The Implementation of OBD-II Vehicle Diagnosis System Integrated with Cloud Computation Technology

Jheng-Syu Jhou
Dept. of CSIE
Shu-Te University
Kaohsiung, Taiwan
s11639108@stu.edu.tw

Shi-Huang Chen
Dept. of CSIE
Shu-Te University
Kaohsiung, Taiwan
shchen@stu.edu.tw

Wu-Der Tsay
Dept. of Logistics Management
Shu-Te University
Kaohsiung, Taiwan
kuas1949@stu.edu.tw

Mei-Chiao Lai
Department of Health and Beauty Business Administration, Taiwan ShouFu University
Tainan, Taiwan
wendylai3@gmail.com

***Abstract*—This paper implemented a cloud computation based second generation on-board diagnostic (OBD-II) system. The proposed system is integrated with OBD-II, 3.5G wireless network, and cloud computing technologies. It can perform real-time vehicle status surveillance. The monitored features cover engine rpm, vehicle speed, coolant temperature, fault codes, and other vehicle dynamics information. The vehicle information will be transmitted to the cloud computing server via 3.5G wireless network for fault analysis. Once cloud computing server detects fault conditions, the proposed system could classify the fault conditions depended on vehicle type and its model year. Then the cloud computing server will report the fault code analysis results to the user and provide the description about repair procedure. The proposed system will greatly shorten the time to detect vehicle trouble condition. The system presented in this thesis has a very high value in the applications of vehicle maintenance and fleet management.**

Keywords-On board diagnostics (OBD), cloud computing, vehicle repair information, android system.

I. INTRODUCTION

With the heightened attentions of global environmental protection as well as energy saving and carbon reduction issues, currently the major vehicle companies are committed to develop new cars with features of low fuel consumption and low emissions. To achieve this goal, the new vehicles are come with various automotive electronic devices, such as electronic fuel injection system, automatic transmission system, emission control systems, and etc. Although these automotive electronic devices could improve the performance of fuel efficiency, they will also increase the complexity of vehicles significantly. According to statistics, modern new vehicles have configured twice number of electronic components than a decade ago. At the same time, IC Insights, the semiconductor market research organization, also pointed out that in 2004 the cost of electronic components is 23% of overall vehicle price. This proportion will increase to 40% in 2010 and may reach 50% in 2020.

The major vehicle companies have took the durability of these automotive electronic devices into account when designing modern vehicles, however, the human failure or improper operation will still lead to unnecessary fuel consumption and exhaust pollution. Because of these modern vehicles equip with lots of electronic components, it is not easy to diagnose these vehicle faults using traditional fault detection methods. According to previous researches [1], the time for finding vehicle fault is 70%, while the time for troubleshooting and maintenance accounts is just 30%. Therefore, the major vehicle companies developed a fault diagnosis system, namely, on-board diagnostic or OBD, into vehicle electronic control unit (ECU).

Figure 1. Various symbols of MIL or the check engine light. (Pictures are copies form Ford, GM, and Toyota vehicle maintain manuals)

The OBD system is designed to consecutively monitor the running condition of vehicle [2]-[4]. Once there is a malfunctioning element that controls the emission of exhaust, the OBD system will turn on the Malfunction Indicator Lamp (MIL) or the Check Engine light, as shown in Figure 1, to notify the driver to repair the vehicle immediately. When the OBD system detects malfunctions, OBD regulations will inform the ECU of the vehicle to save a standardized Diagnostic Trouble Code (DTC) about the information of malfunctions in the memory. An OBD Scan Tool for the servicemen can access the DTC from the ECU to quickly and accurately confirm the malfunctioning characteristics and location in accordance with the prompts of DTC. In addition to DTC, the OBD system can monitor more than 80 items of real-time driving status, e.g., vehicle speed, engine rpm, throttle position, intake air temperature, engine coolant temperature, and etc [2]-[4].

The OBD system is widely used in the current vehicle workshops or service dealers. Due to the operation of OBD is quit difficult, the general drivers could not access OBD data easily. Hence, this paper develops a vehicle diagnosis system integrated with cloud computation technology to help

978-1-4799-3184-2/13 $31.00 © 2013 IEEE
DOI 10.1109/RVSP.2013.55

driver or repairer to determine the faults of vehicle. The vehicle diagnosis system proposed in this paper consists of on-board unit (OBU) and vehicle diagnostic server (VDS). The OBU is divided into OBD and CAN Bus signal receptions, GPS receiver, and 3.5G wireless network module. In addition to diagnostic server monitoring function, the proposed VDS integrates the online expert system and statistical analysis to strengthen the functionality.

The remaining sections of this paper are organized as follows. Sections II and III will introduce the OBU and VDS, respectively. Section IV describes the experimental results. The final section will conclude this paper.

II. ON-BOARD UNIT (OBU)

The OBU module proposed in this paper is designed to acquire the real-time vehicle location and operation information, e.g., date, time, longitude, latitude, speed, engine rpm, coolant temperature, fault code number, and others from GPS receiver and CAN/OBD-II adapter. The real-time vehicle information will be encoded via CAN/OBD-II diagnosis encoder and then transferred to digital bit streams. The OBU module will transmit these digital bit-streams to the vehicle diagnostic server (VDS) through the 3.5G network. Figure 2 is the block diagram of the proposed OBU module. The system is mainly comprised of CAN/OBD-II adapter, GPS receiver, CAN/OBD-II diagnosis encoder, and 3.5G wireless network module. The following three subsections will particularly introduce these three main items.

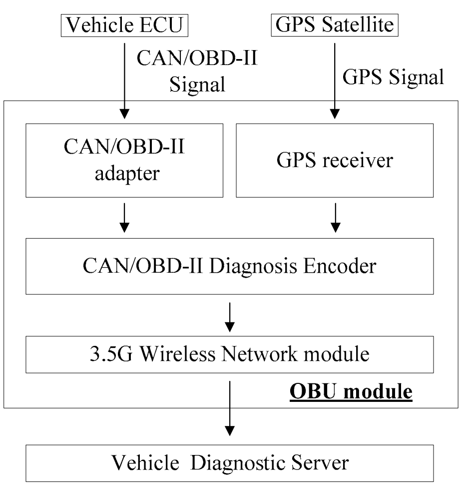
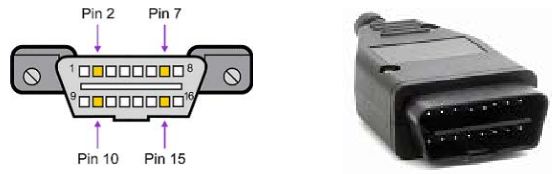


Figure 2. The block diagram of the proposed OBU module.

A. *CAN/OBD-II adapter*

The CAN/OBD-II adapter used in this paper is based on ELM 327 chip and follows SAE/ISO standards [6]-[9], [12]. The main features of CAN/OBD-II are (1) unified J1962 16-pin socket and data link connector (DLC) (as shown in Figure 3); (2) unified DTC and meanings; (3) storage and display DTC; (4) vehicle record capability; and (5) auto-clear or reset function for the DTC. In other words, just one set of CAN/OBD-II scan tool is able to perform the diagnosis task and can scan against variety of vehicles which equipped with CAN/OBD-II system.



(a) (b)

Figure 3. (a) J1962 CAN/OBD-II 16-pin socket, (b) CAN/OBD-II DLC.

There are five codes in total to represent the OBD-II DTC message. Figure 4 shows the definition of the OBD-II DTC. The first code is an English alphabet to stand for the established malfunction system. The remaining four codes are digits; the second code indicates the meaning of malfunction formulated by ISO/SAE or customized by the vehicle manufacturer; the third code shows the area of vehicle system; the remaining two codes represent the definition of the subject malfunction [5].

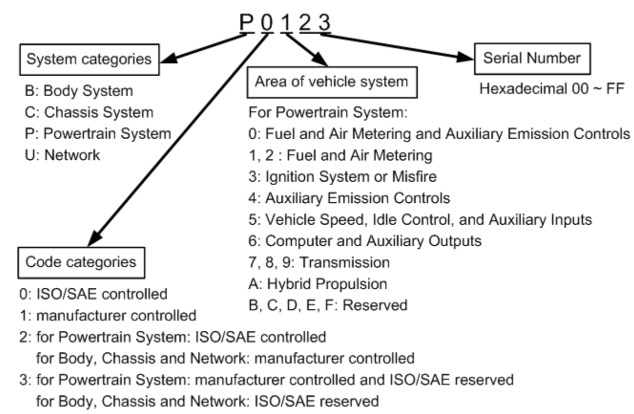


Figure 4. Definition of the CAN/OBD-II diagnostic trouble code (DTC).

B. *GPS receiver*

GPS receiver can receive signals from 8-12 sets of GPS satellite at the same time. The GPS satellite signals include coordinated universal time, ephemeris data, almanac data, coarse/acquisition code, and etc. GPS receiver can receive, process, and transform the information into time, latitude, longitude, velocity, orientation, altitude, estimated position error, and other time-location information [9]. Then, these data will be transmitted to a Geographical Information System (GIS), such as Google Maps to pinpoint and display the vehicle position. The proposed system used the GPS receiver with the SiRF Star III chipset mounted to collect the GPS signals.

C. *CAN/OBD-II diagnosis encoder*

The function of CAN/OBD-II diagnosis encoder is to encode and integrate the GPS signals as well as CAN/OBD information in accordance with the preset transmission format. These encoded digital bit streams will be transmitted to the vehicle diagnostic server via 3.5G wireless network [10]. The vehicle diagnostic server can decode the digital bit steams in accordance with the predefined transmission format to acquire the subject vehicle information, including speed, engine rpm, engine coolant temperature, OBD DTC, and the GPS coordinates for the position of vehicle.

III. VEHICLE DIAGNOSTIC SERVER (VDS)

The VDS proposed in this paper could be regarded as a kind of vehicle diagnostics management platform. It will receive the real-time vehicle data from OBU over the wireless network. These real-time vehicle data include GPS coordinates, vehicle speed, engine rpm, coolant temperature, OBD DTC, and etc. The VDS will analyze these real-time vehicle data using online expert system with statistical analysis. Once the online expert system detects any vehicle abnormal condition, the VDS will immediately notify the drive for the necessary repair.

The built-in online expert system will analyze the vehicle speed, engine rpm, throttle angle, brake, engine temperature, battery voltage, oxygen sensor voltage, fuel injection frequency, instantaneous fuel consumption, and other information by statistical algorithms to determine whether the vehicle is abnormal and perform vehicle fault warning. The VDS also supports the following data management functions: the driver and vehicle data management, real-time vehicle location communications, vehicle running state, the vehicle exception alerts, remote vehicle maintenance instructions, and etc.

A. *Online expert system*

Generally, the expert system is designed for a particular field to solve, judge, or explain a problem through a knowledge database and an inference engine. With the gradual development of a variety of expert systems, the expert systems have been used in the various industries, and more diverse applications.

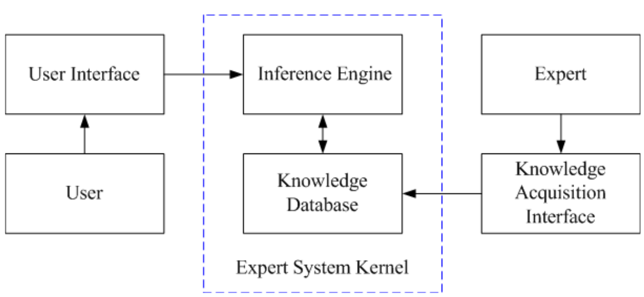


Figure 5. The block diagram of the expert system.

In this paper, the online expert system is mainly designed to enhance the functionality of the VDS. The online expert system contains a knowledge database, knowledge acquisition interface, user interface, and inference engine. Figure 5 shows the block diagram of the expert system.

The knowledge database is built to collect human expert knowledge in systematically express or modular. Hence the computer can carry out inferences and solve the problem. The purpose of knowledge acquisition interface is to help system developers to conduct knowledge extraction, editing and revision of knowledge database and inferences device. It also can test, record, and describe the status as well as results of the expert system. The user interface is a bridge of communication between user and expert system. The design of user interface focuses on compatibility and convenience. It usually provides a variety of methods of operation and indicates the correct behavior patterns.

The inferences engine is the main part of the expert system. It makes use of algorithms or decision-making strategies to conduct the expertise and knowledge database of inferences between knowledge. Common expert system could be divided into rule-based reasoning and case-based management system.

The rule-based inferences engine uses plenty of rules built into the knowledge database. The reasoning process is mainly by the rules of the link, the system must control the initial state to reach its goal of reasoning. Therefore, rule-based expert system is suitable for a known complete range or narrower application. Generally, the rule-based expert system includes three steps:

1. Matching: to find all the rules in line that meet the case.
2. Selection: In all candidate rules, decided one of the most suitable choice of the status of execution.
3. Rule execution: To execute the selection rules of the process.

The case-based inferences engine is derived from machine learning domain. It is essentially a human problem-solving mode. The basic approach is to use the past similar experience to solve new problems. As long as the collection of adequate fault case is enough, the reliability of system will be increase. Case-based expert system has following five main steps.

1. Store the related examples or experiences in a knowledge database.
2. Identify and understand the current problems.
3. Extract the similar case of example or experience from the knowledge database.
4. Use these similar examples or experiences to solve current problems.
5. Once the problem is solved, update this example or experience in the knowledge database.

Since the entire vehicle system composed of various sub-systems, the event of failure may quite different. The cause of the failure may simply occur in the same subsystem. The failure of explicit phenomenon can be judged as a sub-system failure, and it is suitable for rule-based inferences engine. However, the fault may fail to cover the number of sub-systems. It usually does not have explicit symptom and is suitable for use case-type inferences engine. Therefore, this paper will use rule-based and case-based simultaneously to design the expert system.

IV. EXPERIMENTAL RESULTS

This paper used two notebook computers to simulate the OBU and VDS modules. OBU module has a GPS-1155 (USB interface, SiRF III) GPS receiver and a Bluetooth receiver to get the GSP signal and CAN/OBD-II information, respectively. It also comes with a 3.5G network module. The notebook used to simulate VDS installs Microsoft Access 2003 to record the real-time vehicle information and makes use of Google Maps API to indicate the vehicle location in the GIS. VDS has a fix IP address to receive the vehicle information send by OBU module. All of the subsystems proposed in this paper are implemented by C# language and the computer is able to execute this browser when it is installed the Microsoft .NET Framework V2.0. Figure 6 shows the simulation equipments mentioned above.

Figure 6. The simulation equipments of the proposed system.

Figure 7 shows the CAN/OBD-II information displayer implemented in this paper. In this example the temperature of engine coolant, i.e. 164 degree, exceeds the legal limit and hence the VDS will notify the driver as shown in Figure 7.

Figure 7. The CAN/OBD-II information displayer implemented in this paper. They are vehicle speech, engine rpm, tempture of engine coolent, MAF (Mass Air Flow), ECU voltage.

Once VDS detects any fault of vehicle, the VDS will first determine the cause of this fault using the on-line expert system. Then OBU can show the service manual downloaded from VDS. Figure 8 is an example of on-line service manual provided by VDS

Figure 8. The on-line repaire manual provided by VDS.

V. CONCLUSION

This paper integrated CAN/OBD-II system, 3.5G mobile network, GPS, and expert system to develop an intelligent technology for real-time vehicle diagnostics and early fault estimation. This proposed system is comprised of on-board unit (OBU) module and vehicle diagnostics server (VDS). The real-time vehicle data, i.e., vehicle location and CAN/OBD-II operation information, will be transmitted to the VDS via 3.5G mobile network. Then, the expert system built-in the VDS will analyze these vehicle operation data and perform real-time vehicle diagnostics or fault early warning. Once abnormal conditions have been detected, the VDS will inform deriver or qualified factory of the requirement of vehicle maintenance or repair. The proposed system is very useful for the detection of vehicle pollution, warning of vehicle malfunction, remote diagnosis, and roadside repair.

REFERENCES

[1] Hu Jie, Yan Fuwu, Tian Jing, Wang Pan, Cao Kai, “Developing PC-Based Automobile Diagnostic System Based on OBD System,” 2010 Asia-Pacific Power and Energy Engineering Conference (APPEEC), pp.1-5, March 2010.

[2] Diagnostic Trouble Code Definitions Equivalent to ISO/DIS 15031-6, SAE Standard J2012, 2002.

[3] E/E Diagnostic Test Modes — Equivalent to ISO/DIS 15031-5, SAE Standard J1979, 2002.

[4] Diagnostic Connector Equivalent to ISO/DIS 15031-3, SAE Standard J1962, 2002.

[5] Diagnostic Trouble Code Definitions Equivalent to ISO/DIS 15031-6, SAE Standard J2012, 2002.

[6] E/E Diagnostic Test Modes — Equivalent to ISO/DIS 15031-5, SAE Standard J1979, 2002.

[7] C. E. Lin, Y.-S. Shiao, C.-C. Li, S.-H. Yang, S.-H. Lin, C.-Y. Lin, “Real-Time Remote Onboard Diagnostics Using Embedded GPRS Surveillance Technology,” *IEEE Trans. on Vehicular Technology*, Vol. 56, No. 3, pp. 1108-1118, May 2007.

[8] C. E. Lin, C. C. Li, S. H. Yang, S. H. Lin; C. Y. Lin, “Development of On-Line Diagnostics and Real Time Early Warning System for Vehicles,” in *Proc. IEEE Sensors for Industry Conference*, pp. 45-51, Feb. 2005

[9] NMEA data. Available: http://gpsinformation.org/dale/nmea.htm

[10] H. Holma and A. Toskala, HSDPA/HSUPA for UMTS - High Speed Radio Access for Mobile Communications, Wiley, John & Sons Ltd, 2006.