Abstract: The detection method of automotive controller area network bus is researched in this paper. Failure identifying of CAN bus under different working conditions has been realized. In order to realizing intelligent failure diagnosis, data fusion means has been put forward in this paper. The composition of analysis and detection system is introduced. By analyzing and processing the data of CAN bus and sensors, work condition of automotive is achieved. Multi-pattern data fusion model and algorithm for failure diagnosis are researched. The analyzer and detection system designed in this paper can be applied to automotive fault analysis, troubleshooting and maintenance.

Keywords: Controller area network, Bus, Automotive, Detection, Data fusion.

1. Introduction

Many microcontrollers have been used in automotive. The communication of information is ubiquitous in automotive engine, chassis and electrical system. The status information of each system can be shared. Within an automotive communication system the information transfer is frequently achieved by controller area network which acts as a carrier for the information signal. So a highly advanced ECU (electronic control unit) of engine, chassis and vehicle body should have the function of data acquisition, data management, transmission and information sharing. Controller Area Network technology has been quickly adopted by automotive industry in 1993, it became the international standard known as ISO 11898. CAN bus is an asynchronous serial bus network that connects devices, sensors and actuators for control applications. First proposed by Bosch Company, CAN bus is part of a computer network system and is widely used in automotive. Automotive control units can be connected to form a vehicle network system by using CAN data bus. The exchange and sharing of data can be achieved between each control unit in the automotive.

The application of CAN data bus technology greatly reduces the number of sensors and wires. Safety, comfort, emission and economic performance have been greatly improved by using CAN bus. In order to improve the reliability of CAN, the detection method of automotive controller area network bus is studied in this paper. This paper presents the importance and necessity for CAN detecting. Reliability and faults diagnosis of hardware are described in detail. This paper classifies the software and hardware reliabilityrationally on the basis of collecting and analyzing bus information. Systematic methods of data acquisition, analysis and detection are presented [1-3].

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2. Detection Method of Automotive Controller Area Network Bus

By testing voltage, current, waveform and pulse signal of sensors placed in auto parts, the status of the car will be judged. This is a traditional vehicle fault detection and diagnosis method. With the development of data bus technology, many cars provide the CAN bus communication interface instead of the sensor interface. Once the engine malfunction occurs, because of the lack of CAN bus test equipment, sensor signal cannot be measured directly. So the working condition of the ECU cannot be detected. The work of maintenance staff will be limited. When vehicles equipped with CAN bus transmission system have a failure, maintenance staff should first detect whether the data transmission system is working properly. If the multiplex system has breakdown, then some information in entire automobile data transmission system are unable to transmit. Therefore, electronic control modules cannot receive data information and are unable to work in good condition. General troubleshooting techniques of automotive are depth analysis according to the multiplex system's concrete structure and control loop. Therefore, the development of test instruments based on CAN bus should satisfy the broad market demand of auto maintenance. This kind of instrument can be used in real-time analysis of ECU unit operation. It will works under various actual conditions during operation parameters testing. It should have strong resistance to Electromagnetic interference, and be suitable for the requirements of the car EMC.

Traditional automobile decoder collects data stream from OBD II standard interface. Because CAN data transmission system's information and breakdown code are quite simple, complex malfunction is unable to be diagnosed reliably based on Fault code. Based on the data stream capture from CAN bus, the system developed by this paper has achieved breakthrough and development in some aspects. Traditional fault detection and diagnosis methods need to collect the data flow through a common interface and sensor signal. The system can detect the vehicle CAN bus data, the operation of ECU, the sensor signal failure and other information directly [4-7].

The length of CAN bus standard data frame changes from 44 to 108 bit. Extended data frame length changes from 64 to 128 bit. CAN bus message is mainly composed of a start frame, arbitration field, data field, CRC checking field, response field and the end of the frame. The standard frame form is shown in Fig. 1. CAN bus can use many kinds of physical media, for example twisted pair line, optical fiber and so on. The twisted pair line is most commonly used on automobiles. The signal is sent by difference voltage. Twisted pair wires were called CAN_H and CAN_L. Through collecting CAN_H and CAN_L voltage signal by detection system, CAN bus data and basic data link work conditions can by acquired.

![Fig. 1. The standard frame form of CAN bus.](image1.png)

The schematic diagram of CAN bus analyzer and diagnosis system is shown in Fig. 2.

![Fig. 2. The schematic diagram of CAN bus analyzer.](image2.png)

The speed and complexity of information transmission may not be the same for different automotive control system. Automotive engine, automatic transmission, suspension and ABS system need to collect sensor's information with high speed and achieve rapid control of fuel injection, ignition and brake actuators. The response speed of the instrument and information display system is relatively medium. Additionally, the control speed of seat, door and window is lower.

From the perspective of the reasonable design, according to the different requirements of information transmission speed and properties, CAN bus system can be divided into different levels of subsystems such as high, medium and low speed. Gateway technology of CAN bus allows data that was previously transmitted in the circuit domain to be transmitted in the packet domain. The key technology of CAN bus detection is analyzed elaborately.

In digital signal technology, a signal that uses a positive (or negative) excursion and ground as the two binary signal states. There is a range of voltages that the circuit will recognize as a high or low level within CAN bus. CAN transmits signals on the CAN bus which consists of two wires. These two wires are operating in differential mode. They are carrying inverted voltages to decrease noise interference. Using two signal transmission lines, voltage outputs of CAN bus are in forms of difference which are called V-high and V-low. Ordinarily, the voltage of two lines is same. The voltage is approximately equal to 2.5 Volts. Differential voltage of two wires which
is called V-diff approximates to zero. During the process of signal transmission, the high level of V-high is 3.5 volts and the low level of V-low is 1.5 volts. In this case the difference voltage known as V-diff is equal to 2 volts. As a result, there are two kinds of logic state on the CAN bus. One is recessive state which is same as the voltage level of two wires. The other is dominant state which is differential level of two wires. CAN bus is respectively represented by the dominant kind and recessive kind of logic value. The communication is handled according to rules given by manufacturers. The voltage of CAN bus is shown in Fig. 3. Typical dominant and recessive logic voltage values of CAN bus signal are shown in Table 1.

![Fig. 3. The voltage of CAN bus.](image)

**Table 1.** Dominant and recessive logic voltage value.

<table>
<thead>
<tr>
<th>Voltage of CAN Bus</th>
<th>V-high</th>
<th>V-low</th>
<th>V-diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recessive</td>
<td>2.5 V</td>
<td>2.5 V</td>
<td>0 V</td>
</tr>
<tr>
<td>Dominant</td>
<td>3.5 V</td>
<td>1.5 V</td>
<td>2 V</td>
</tr>
</tbody>
</table>

3. The Design of Automotive Can Bus Detection System

When the automobile has a breakdown, related signals need to be tested by controller area network detection system. Troubleshooting is based on the results of testing analysis. In addition, massive experiments need to be carried on when calibrating parameters of automotive electronic control unit. In experimental process, the internal signal and running parameters of controller should be acquired in time. This information is taken to carry on the optimization of the control system as the basis. This needs to develop a set of CAN bus monitoring and debugging software that can test various kind of parameters in real-time and debug online control parameters and variables. Data transmission of CAN bus is shown as Fig. 4.

![Fig. 4. Data transmission of CAN bus.](image)

By collecting data stream of CAN bus, dynamic operation parameters of automotive will be acquired. All collected data is transmitted to computer, so working status of automotive can be tested and the fault can be diagnosed. This system will carry on examination to the electronic control module, inquiry whether the output signal, workload and other situations are normal. Defect diagnostics and analytics for communication between different control units has been realized by CAN bus test module.

4. Data Fusion Model and Algorithm

In order to meet the need of the fault diagnosis, the integration of processing the large number of complex data should be considered. Complex data need to be converted to distinguish information effectively. The core of the system is the design of corresponding data extract algorithm, data fusion model, and information forecast. As a result, the research of multi-pattern data fusion model and algorithm for failure diagnosis is very important.
The data fusion is mainly used in processing of multi-sensor data. In the ordinary circumstances, it carries on under different rules. Properly data acquisition is produced through multi-sensor collection, classification and integration. The basic objective is to derive more information from data combination. In order to improve the synergistic effect, joint operation advantages of multiple sensors should be made use of. Therefore, the overall effectiveness of the sensor system is improved [8-11].

Adaptive weighted algorithm is adopted by detection system to fuse the vehicle's feature information, sensor information and CAN bus data information. A variety of sensors are installed on vehicle. Because the precision of sensors is various and external detection condition is quite complex, there are large inhomogeneity for the object to be measured. Therefore, this paper adopts the adaptive weighted data fusion algorithm based on measured data. Corresponding weights of different data are determined by the measurement accuracy. Weights indicate the relative importance of measurement data. Because the error of high precision sensor is small, corresponding weight is large. The measured data were multiplied by weight number. The different sensor has the corresponding weight number. In order to get the smallest total mean error, the measured value of each sensor needs the corresponding weight factor using adaptive method. Test system's data fusion value is shown as Eq. 1.

\[ X = \sum_{i=1}^{n} W_i X_i, \]  

\[ \sum_{i=1}^{n} W_i = 1, \]  

where \( W_i \) is the weight factors of various sensors, \( X_i \) is the observed values of various sensors.

Total standard deviation is shown as Eq. 3.

\[ \sigma_i = \frac{\sum_{i=1}^{n} W_i \sigma_i^2}{\sum_{i=1}^{n} W_i}, \]  

where \( \sigma_i \) is the weight factors of various sensors, \( \sigma_i^2 \) is the fusion value, \( \sigma_i^2 \) is the observed values of various sensors.

Weight factors of various sensors are shown as Eq. 4.

\[ W_i = \frac{1}{\sigma_i^2 \sum_{j=1}^{n} 1/\sigma_j^2}, \]  

Total standard deviation \( \sigma_i^2 \) is the minimum value.

Therefore, after extracting the best weight factor, the estimated value of data fusion \( \hat{X} \) can be calculated.

By comparing and analyzing experimental results, the test system is able to accurately obtain the fault information of automotive controller area network. According to the data flow of various sensors, the system can also analyze the fault information. Tips and solutions are presented. The system achieves the original design requirements. The accuracy and reliability is quite satisfactory. Experimental result of automotive CAN bus waveform is shown in Fig. 6.

![Fig. 6. Automotive CAN bus waveform.](image)

5. Conclusions

By designing hardware and software system, real time data acquisition, monitoring recorder and identification of automotive controller area network are achieved. The data of automotive CAN bus and sensors are processed and analyzed. Dynamic operation parameters of automotive are acquired by the analyzer and detection system through collecting data stream of CAN bus. Although the error detection, signaling and fault confinement defined in the CAN standard makes the information of CAN bus correct and consistent. Fault detection can be handled automatically by the CAN bus analyzer. CAN bus analyzer make sure that the system is more reliable. The detection system is of great value to removing incipient fault of running vehicle, improving reliability, rational maintaining and proper inspection.

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References


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