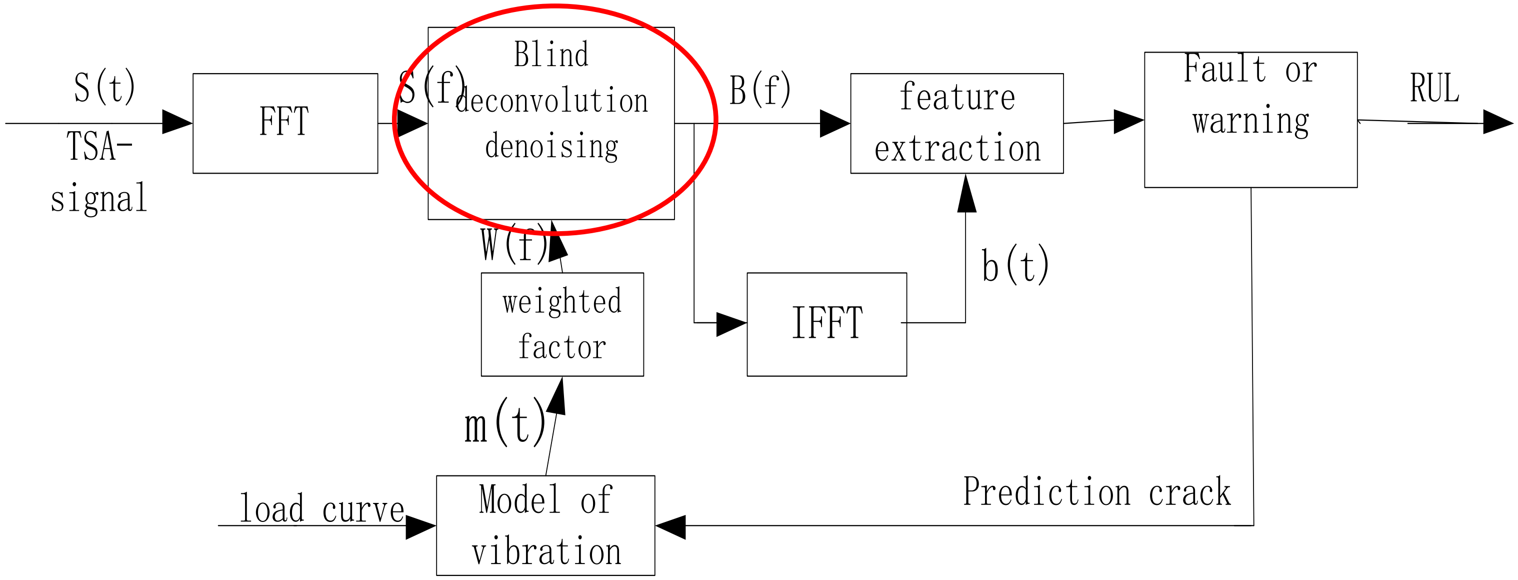


Bearing probability values

Fault diagnosis and prediction research for gears using Machine learning

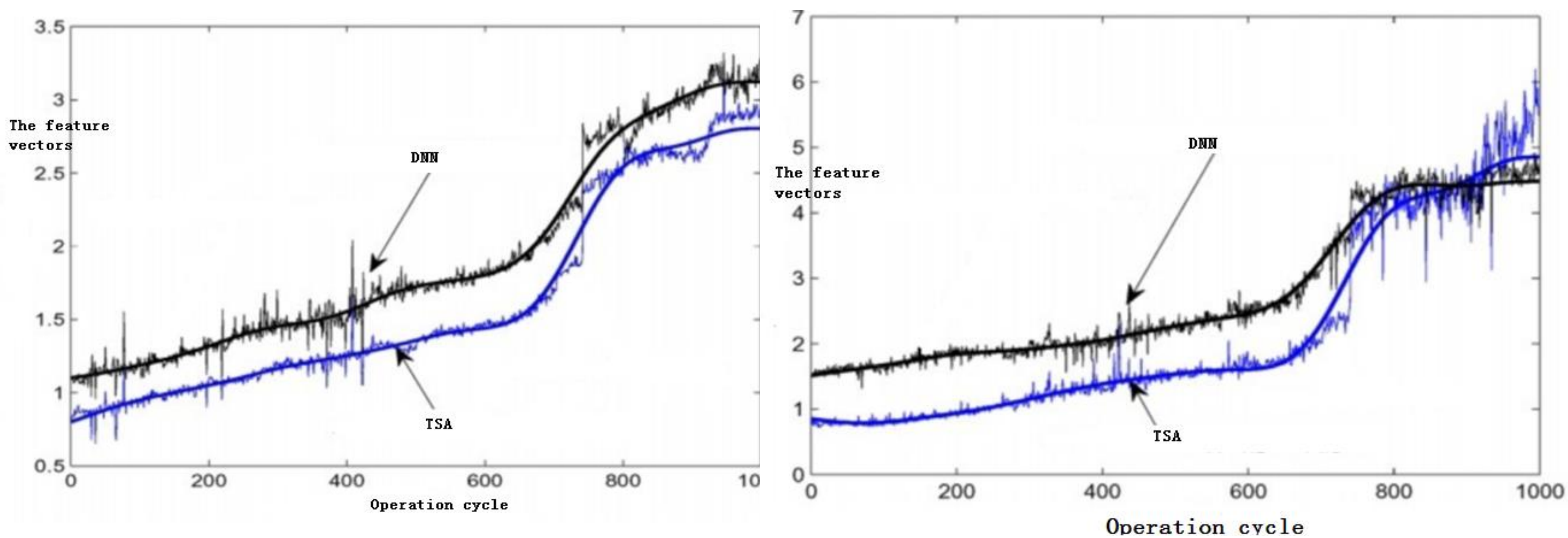
gear fault diagnosis

- Blind deconvolution denoising scheme：



gear fault diagnosis

■ The time domain denoising method compared with TSA：



gear fault diagnosis

- Accuracy analysis of gear crack length：

$$CCR(x,y)=\sqrt{\frac{ss_{xy}^{2}}{ss_{xx}ss_{yy}}}$$

$$ss_{xy}=\sum_{i=1}^{l_x}(x_i-\underline{x_i})(y_i-\underline{y_i}) \qquad ss_{xx}=\sum_{i=1}^{l_x}(x_i-\underline{x_i})^2 \qquad ss_{yy}=\sum_{i=1}^{l_x}(y_i-\underline{y_i})^2$$

gear fault diagnosis

- The average percentage deviation ：

$$PMD(x,\bar{x}) = \frac{\sum_{i=1}^{l_x} \frac{x_i - x_i^{'}}{x_i^{'}}}{l_x} \times 100$$

torque	20%		40%		100%	
	TSA	D-N	TSA	D-N	TSA	D-N
noise-signal ratio	1.12%	1.84%	4.85%	3.31%	5.65%	2.90%
The average percentage deviation	1.05%	0.96%	1.19%	0.93%	3.05%	0.80%

gear fault diagnosis

- The accuracy and performance index under different torque ：

torque	20%		40%		100%	
	TSA	D-N	TSA	D-N	TSA	D-N
CCR	0.943	0.975	0.979	0.985	0.953	0.983
CCS	0.950	0.982	0.986	0.992	0.971	0.991
PMD	2.06%	2.01%	2.57%	2.73%	5.57%	3.57%

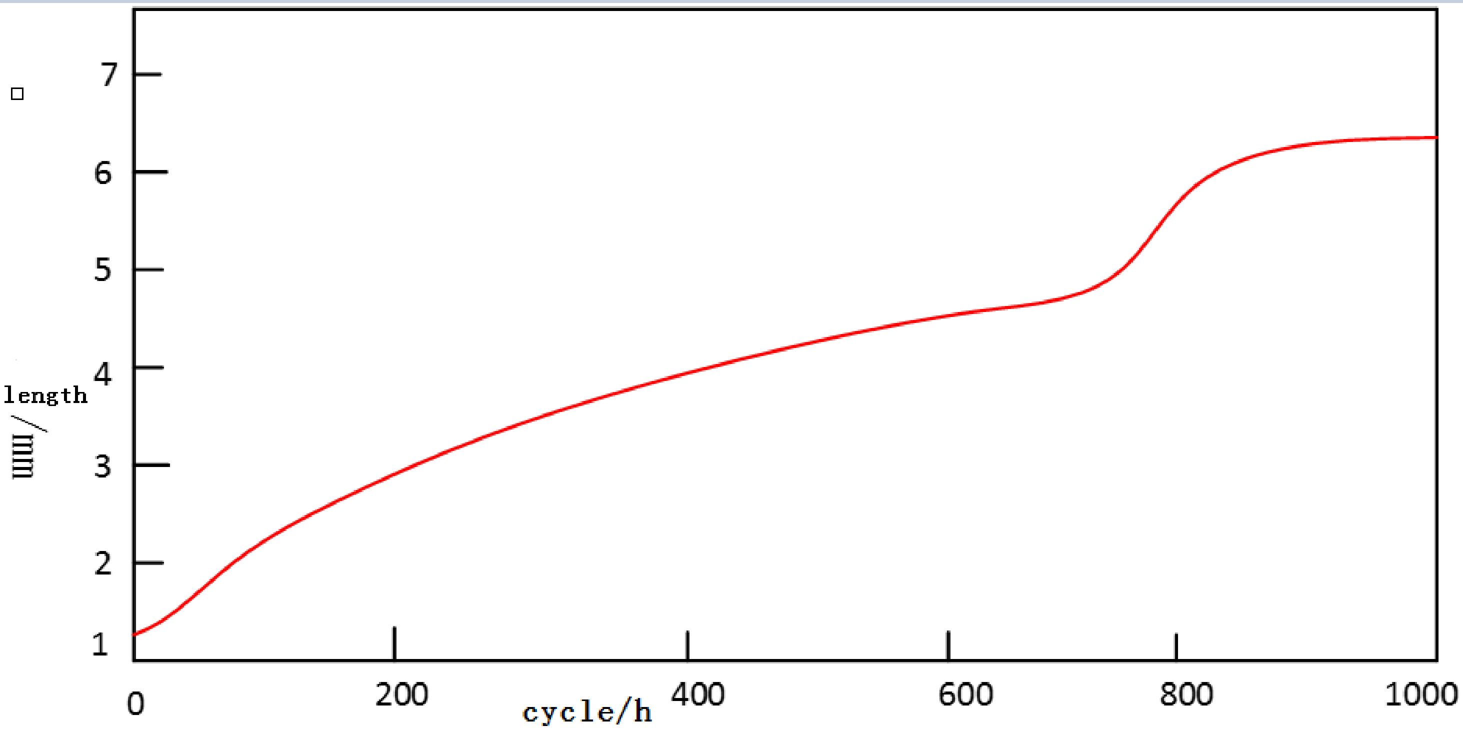
gear fault diagnosis

- Crack growth state model and model parameter estimation：

$$
\begin{cases}
L(t+1) = L(t) + C \cdot \alpha(t) \cdot (\Delta K(t))^m + w_1(t) \\
\alpha(t+1) = \alpha(t) + w_2(t) \\
\Delta K(t) = f\left(Load(t)\right) \\
F(t) = h(L(t)) + v(t)
\end{cases}
$$

gear fault diagnosis

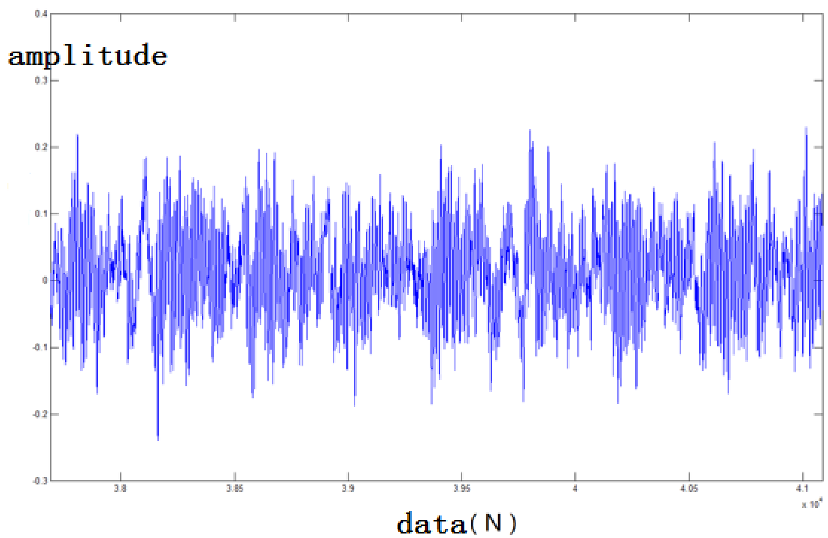
- Gear crack length curve：



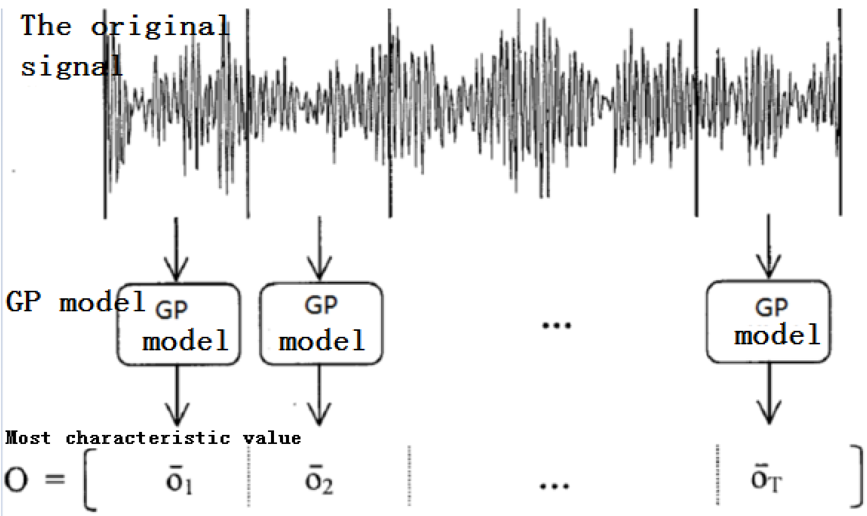
Fault diagnosis and prediction research for bearing using Machine learning

Bearing life prediction

- Through the Gauss process to extract the signal characteristic value

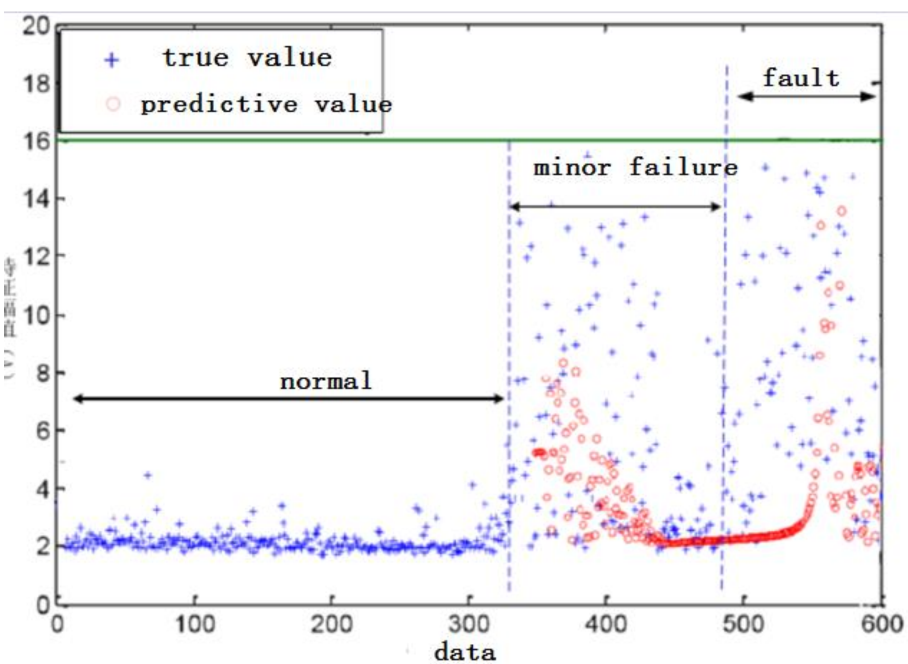


original signal

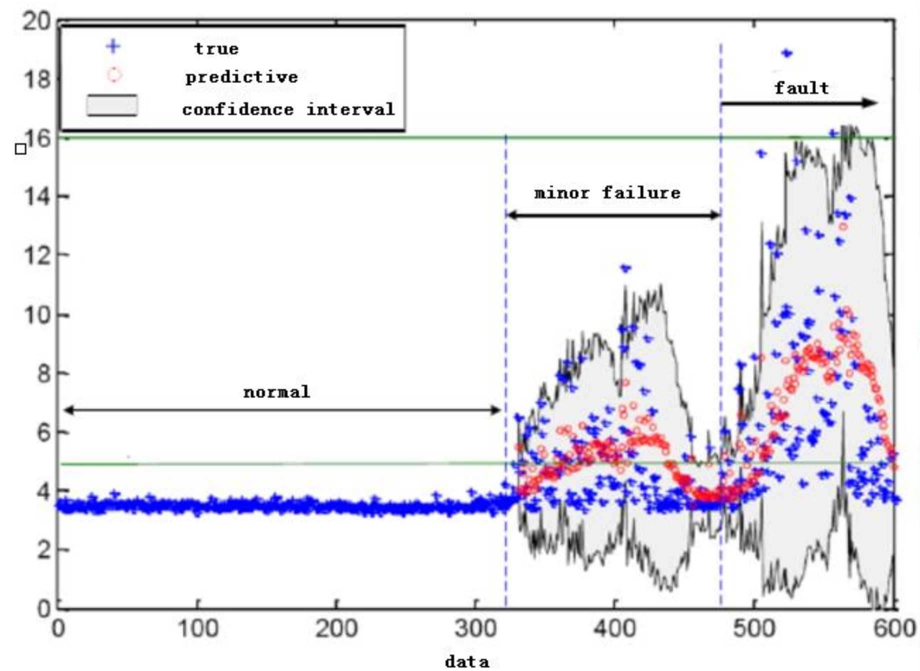


Bearing life prediction

- Comparison of prediction experiments between Gauss process and mixed model：



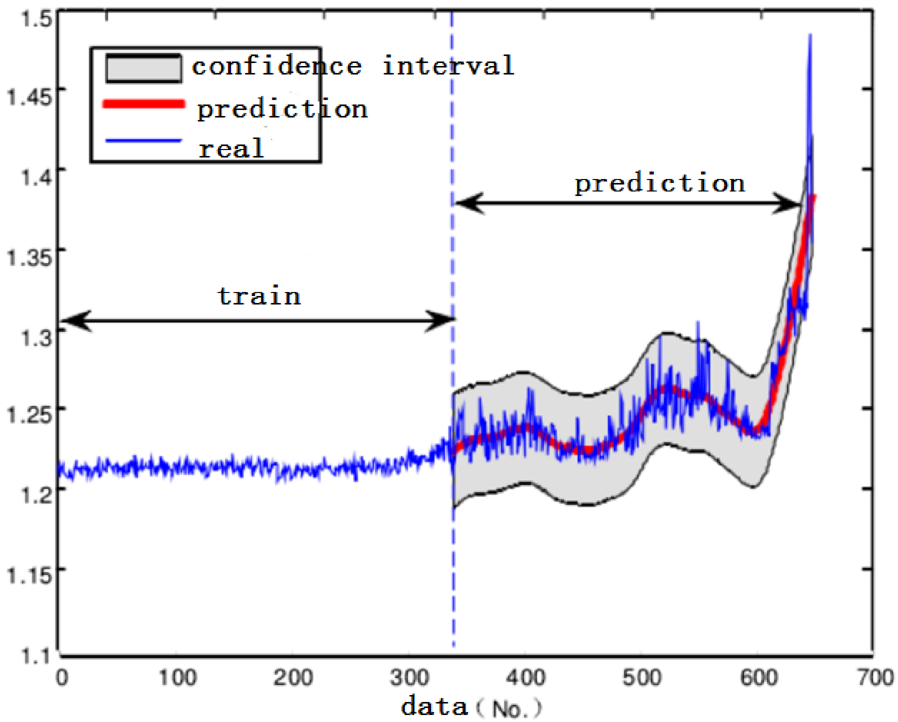
Gauss process model

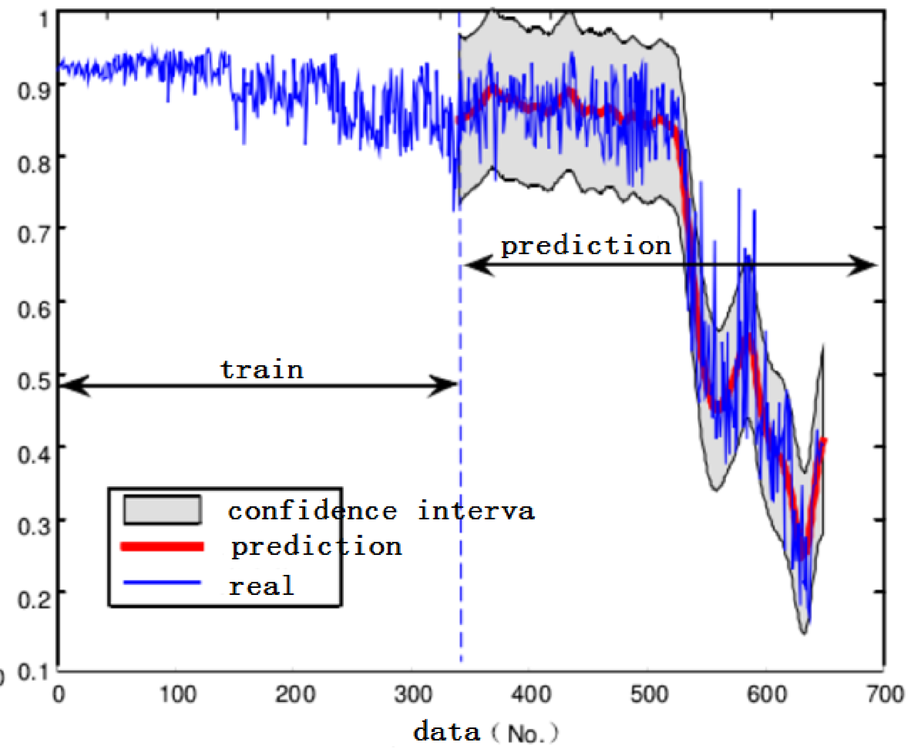


HMMGP hybrid model

Bearing life prediction

- the signal characteristic value of Gauss process：





Prediction of bearing aging based on fusion signal Prediction of bearing aging based on probabilit

Summary and outlook

Summarization and prospect

- Finish fault diagnosis model of locomotive transmission device, further research on the core algorithm. But the accuracy of the measured data may be different from the actual value. This part of the work needs to be done carefully.
- The machine learning method applied to diagnosis is still in the primary stage, and is not very mature. Other algorithms on large data can be studied to conduct a comprehensive analysis. The advantages of these methods can be applied to other key equipment .
- In this presentation, HMM fault diagnosis method are studied in the experiment table of typical faults occur independently. There is a certain gap between various diagnosis and prediction, therefore, need to start the research with application.

THANKS FOR YOUR ATTENTION!