Realization of Vehicle Remote Fault Diagnosis Based on MATLAB

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Abstract. A fault diagnosis method of anti-lock braking system based on vehicle data flow was proposed and a fault diagnosis software platform was developed for example application. 9 parameters were selected based on the selection principles of fault diagnosis parameters analyzed, and then neural network models were trained and validated by using the 48 sets of test data. Smoothing factor values were adjusted and optimized to achieve 100% accuracy of diagnostic results. The mixed programming technology of MATLAB and Visual Studio was used to develop the software platform. The results show that the neural network model based on vehicle data flow can achieve accurate fault diagnosis and the software platform can realize the function of fault diagnosis.

1. Introduction
The anti-lock braking system is essential for safe driving, and it is of great significance to detect faults in time. Traditional fault diagnosis methods have the disadvantages of being untimely and inconvenient. In this paper, the vehicle data flow and machine learning algorithms were deeply integrated, and a new fault diagnosis scheme was proposed, which can help to solve the problem of time and space limitation on vehicle fault diagnosis [1] and improve the safe level of vehicles by taking measures at the first time [2].

Since 2000, the vehicle fault diagnosis expert system has developed toward multi-knowledge and multi-model diagnosis [3]. With the application of artificial intelligence technology in the field of diagnosis, a knowledge-based diagnostic reasoning method is generated [4], including expert system [5], neural network [6], fuzzy logic [7] and so on. BP neural network and RBF neural network are both artificial neural networks with strong function and good application, which are widely used in function fitting, pattern recognition, classification and other fields [8]. Therefore, they are the preferred solution for fault diagnosis based on vehicle real-time data flow.

There are many researches on fault diagnosis based on neural network, but there are few researches on fusion analysis based on vehicle real-time data flow. In this paper, the data flow in vehicle fault state was obtained by the vehicle test, and it was used to train and validate the neural network. Finally, the software platform was developed and validated. The technical scheme is shown in figure 1.
2. Implementation of fault diagnosis based on data flow

2.1 Selection of neural network model types
There are many types of neural network models, which are applicable to different fields according to their characteristics.

Remote fault diagnosis based on neural network algorithm has three requirements for the model. First, the model can process large amounts of data a short period of time. Second, the model should be self-adaptive and optimize itself according to the new data constantly, so that it can improve the accuracy and adaptability of the algorithm. Third, the model should have good expansion performance, with the result that it can add new types of faults at any time.

The probabilistic neural network combines density function estimation and Bayesian decision theory based on radial basis function neural network. It can realize arbitrary nonlinear approximation, and has the advantages of fast convergence speed, good expansion performance and strong fault tolerance, which is very suitable for real-time processing. Therefore, the probabilistic neural network model was used herein.

2.2 Fault simulation testing

2.2.1 Parameters. 3 principles of parameters selection were set to improve the accuracy, speed and credibility of the algorithm.

First, the parameters should be closely related to the working state of the ABS system, including the parameters issued by the anti-lock braking system and the operating state of the vehicle caused by the anti-lock braking.

Second, the number of parameters should be appropriate. Too few parameters will result in inaccurate calculation results, and too many parameters will cause the calculation speed to be slow or even convergent. According to experience, 8-12 parameters were determined to be selected generally.

Third, the parameters should be easy to obtain. According to the SAE J1939 protocol and the configuration of the test vehicle, data of messages such as "EBC1", "EBC2", "CCVS1", and "VDC2" were determined to collect.
In summary, the following 9 parameters were finally determined to be collected as shown in table 1.

| Parameters                  | Message name                                             |
|-----------------------------|----------------------------------------------------------|
| Left front wheel speed      | SAE_Chassis__EBC2__Relative_Speed_FA_Left_Wheel          |
| Right front wheel speed     | SAE_Chassis__EBC2__Relative_Speed_FA_Right_Wheel         |
| Left rear wheel speed       | SAE_Chassis__EBC2__Relative_Speed_RA_1_Left_Wheel       |
| Right rear wheel speed      | SAE_Chassis__EBC2__Relative_Speed_RA_1_Right_Wheel      |
| Vehicle speed               | SAE_Chassis__CCVS1_E__Wheel_Based_Vehicle_Speed          |
| Brake pedal position        | SAE_Chassis__EBC1__Brake_Pedal_Position                  |
| Lateral acceleration        | SAE_Chassis__VDC2__Lateral_Acltn                         |
| Steering wheel angle        | SAE_Chassis__VDC2__Steering_Wheel_Angle_VDC2            |
| Yaw rate                    | SAE_Chassis__VDC2__Yaw_Rate                              |

2.2.2 Fault modes. 3 principles of the selection of fault modes were set to be convenient for vehicle fault simulation test. First, there should be significant data flow changes after the fault occurs. Second, the fault should be easy to operate and recover. Third, repeated types of faults should be avoided.

In summary, 3 fault modes were selected to simulate, that is, short circuit of left front wheel speed sensor, left front wheel speed sensor gap too large leads to no signal and left front solenoid valve disconnect.

2.2.3 Test Scheme. The test vehicle model was HOWO T7H, the data acquisition equipment was the Core Technology CAN Analyzer, the data recording and analysis software was CANalyzer.

In accordance with the principle of controlling a single variable, the test was divided into 16 groups according to the fault modes, the test situation, and the initial operating conditions of the vehicle, including straight-line driving at different initial speeds and cornering at different corners of the curve. Each group of tests carried out 3 times, so that a total of 48 groups of test data were obtained.

2.3 Training and validation of neural network model

2.3.1 Test data preprocessing. Data preprocessing included unification of data frequencies and data tailoring so that the data can be used to train neural network models.

The transmission frequency of the selected 9 parameters in CAN is shown in Table 2. The data at the same time point is comparable. In consideration of the higher the data evaluation rate is, the better the accuracy of the model calculation results are. Therefore, the frequency of all the parameters was unified to 10 Hz.

| Parameters                               | Transmission frequency |
|------------------------------------------|------------------------|
| Wheel speed, vehicle speed, brake pedal  | 10 Hz                  |
| position                                 |                        |
| lateral acceleration, steering wheel     | 100 Hz                 |
| angle, yaw rate                          |                        |

The purpose of data clipping is to make each set of test data have the same length. In order to facilitate the data length, the test data was divided into 3 stages, as shown in figure 2, where horizontal coordinates represent time, ordinates represent the value of parameters, and curves of different colors represent parameter types.

The first stage is the uniform driving stage. After starting up, the vehicle accelerated to the specified by the test and drove at a uniform speed. In this stage, the vehicle speed was maintained at 30-40 km/h, and other parameter data do not change significantly.

The second stage is the emergency braking stage. This stage was from the moment when the position of brake pedal starts to change from “0” to the moment when the vehicle speed gradually decreases to “0”. The parameters change a lot in this stage.
The third stage is the end of braking. This stage was from the moment when the vehicle speed decreases to “0” to the end of the test. At this stage, the vehicle speed was always “0”, the brake pedal position was gradually reduced from a certain value to “0”, the rest of the parameters have slight changes.

![Figure 2. Three stages of a test data.](image)

![Figure 3. The raw data (above) and the normalized data (below).](image)

In summary, a total of 5 seconds of data from the second and third stage were selected to form samples that was used to train and validate the neural network model.

### 2.3.2 Training and validation of model

Different data were used to form training samples and test samples. Training samples were used to build mathematical models, and test samples were used to find the difference between mathematical models and the fact.

Normalized data of the training samples are shown in figure 3, and the given characteristic value is shown in table 3. The value of the smoothing factor had a great influence on the calculation results of the model. Therefore, the accuracy of the model under different smoothing factor values was calculated, as shown in table 3. After multiple calculations, when the smoothing factor value was between 6 and 11, the accuracy of the model calculation was 100%.

![Table 3. Calculation results of different smoothing factor values.](image)

| Fault                  | Characteristic value | Smoothing factor values |
|------------------------|----------------------|-------------------------|
| No fault               | 1                    | 1 2 5 8 10 20           |
| Short circuit of speed sensor | 2 | 1 3 3 2 2 2 |
| Wheel speed sensor no signal | 3 | 1 3 3 3 3 2 |
| Solenoid valve disconnect | 4 | 1 4 4 4 4 4 |
| Calculation results    | \            | 25% 75% 75% 100% 100% 75% |

### 3. Development and verification of the software platform

#### 3.1 Mixed programming technology of MATLAB and Visual Studio

The syntax and principle of each programming language are somewhat different, but in the end it must be converted to machine language to execution. And through some computer foundations, the role of different languages can be maximized and utilized, such as com technology, webservice technology. The mixed programming aims to make full use of the advantages of data computing and visualization.

MATLAB Compiler tool was used to carry out the mixed programming of MATLAB and Visual Studio. The Matlab Compiler can convert m files into C/C++ code, which was compiled and linked into a standalone application by the C/C++ compiler.
3.2 Development of the software platform

The remote fault diagnosis software platform has two core functions: one is the reading of the real-time data flow, which should be able to store, read and display the data of the selected 9 parameters, and the other is to be able to calculate the collected data into the mathematical model and display the results of the diagnosis.

Based on C++ language, ICOP technology, SQL Server data, and CCS + JavaScript technology, the vehicle remote fault diagnosis software platform was developed, including data flow reading module and fault diagnosis module.

3.3 Verification of the software platform

After the software platform was developed, a real test was required to verify the fault diagnosis function. This test replaced the test vehicle and driver to verify whether different vehicles or different driving habits had an impact on the diagnosis results. If the model can accurately diagnose the fault, it proves that the model is robust and universal, otherwise the algorithm needs to be adjusted and optimized.

One of the faults were taken as an example. First the vehicle was connected to the software platform, and the vehicle's left front wheel speed solenoid valve was disconnected, then 6 tests were carried out, as shown in Figure 4.

During the test, the real-time data flow and fault diagnosis results of the vehicle were observed through the software platform. As shown in Figure 5, a total of 6 fault diagnosis records were produced on the software platform, and the diagnostic results were all correct.
4. Conclusions and prospects

A fault diagnosis method of anti-lock braking system based on vehicle data flow was proposed and a fault diagnosis software platform was developed for example application. 9 parameters selected and 48 sets of test data collected were used to train and validate the probabilistic neural network models. Smoothing factor values were adjusted and optimized to achieve 100% accuracy of diagnostic results. The mixed programming technology of MATLAB and Visual Studio was used to develop the software platform. The results show that the neural network model based on vehicle data flow can achieve accurate fault diagnosis and the software platform can realize the function of fault diagnosis.

However, limited by the test vehicle, site and other conditions, the number of fault types and test times is not enough, which leads to limitations of the model algorithm. In the next stage, the test data should be further enriched to improve the algorithm model, and similar methods can be used to research the fault diagnosis of engine, transmission and other systems.

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