EPH - International Journal of Science And Engineering
ISSN (Online): 2454 2016
Volume 07 Issue 03 September 2021

DOI: https://doi.org/10.53555/ephijse.v7i3.186

RESEARCH ON SHIP ENGINE ROOM MONITORING AND FAULT DIAGNOSIS SYSTEM BASED ON LABVIEW

Wang Ming-qian[1]*
*[*1]School of Information Engineering, Changzhou Vocational Institute of Mechatronic Technology, Changzhou, Jiangsu Province, 213164*

Corresponding author:

Abstract: *The structure of marine engine room system is complex, with many fault sources and abundant symptom parameters. There is no simple correspondence between faults and symptoms, but they are interrelated and intricate. The existing fault diagnosis of ship engine room is mostly based on expert system, but the bottleneck of knowledge acquisition, lack of learning ability and the complexity and efficiency of the expert system are restricting its further development. In order to overcome the above shortcomings of expert system, the support vector machine (SVM) is introduced into the expert system, and the support vector machine (SVM) is used to solve the problem of small sample self-learning ability and high-dimensional space self-adaptation ability. The expert system is used to achieve the automatic knowledge acquisition and rapid logical reasoning. Knowledge base management and maintenance, symbolic reasoning and related explanations, and give full play to the advantages of both SVM and expert system. Finally, the fault diagnosis of marine diesel engine booster system is introduced as an example. The MATLAB Script is used to call the MATLAB SVM analysis toolkit, and the combination of SVM and expert system is used to diagnose the fault.*

Key words: *Ship engine room; Monitoring; LabVIEW; Support vector machine (SVM); Fault diagnosis*

CLC number: TP277 **Document code: A**

INTRODUCTION

With the development of computer technology and the continuous improvement of the level of ship automation, ship automation technology to the ship integrated automation phase of development, all kinds of navigation, monitoring, management system used in ships. In the ship automation, the cabin automation system is the power system and auxiliary system "heart", it mainly consists of host remote control system, host safety protection system, engine room monitoring alarm system, power station automatic control system, and pump, fan, main and auxiliary boiler automatic Control and other system components [1]. It has a direct impact on the safety, maneuverability and reliability of the ship's navigation. The main equipments such as generator, generator, rudder, clutch and air compressor play an important role in the normal navigation of the ship, Real-time understanding of the cabin in the main auxiliary, generators and other equipment, patrol management and control is very important [2].

The purpose of this paper is to build a monitoring and fault diagnosis system based on LabVIEW in the virtual instrument technology environment. It can monitor, alarm and diagnose the engine room and remote transmission of the data, and focus on the support Vector Machine Fault Diagnosis Expert System and Its Application in Actual Diagnosis.

1 Virtual Instrument Overview

1.1 The Concept of Virtual Instrument

Virtual Instruments is an important new technology in Computer Aided Testing (CAT). It refers to the microcomputer as the core, the computer and measurement system integration in one, with computer software instead of the traditional instrument of some of the hardware functions, with a computer display instead of the traditional instrument physical panel measuring instruments.

1.2 The System Structure of the Instrument

The virtual instrument mainly includes the hardware system constitution and the software system constitution.

1.2.1 The Hardware System of Virtual Instrument

Virtual instrument hardware system is generally divided into computer hardware platform and monitoring and control functions platform. The computer hardware platform may be any type of computer. As shown in Figure 1, the virtual instrument system hardware [3].

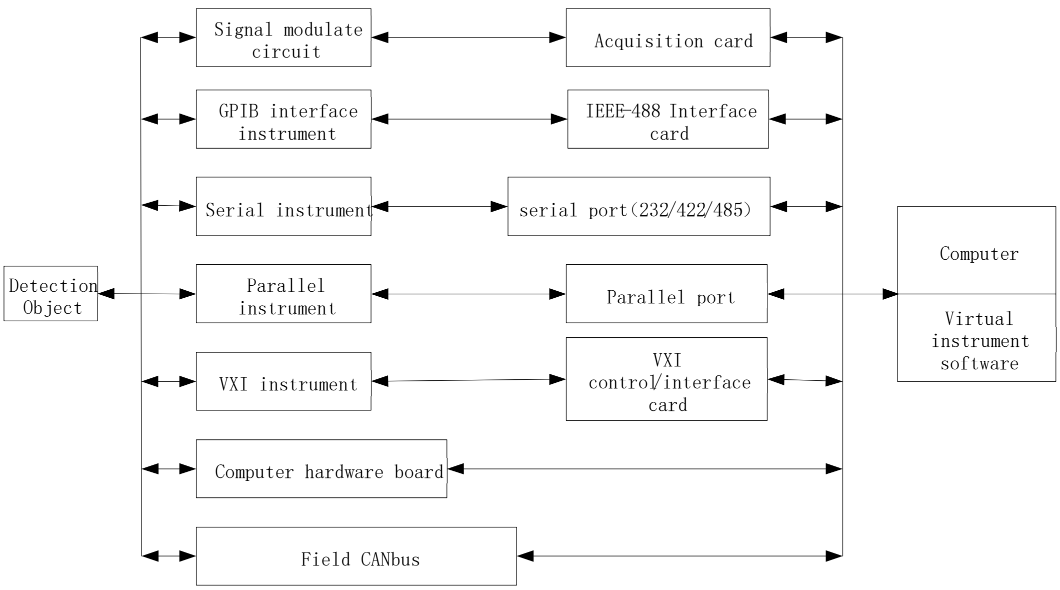

Figure 1 Virtual instrument hardware system structure

1.2.2 The Software System of Virtual Instrument

Usually, the virtual instrument system software structure is divided into four levels [4], as shown in Figure 2.

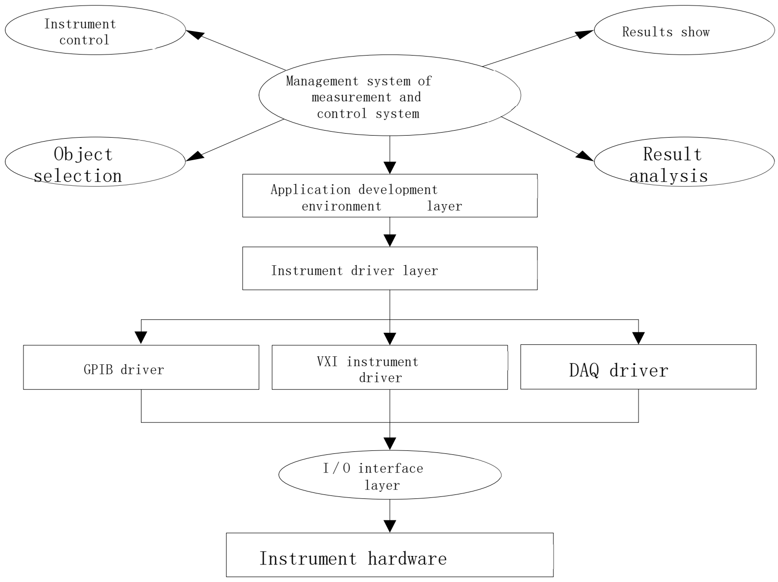

Figure 2 Virtual instrument software system

2 Engine Room Monitoring System and Function Module Design

2.1 Design of Cabin Monitoring System

The original signals of the operating states of the components in the engine room are processed by multiple data acquisition modules (according to the economy, high frequency and low frequency, using different channels, synchronous or roving mode) configured in the programmable automatic controller, and processing results through the CAN bus, sent to the engine room control room computer system, from the "state monitoring and fault forecasting" system analysis and the results show. At the same time, the field bus will also send this pretreatment data to the bridge cab computer system, and the control room of the computer system analysis results are sent to the cab, the principle can be seen in Figure 3[5- 9].

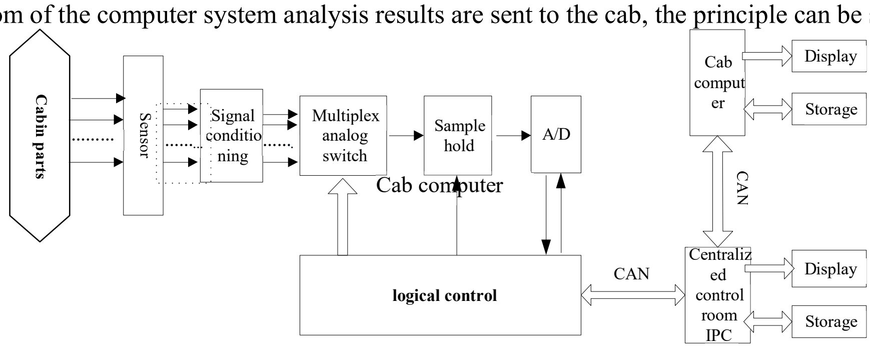

Figure 3 Schematic diagram of the engine room monitoring system

2.2 The Hardware Part of the System

System in the choice of hardware to take full account of the cabin-specific work environment, the choice of high-performance, high stability of the hardware equipment, taking into account the rapid and accurate requirements. The hardware part consists of sensor, data acquisition device and computer.

Cabin monitoring system hardware (network system) includes three nodes: the cabin site, cabin control room and cab. From the point of view of improving the reliability of the system, the on-site node of the engine room can adopt the redundant way, two sets of identical systems work at the same time, carry on hot backup with each other, and switch when necessary (oneself fail).

2.3 The Software Part of the System

The software of the system is divided into three parts according to the network nodes: pretreatment of the field data (in the conversion box), analysis of the operating status of the cabin and expert system of fault forecasting (the control room), the operating status of the cabin and the result of the fault forecast of the display (cab to achieve).

Modular programming design, through the division of functional modules, the design of the data flow between the various modules as shown in Figure 4.

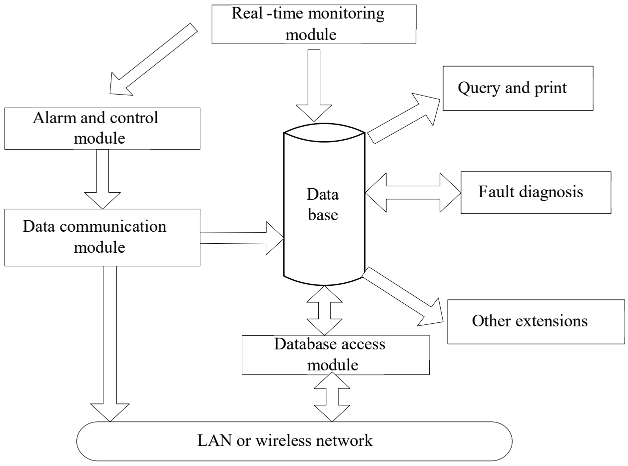

Figure 4 System module data flow chart

2.4 System Software Functions

2.4.1 System Program Flow

System software program flow shown in figure 5 After user authentication, you can enter the monitoring interface, if the administrator can choose to configure the system parameters and some data to be updated. The system does not interrupt the different sampling data (switch, analog, etc.) for the corresponding analysis, processing, processing results stored in the system database on a regular basis, while the collection time for the file name to save the collected sample data.

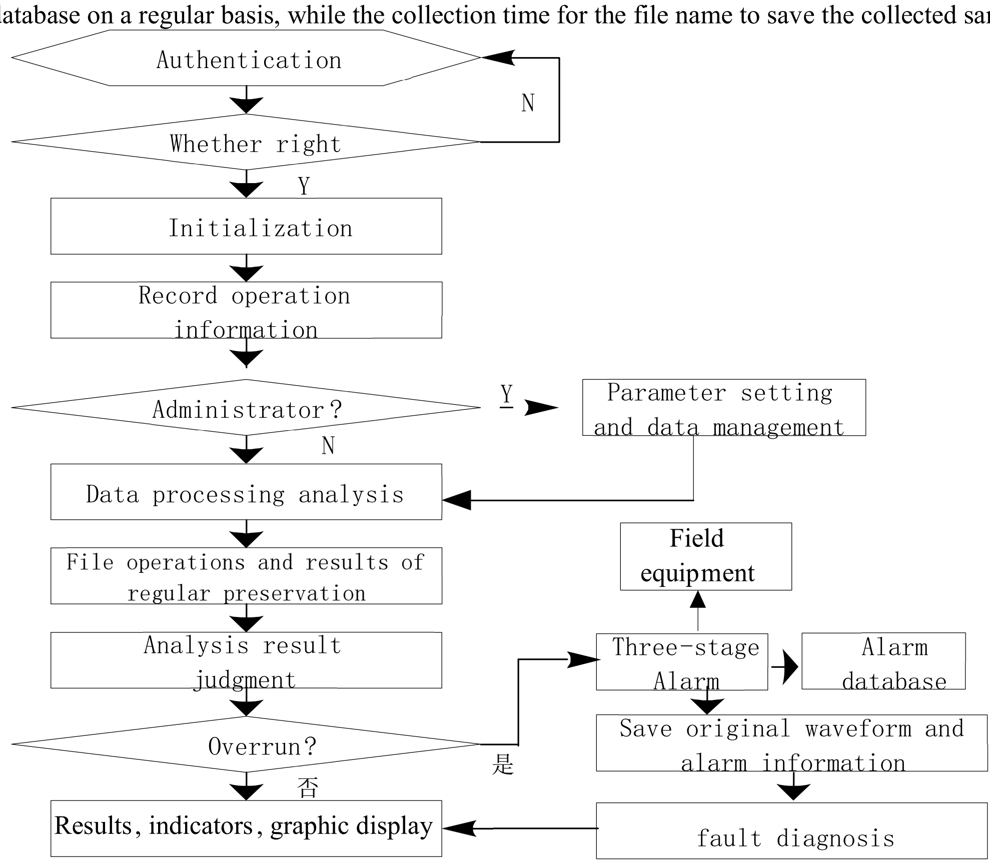

Figure 5 Software program flow chart

2.4.2 Design of Data Acquisition Program Based on LabVIEW

The data collection function is realized by using some function sub-modules in DAQmx-Data Acquisition in LabVIEW function module. The program adopts sequential structure, which includes sampling frequency setting, physical channel definition, sampling timing selection, acquisition task start, Acquisition results read and store a few steps.

3 Signal Feature Extraction and Analysis Based on LabVIEW

3.1 Signal Amplitude Domain Analysis

Through signal amplitude domain analysis various amplitudes of various dynamic parameters can be obtained (such as peak and RMS values and average, etc.), as well as various statistical parameters (probability density function, probability distribution function, etc.). Normally, these parameters include dimensionless and dimensionless quantities.

Introduced the dimensionless amplitude parameters, which are insensitive to the amplitude and frequency of the signal, they have little to do with the operating conditions of the machine and are sufficiently sensitive to the fault. Commonly used dimensionless parameters are defined as follows [10-12]:

(1) Peak value

$$\hat{X} = \max|x(t)| \qquad (1)$$

(2) Absolute value

$$\overline{X}_p = \frac{1}{T}\int_0^T |x(t)|dt \qquad (2)$$

(3) RMS

$$X_r = \left(\frac{1}{T}\int_0^T |x(t)|^{\frac{1}{2}} dt\right)^2 \qquad (3)$$

(4)Skewness

$$\alpha_3 = \int_{-\infty}^{\infty} x^3 p(x)dx \qquad (4)$$

(5) Kurtosis

$$\alpha_4 = \int_{-\infty}^{\infty} x^4 p(x)dx \qquad (5)$$

In the equation x(t) is the time course of the signal; *T* is Sampling period; p(x) is probability density function

(6) Kurtosis factor

$$F = \frac{\alpha_4}{\sigma_x^4} \qquad (6)$$

(7) Pulse factor

$$I = \frac{\hat{X}}{\overline{X}_p} \qquad (7)$$

(8) Peak factor

$$C = \frac{\hat{X}}{X_{rms}} \qquad (8)$$

In the equation, X_{rms} is the effective value.

$$X_{rms} = \left[\frac{\int_0^T x^2(t)dt}{T}\right]^{\frac{1}{2}} \qquad (9)$$

(9) Waveform factor

$$K = \frac{X_{rms}}{\overline{X}_p} \qquad (10)$$

The extraction of the characteristic parameters and the fault diagnosis are closely related.

Table 1 shows the sensitivity and stability comparison of the amplitude parameter to the fault.

Table 1 Sensitivity and stability of the amplitude parameters

Amplitude domain parameter	Sensitivity	Stability
Waveform index	Bad	Fine
Peak index	General	General
Pulse index	Better	General
Amplitude domain parameter	Sensitivity	Stability
Margin index	Fine	General
Kurtosis index	Fine	Bad
Root mean square value	Poor	Better

As shown in figure 6 is the host injector failure fuel injection pressure waveform display and characteristic parameter extraction, margin index close to 1, the pulse index is greater than 2, the engine personnel can use the system to provide fault diagnosis using these results on the fault diagnosis

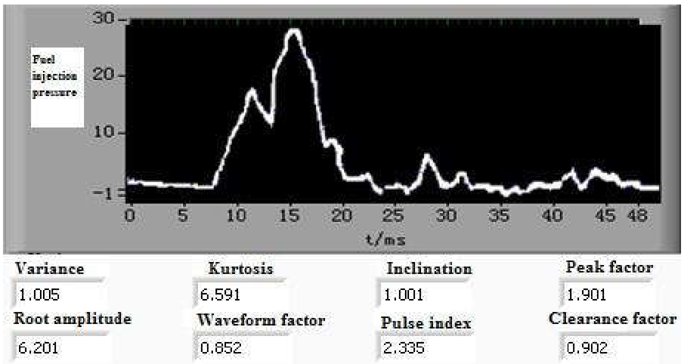

Figure 6 Waveform of oil injection pressure and feature extraction

3.2 Wavelet Analysis

For some signals or in the fault diagnosis, it is necessary to analyze the time and frequency domain of the signal at the same time to judge the time and frequency region of the fault.

3.2.1 Continuous Wavelet Transform

Let *x (t)* be a square integrable function (denoted as *x (t)* ϵ *L2 (R)*), and *ψ (t)* be a function called a basic wavelet or mother wavelet.

$$WT_x(a,\tau)=\frac{1}{\sqrt{a}}\int x(t)\psi^*(\frac{t-\tau}{a})dt=\langle x(t),\psi_{a\tau}(t)\rangle \quad (11)$$

Then wavelet transform of x (t)is performed. Where a > 0 is the scale factor, **τ** reflects the displacement, the value can be positive or negative. The sign Q represents the inner product, which means that (superscript * represents the conjugate)

$$\langle x(t),y(t)\rangle=\int x(t)y^*(t)dt \quad (12)$$

Where $x(2t)\in\phi(t)<\phi(t-k);k\in z>$ is based on wavelet displacement and scaling. In Equation (11), t, a, τ, are continuous variables, so they are called continuous wavelet transform (CWT). The frequency domain representation of wavelet transform is:

$$WT_x(a,\tau)=\frac{\sqrt{a}}{2\pi}\int X(\omega)\Psi^*(a\omega)e^{j\omega\tau}d\omega \quad (13)$$

In the formula, $X(\omega),\Psi(\omega)$ are respectively the Fourier transform of x(t)and ψ (t).

3.2.2 The Definition of Discrete Wavelet Transform

After the one-dimensional signal x (t) is wavelet transformed into $< x(t), y(t) >= \int x(t)y^*(t)dt$ its information is redundant. Therefore, from the point of view of compressed data and saving computation, it is desirable to calculate the wavelet transform under some discrete scale and displacement values without loss of information. Current approach is to scale the power series by 2 for the discretization. The corresponding wavelet function is

$2^{\frac{j}{2}} \psi\,[2^{-j}(t-\tau)]$, j = 0, 1, 2, ..., where $a = 2^0, 2^1, 2^2, \ldots, 2^j$.At a certain j value, $\tau = 2^j \tau_0$

(The selection of τ_0 should meet the Nyquist sampling rate requirements).So $\psi_{a\tau}$ (t)can be rewritten as discrete:

$$\psi_{jk}(t) = 2^{-j/2}\psi\left(2^{-j} - k\right),\quad j = 1,2,\ldots\ k \in Z \tag{14}$$

For convenience, usually for the τ axis for normalization, that is, take $\tau_0 = 1$, the simplification of the above equation:

$$\psi_{jk}(t) = 2 - j/2\psi\,(2 - j - k) \tag{15}$$

The corresponding wavelet transform is:

$$WT_x(j,k) = \int x(t)\psi^*{}_{jk}(t)dt \tag{16}$$

The above equation is called "discrete wavelet transform"(DWT).

3.2.3 Realization of Wavelet Transform in LabVIEW

We use wavelet to predict the signal, denoise and extract the weak signal. When the conditions permit, we use the Wavelet Analysis of LabVIEW. As shown in Figure 7.

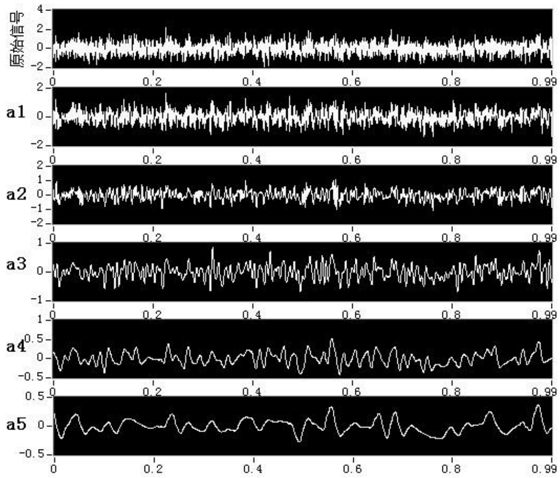

Figure 7 Analysis of the trend of the results of wavelet analysis

Figure 8 shows the results of denoising the pressure of the generator high-pressure tubing with noisy signals. From the obtained results, the signal after wavelet denoising is clearer and smoother, and it is more widely used in practice.

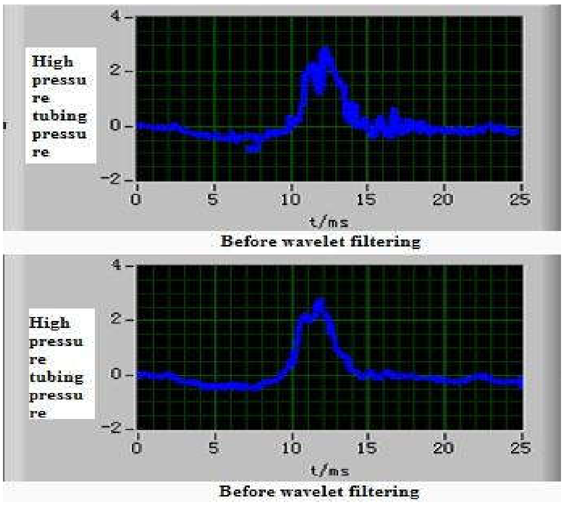

Figure 8 Wavelet denoising results

3.3 Signal AR Spectrum Analysis

3.3.1 Definition of AR Spectrum

Time series analysis is a statistical method of statistical processing and analysis of ordered random data [13]. Assuming that observation data x i_i, 1,2, ,n is a stationary, zero-mean time series, it can be fitted to a stochastic difference equation [14] of the following form: based on the AR model, the AR spectrum of the vibration signal is calculated and calculated. In the general AR spectrum, the fault information is abundant. Compared with the traditional periodic spectrum, the AR spectrum is smooth, Highlighting and positioning accuracy, to overcome the spectral line leakage, low resolution, weak signal submerged defects. Figure 9 shows the time-domain waveform and the response AR spectrum of the cylinder head of the main engine cylinder in the state of the valve from normal to severe air leakage.

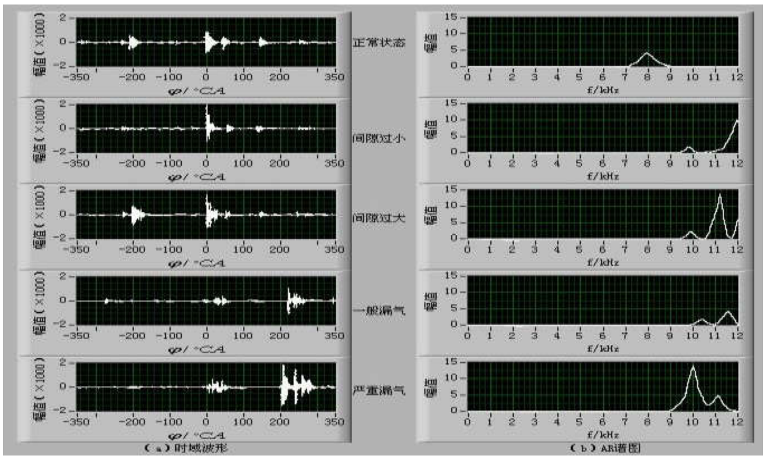

Figure 9 Time-domain waveform and AR spectrum of vibration signal of cylinder head

3.3.2 Feature Extraction of AR Spectrum and Realization of LabVIEW Program

AR spectrum is also the power spectral density (PSD), from which the extraction of energy from (19) to achieve:

$$E = \sum_{i=1}^{N} PSD(i) \Delta f \quad (19)$$

In the equation, N is the number of spectral lines in a particular analysis band on the AR spectrum, $PSD\ i(\ )$ is the value of the power spectral density function corresponding to the i th spectrum, and f is the frequency resolution. According to the literature, a series of AR spectral parameter sets provided from the normal to severe leakage state of a host cylinder head are provided to create a cluster array, and the eigenvectors of the monitored real-time AR spectral characteristic parameters are compared by the matrix operation method. An operating state, as shown in figure 10 below.

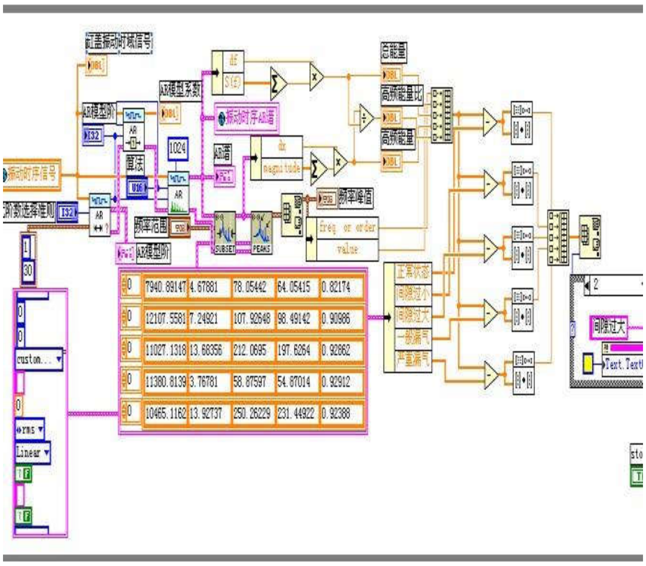

Figure 10 The block diagram of characteristic parameters extraction of AR spectrum

4 Expert Diagnostic System Based on Support Vector Machine

4.1 Support Vector Machine and Expert System

The expert system overcomes the limitations of using precise mathematical models to solve the problem, and makes full use of a great deal of knowledge and experience in the field. However, the bottleneck, narrow step, lack of learning ability and the complexity and efficiency of knowledge acquisition and other issues, making it more and more cannot meet the actual needs of the diagnosis. Support Vector Machine (SVM) has the best generalization that can be guaranteed theoretically. It can achieve the classification and extension well in the case of few training samples. The knowledge acquisition from the training samples automatically breaks through the bottleneck of knowledge acquisition. And the structural risk minimization, there is no over-learning problem of the neural network; the algorithm finally transforms into a convex optimization problem, which guarantees the global optimality of the algorithm and avoids the local minimum. Using the nuclear technology, the nonlinear problem in the input space, dimensional function space to construct a linear discriminant function to overcome the dimensionality disaster and other advantages [14]. The support vector machine is integrated into the expert system as shown in figure 11. The knowledge acquisition and rapid logical reasoning are realized. The expert system completes knowledge base management and maintenance, symbol reasoning diagnosis and human-computer interaction.

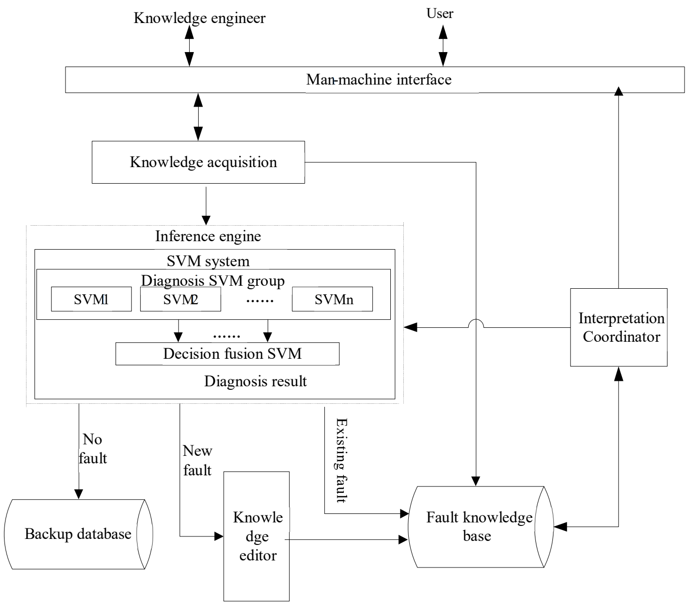

Figure 11 Schematic diagram of the expert system embedded in SVM

4.2 The realization of LabVIEW and MATLAB mixed program

LabVIEW uses the MATLAB Script node to call the MATLAB toolkit, in the MATLAB Script node to write in line with the MATLAB syntax part of the program, this article calls and writes MATLAB part of the main block diagram shown in figure 12:

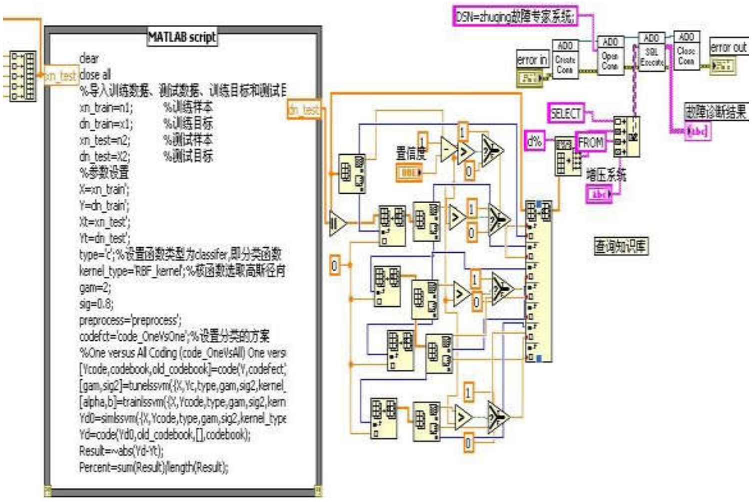

Figure 12 Using the MATLAB Script node to call the SVM and expert system connection program

5 Conclusion

With the development of world industry and the progress of science and technology, the field of engine room monitoring has created a new situation. It has become an important subject of ship research. Shipboard cabin monitoring intelligentization, network integration, standardization, ship-shore information integration has become an inevitable trend. The research idea of this article follows this law of development. The following is a brief summary of the content of this paper:

(1) In this paper, with the help of virtual instrument technology, we develop the signal acquisition, processing and analysis, alarm control, query printing, communication and data management of cabin components with CAN bus as the background. The modular and object-oriented programming technology makes the man-machine interface friendly, the operation is strong, the movement speed is quick, the maintenance is convenient and so on.

(2) The methods of signal analysis and analysis based on amplitude, wavelet analysis and AR spectrum analysis are studied in this paper. The real-time monitoring, alarm judgment and trend analysis of the cabin operation data are realized by these methods. To facilitate.

(3) Aiming at the shortcomings of the fault diagnosis of the existing cabin expert system, the support vector machine embedded expert system is introduced to improve the existing ship engine room fault diagnosis system. In this paper, the principle of support vector machine and expert system, and the principle of combining them and the implementation of LabVIEW are described.

References

[1]. Hai-tao Zhang, Jian-lin Ha. Development trend of ship automation [J]. China Water Transport (Theory Edition), 2006.4 (5): 34-36.
[2]. Hong-jing Cao. Based on CAN bus T50A ship cabin automation system application research [D]. Harbin Engineering University, 2006: 4-6.
[3]. LabVIEW8 20：Continuously Innovation in 20 Years test or measurement. http://www.cqvip.com/
[4]. Le-ping Yang, Hai-tao Li, Yong Zhao etc. LABVIEW Advanced Programming [M]. Beijing: Tsinghua University Press, 2003.46-53.
[5]. Xiao-qiang Dai, Wei-ting LIU, Zhi-yu Zhu. Implementation method of ship engine room automation platform based on Labview [J]. Computer Information, 2006 (22) 4-1: 156-158.
[6]. Quan-shui Huang, Diesel Engine Intelligent Monitoring and Diagnosis Technology Based on Lab VIEW [D]. Jiangsu University of Science and Technology. 2007: 20-30.
[7]. Yue Liu, Wei-ting Liu, Xiao-bo Zhuang. Design of Automatic Monitoring and Control System for Marine Engine Room Based on .NET [J]. Jiangsu University of Science and Technology. 2008: 25-30.
[8]. Xiao-bo Zhuang, Xiao-qiang Dai, Design of ship engine room monitoring and alarming platform [J]. Ship Engineering, 2006 (1): 69-71.
[9]. Xiao-jun Ma, Based on LabVIEW Diesel Engine Remote Fault Diagnosis System [D]. Jiangsu University of Science and Technology, 2007: 38-50.
[10]. A holistic approach to automation Shipping World & Shipbuilder, 2006 Vol.206 No.4213 A study on intelligent fault diagnosis in engine room by Bayes method. 2008, 6:122-136.
[11]. OnesJ N B, Li Yu-hua. Review of condition monitoring and fault diagnosis for diesel engines [J]. Ship Engineering, 2008 (3): 66-71.
[12]. Chen Xu, Rui-zhen Zhao, Xiao-bing Gan. Application of Wavelet Analysis Algorithm [M]. Beijing: Science Press. 2004.52-59.

[13]. Jian-jun Ding, Implementation of integrated evaluation system for marine diesel engine [D]. Jiangsu University of Science and Technology, 2006: 41-43.
[14]. Jin-ze Zhang, Jiang-qiao Lan. Fault Diagnosis Expert System of Equipment Based on Support Vector Machine [J]. Fire Control and Command Control, 2007, 5 (28): 16 -18.