A Study on Remote On-Line Diagnostic System for Vehicles by Integrating the Technology of OBD, GPS, and 3G

Jyong Lin, Shih-Chang Chen, Yu-Tsen Shih, and Shi-Huang Chen

Abstract—This paper presents a remote on-line diagnostic system for vehicles via the use of On-Board Diagnostic (OBD), GPS, and 3G techniques. The main parts of the proposed system are on-board computer, vehicle monitor server, and vehicle status browser. First, the on-board computer can obtain the location of deriver and vehicle status from GPS receiver and OBD interface, respectively. Then on-board computer will connect with the vehicle monitor server through 3G network to transmit the real time vehicle system status. Finally, vehicle status browser could show the remote vehicle status including vehicle speed, engine rpm, battery voltage, engine coolant temperature, and diagnostic trouble codes. According to the experimental results, the proposed system can help fleet managers and car knockers to understand the remote vehicle status. Therefore this system can decrease the time of fleet management and vehicle repair due to the fleet managers and car knockers who find the diagnostic trouble messages in time.

Keywords—Diagnostic Trouble Code (DTC), Electronic Control Unit (ECU), Global Position System (GPS), On-Board Diagnostic (OBD).

I. INTRODUCTION

ON-BOARD Diagnostic (OBD) regulations require passenger cars to report diagnostic information and standardized fault codes for malfunctions detected by the OBD system [1], [2]. As early as in 1985, the California Air Resources Board (CARB) enacted an ordinance that demands the vehicles outfitted with the OBD system. The European Union followed to legislate for a compulsory installation of OBD system in vehicles. The Taiwan (R.O.C.) Environmental Protection Administration also implemented a mandatory regulation in January 2008 for its Phase 4 Emission Standards against all the gasoline vehicles in Taiwan. Therefore all of the vehicles must be outfitted an OBD system from then on as an

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effort to put the pollution from vehicles into surveillance. Any vehicles without this device mounted shall not be issued the license plate to hit the road. Thus it can be seen that OBD system will be the standard outfit to all of the vehicles in the future.

The OBD system can always monitor the running condition of engine. Once there is a malfunctioning element that controls the emission of exhaust, the OBD system will turn on the Malfunction Indicator Lamp (MIL) (as shown in the Fig. 1) in the in-car dashboard to urge the driver to fix it immediately. The element for emission control of exhaust gas can resume its normal operation as soon as possible in order to avoid driving a malfunctioned vehicle continuously that leads to a higher fuel consumption and pollution emission. When the OBD system detects a malfunction, OBD regulations require the Electronic Control Unit (ECU) of the vehicle to save a standardized Diagnostic Trouble Code (DTC) about the information of malfunction in the memory. An OBD Scan Tool for the servicemen can access the DTC from the ECU quickly and accurately to confirm the malfunctioning characteristics and location in accordance with the prompts of DTC that shortens the service time largely. Moreover, currently the number of item for the real-time driving status that OBD can monitor is as high as up to 80 items and more including the vehicle speed, engine rpm, engine coolant temperature, battery voltage, and etc.

Fig. 1 Variety of icons for Engine Malfunction Indicator Lamps

Although OBD can shorten the service time of vehicles, a demand for the immediateness and mobility relevant to the vehicular diagnostics is growing increasingly. Therefore, if it is possible that the DTC can be delivered to the server through the mobile communication, not only the OBD Scan Tool can read the message, but the servicemen also can inquire the real-time malfunction message from a remote vehicle. Thus the deficiency of immediateness and the mobility can be made up consequently [3]–[5].

In addition to the need of concerning the immediateness and

the mobility of vehicular diagnostics, currently the logistic industry, bus transportation service providers, taxi service providers, etc. have an uneasy task for their commercial fleet management. For this reason, this study constructed a remote on-line diagnostic system comprised of an on-board computer, a vehicle monitor server and a vehicle status browser. The remote on-line diagnostic system is for the fleet manager to understand the real-time driving status and the OBD DTC of each car on a real-time basis via 3G network. Accordingly, the fleet manager can inform the driver how to take care of the situation in a telecommunication manner. In the future, the fleet manager can not only know the driving locations of thereof fleet, but also acquire the real-time driving status of each car. Hence, in addition to mend the deficiency in immediateness and mobility, the system benefits the commercial fleet largely as well.

II. System Configuration

The remote on-line diagnostic system proposed in this paper includes three major modules, namely the on-board computer, vehicle monitor server, and vehicle status browser. Fig. 2 shows the integrated configuration of these three modules. It follows from Fig. 2 that the on-board computer is responsible for collecting the information of driving, including vehicle speed, engine rpm, battery voltage, engine coolant temperature, OBD DTC, location of vehicle, and etc. This information will be processed with digital encoding and transmitted back through a 3G network to the vehicle monitor server. The driving information will be recorded for user's immediate or future retrieval. The vehicle status browser for driving real-time information is exclusively developed for the remote on-line diagnostic system and to allow the user to synchronously browse the real-time information, e.g., vehicle speed, engine rpm, battery voltage, engine coolant temperature, OBD DTC, location of vehicle, and etc. The following three sections describe these three modules separately.

Fig. 2 Configuration of remote on-line diagnostic system

III. On-Board Computer

On-board computer is the most important key module

brought up in this paper. Its function is to acquire the information of vehicle speed, engine rpm, battery voltage, engine coolant temperature, OBD DTC, and GPS signal. The on-board computer will transmit these digital bit-streams back to the vehicle monitor server through the 3G network. Fig. 3 is the block diagram of the on-board computer proposed in this paper. The system is mainly comprised of OBD-II to RS232 adapter, GPS receiver, encoder, 3G module, and etc. The operating commands of user include the start, run, network setup, and etc. Since the majority of 3G modules support the Windows Operating System only, in order to let the system have a smooth operation, the on-board computer mentioned in this paper is practically implemented by a notebook computer with Windows operating platform.
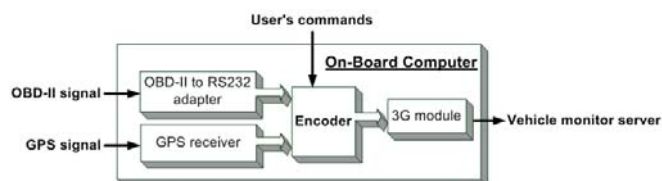

Fig. 3 Block diagram of system for on-board computer

A. OBD-II

In the very beginning of 1980s, most car manufacturers in Europe, USA and Japan had incepted producing their injection-engine cars with the OBD system equipped in a bid to monitor the running status of engine. However, the early OBD had a serious problem, that is, these car makers made thereof OBD system incompatible with one another. As an effort to rid off this defect of an incompatible OBD system, the CARB undertook to devise a new OBD system. For the purpose of differentiating it from the used system at early stage, this newly formulated system is called the OBD-II (The second generation of On-Board Diagnostic system).

The biggest betterment of OBD-II is its standardization, that is, just one set of instrument is able to perform the diagnosis and scan against variety of vehicles. In addition to the diagnosis against a totally failed element for pollution control of emission, OBD-II is able to further carry out a diagnostic against the pollution of emission exhausted from those aged or partially malfunctioned elements. When the signal from the circuit of electronic control system appears an abnormality, the OBD-II will diagnose to determine if this is a malfunctioned part. Here the abnormality is out of the range of normal deviation while this abnormal phenomenon has not disappeared within a specified amount of time duration. At this moment, the malfunction indicator lamp (MIL) will be turned on. Meanwhile, the monitor will save this malfunction in the memory inside ECU in a code form. Thus the saved DTC can be retrievable through an OBD-II Scan Tool.

The vehicle and OBD-II Scan Tool connectors each are capable of accommodating 16 contacts. Nine contacts of the 16 contacts have thereof fixed function, and the function for the rest of contacts is left to the discretion of the vehicle

manufacturer [6]. Table I tabulates the function of OBD-II contacts in details.

TABLE I
VEHICLE CONNECTOR CONTACT ALLOCATION OF OBD-II

Contact	Allocation
1#	Discretionary
2#	Bus positive line of SAE J1850
3#	Discretionary
4#	Chassis ground
5#	Signal ground
6#	CAN_H line of ISO 15765-4
7#	K line of ISO 9141-2 and ISO 14230-4
8#	Discretionary
9#	Discretionary
10#	Bus negative line of SAE J1850
11#	Discretionary
12#	Discretionary
13#	Discretionary
14#	CAN_L line of ISO 15765-4
15#	L line of ISO 9141-2 and ISO 14230-4
16#	Permanent positive voltage

There are five codes in total to represent the OBD-II malfunction. 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 SAE/ISO 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 (as shown in Fig. 4) [1].
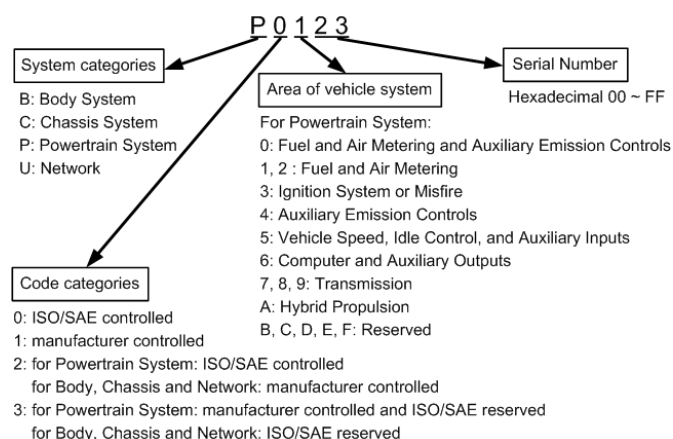

Fig. 4 Definition of OBD-II Diagnostic Trouble Code

B. OBD-II to RS232 Adapter

Since the market-sold computer has not been equipped with the OBD-II interface, an OBD-II to RS232 adapter was fabricated to accommodate with the on-board computer for a practical implementation to acquire the real-time driving status.

OBD-II is international standardized to be applicable to the following communication protocols: SAE J1850 PWM, SAE J1850 VPW, ISO 9141-2, ISO 14230-4 KWP, and ISO 15765-4 CAN. The finished product of OBD-II to RS232 adapter that is practically implemented in this paper is shown in Fig. 5. In Fig. 5, the port at left side is to connect the OBD-II interface so that the OBD-II signals can be converted into RS232 electrical signals via the conversion circuit of OBD-II to RS232 adapter in the middle section and output from the port at right side. Now the computer is able to take the advantage of this RS232 interface to communicate with the OBD-II.
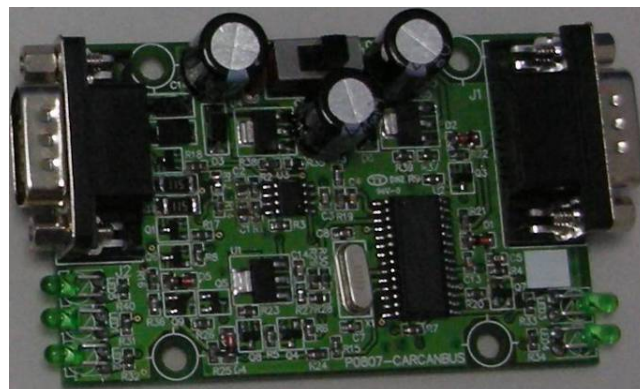

Fig. 5 OBD-II to RS232 adapter

C. GPS Receiver

GPS receiver can receive signals from 8-12 sets of GPS satellite at the same time, and the satellite signals to be received by the receiver include: Coordinated Universal Time, ephemeris data, almanac data, Coarse/Acquisition code, etc. GPS receiver can receive, process, and transform the information into time, latitude, longitude, velocity, orientation, altitude, Estimated Position Error, and etc.

For example, a sentence amongst the GPS information sentences is as follow: $GPGGA, 055730.367, 2238.2122, N, 12017.7504, E, 1, 06, 7.0, 133.9, M, 10.0, M, 0.0, 0000*74; therein, the denotations of respective data are explained below [7]:

GGA (Global Positioning System Fix Data): Time, position, and fix related data for a GPS receiver.

055730.367: UTC time format, fix was taken at 05:57:30 UTC.

2238.2122, N: Latitude format, it is 22 degree 38.2122' of north latitude.

12017.7504, E: Longitude format, it is 120 degree 17.7504' of east longitude.

1: Fix quality, the measured indicator 1 indicates that the information has made a fix using GPS.

06: The number of satellites was tracked.

7.0: Horizontal dilution of position: 0.5 m to 99.9 m, the measured value is 7.0 m.

133.9, M: Altitude above mean sea level, the measured altitude is 133.9 m.

10.0, M: Height of geoid above World Geodetic System 1984 (WGS 84) ellipsoid, the measured height is 10.0 m.

0.0: Time in seconds since last Differential GPS (DGPS) update, the measured value 0.0 shows that this GPS receiver did not use DGPS fix.

0000: DGPS station ID number.

*74: Checksum.

Then, these data will be transmitted to a Geographical Information System (GIS), such as the PAPAGO® software of Maction Technologies, Inc., for it to pinpoint and display the position. Since the SiRF Star III chips are capable of promptly and accurately receiving the GPS signals, this paper used the GPS receiver with the SiRF Star III chipset mounted to collect the positioning signals.

D. Encoder

The function of encoder is designed to encode and integrate the GPS signals and OBD data in accordance with the preset transmission format. These data will be transmitted to the vehicle monitor server via 3G so that the vehicle monitor server can decode the transmitted data in accordance with the predefined transmission format to acquire the subject vehicle's speed, engine rpm, battery voltage, engine coolant temperature, OBD DTC, and the GPS coordinates for the position of vehicle.

In order to cope with the updating frequency for GPS to receive the signals once per second, this paper also set the frequency at once per second to acquire the OBD DTC and the real-time driving status. Meanwhile, this paper defined a transmission format as follows:

On-board computer ID number| GPS data | OBD DTC | vehicle speed, engine rpm, battery voltage, engine coolant temperature

With the aim of saving the transmission of bits, this study acquired only the GGA contents amongst the GPS signals as the positioning data and transmitted the DTC, speed, rpm, voltage, and temperature in a decimal system after processing the analytics. For instance:

On-board computer ID number: 1043

GGA data from GPS: $GPGGA, 055730.367, 2238.2122, N, 12017.7504, E, 1, 06, 7.0, 133.9, M, 10.0, M, 0.0, 0000*74

DTC: P0123

Vehicle speed: 57km/hr

Engine rpm: 1649 rpm

Battery voltage: 13.375V

Engine coolant temperature: 95$^\text{O}$C

The data for transmission after being encoded by the encoder are: 1043 | $GPGGA, 055730.367, 2238.2122, N, 12017.7504, E, 1, 06, 7.0, 133.9, M, 10.0, M, 0.0, 0000*74 | P0123 | 57, 1649, 13.375, 95

IV. VEHICLE MONITOR SERVER

The driving information acquired by the on-board computer, including the vehicle speed, engine rpm, battery voltage, engine coolant temperature, OBD DTC, and GPS coordinates, will be processed through digital encoding and transmitted to the vehicle monitor server via a 3G network as a provision for

the user to retrieve the driving real-time information or to retrieve the information in the future. The vehicle monitor server will save the driving information from the on-board computer into the Access 2003 database. Then the vehicle status browser can retrieve the vehicle information, e.g., speed, engine rpm, battery voltage, coolant temperature, OBD DTC, and location of vehicle. In addition, the vehicle monitor server will take the advantage of Geographical Information System to send out a map file produced according to the GPS coordinates.

A. Access 2003 database

Microsoft Access 2003 is a relational database. Its user interface is simple, ease of operation and compatible to ANSI SQL-92 standard. Since this system is a prototyping system developed only for authenticating the feasibility of system configuration, therefore the Access 2003 database is adequate for storing the information of this system.

This paper established a data table with the "DiagnosticData" titled to cover the vehicle-driving information, while the field name, data type, and description are shown in Fig. 6. Therein, the field names of primary key are "OnBoardComputerID" and "RecordTime" that cannot be repeated. The longitude and latitude in the data table are adopted a format of WGS84 with an accuracy up to the sixth digit after the decimal point. That is, the accuracy can be within 10 cm approximately when converted into distance. Besides the foregoing field, the data table has more fields to further cover the OBD DTC, vehicle speed, engine rpm, battery voltage, and engine coolant temperature.

Field Name	Data Type	Description
OnBoardComputerID	Number	On-board computer ID number
RecordTime	Date/Time	Date and time of this record
Longitude	Number	Longitude for the position of vehicle
Latitude	Number	Latitude for the position of vehicle
DTC	Text	OBD DTC of vehicle
Speed	Number	Speed of vehicle
RPM	Number	Engine RPM of vehicle
Voltage	Number	Battery voltage of vehicle
Temperature	Number	Engine coolant temperature of vehicle

Fig. 6 Data table details relevant to the driving information

B. Geographical Information System

Geographical Information System is a science that integrates the geography, mathematics, land surveying, and computer science and serves as a computer system that can be used for input, storage, inquiry, analysis, and display of geographic data. The Geographical Information System is comprised of the following elements: maps, spatial information, database engine, analytical tools, graphic display techniques, operators, and decision-makers involved, etc. Its scope of application includes the visible objects above and below the surface of earth, such as the traffic transportation, land utilization, exploration of geology, and etc.

The PaPaGO! SDK is a Geographical Information System developed by the Maction Technologies. It can be executable in server, desk computer, and PDA. With the future expandability

taken into consideration, the PaPaGO! SDK was adopted to undertake an implementation. This paper used the PaPaGO! SDK search engine to locate the driving location with red-star pinpointed and displayed (as shown in Fig. 7), transformed it into a map file and sent it to the vehicle status browser.

Fig. 7 Mapping display of driving location

V. VEHICLE STATUS BROWSER

Vehicle status browser is exclusively used for the remote on-line diagnostic system so that the user can synchronously browse the driving date/time, OBD DTC, vehicle speed, engine rpm, battery voltage, engine coolant temperature, and driving location, etc. The basic operation in this regard is to log on the vehicle monitor server, choose the vehicle to be monitored, choose to browse the real-time information or historical record. Then it can receive the driving information from the vehicle monitor server with the driving date/time, OBD DTC, vehicle speed, engine rpm, battery voltage, engine coolant temperature shown in text form and the driving location displayed in map form in the screen (as shown in Fig. 8).

Fig. 8 demonstrates a schematic operation of vehicle status browser. In the figure, the Car ID and driving date/time are shown in the left upper block, the vehicle speed, engine rpm, battery voltage, and engine coolant temperature are shown in the upper middle block, the OBD DTC and corresponding malfunction message are shown in the upper right block, and the driving location at the time is pinpointed with a red star in the major block of the figure.
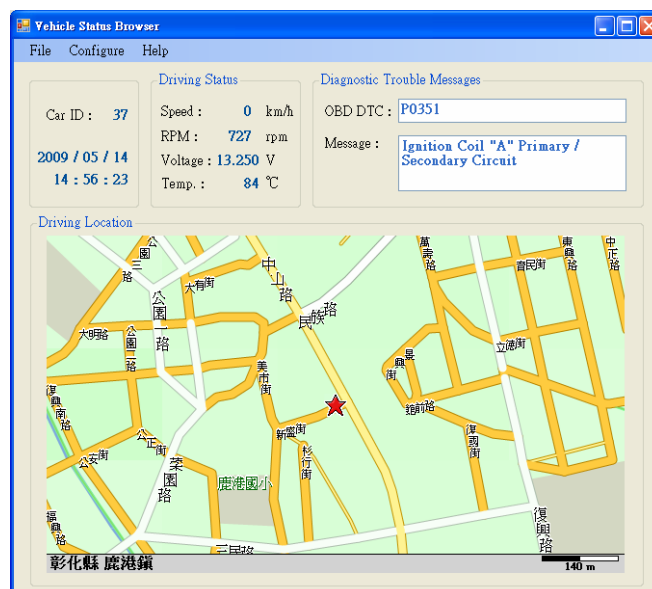

Fig. 8 Schematic operation of vehicle status browser

VI. RESULTS OF EXPERIMENT

This paper used a notebook computer configured with Intel Core 2 Duo T5500 1.66GHz CPU, 2GB RAM, Window XP® Professional SP3 operating system as the on-board computer, a BU-353 (USB interface, SiRF Star III chips) from Globalsat Technology Corporation as the GPS receiver, a network interface card of Huawei E220 HSDPA USB from Chunghwa Telecom as the 3G network module, and fabricated an OBD-II to RS232 adapter and took the C# language to implement the on-board computer system.

Regard for the vehicle monitor server, an IBM server configured with Intel Xeon® E5335 2.00GHz CPU, 2GB RAM, Windows Server 2003® R2 SP2 operating system is used together with the use of a Microsoft Access 2003 to store the driving information, a PaPaGO! SDK software from Maction Technologies Inc. to generate the map, a 6M/6M FTTB optical network from Chunghwa Telecom for networking, an IP-fixed receiving on-board computer to link with the vehicle status browser, and a C# language to program the functions of vehicle monitor server.

The vehicle status browser is likewise programmed by C# language, so the computer is able to execute this browser once installed the Microsoft .NET Framework V2.0. This paper used a desk computer configured with Intel Pentium 4 2.4GHz CPU, 1GB RAM, and Window XP® Professional SP3 operating system to perform the vehicle status browser.

This study took a Ford Focus 1.8 vehicle as the test subject, wherein, the OBD-II port was located at the left lower part of the steering wheel (the left part as shown in the Fig. 9) to connect the OBD-II to RS232 adapter (the right part as shown in the Fig. 9). Thus, when obtained the OBD DTC, etc. real-time driving status, and GPS coordinates, the on-board computer sent the received information to the vehicle monitor server via 3G network.

Fig. 9 OBD port (left part), OBD-II to RS232 adapter (right part)

In order to authenticate the feasibility of the proposed system, this study undertook an offline testing against an experimental car parked along the roadside for thereof ignition coil inside the engine chamber (as shown in the Fig. 10). After disconnecting the line of the said ignition coil, for the safety concern, the car was left at a still status (vehicle speed was 0). Then, the vehicle status browser was taken to check up the information of car; a DTC P0351 appeared to indicate that Ignition Coil "A" Primary/Secondary Circuit. Meanwhile, some information relevant to the car was shown as well: driving date/time, vehicle speed, engine rpm, battery voltage, engine coolant temperature, and driving location (as shown in the Fig. 11).

Fig. 10 Offline testing of ignition coil

Through the aid of Remote On-Line Diagnostic System, the management personnel of an automotive maintenance/repair shop or commercial fleet is able to remotely learn the current driving information and whether there is a malfunction message or not via network instead of going to the field.
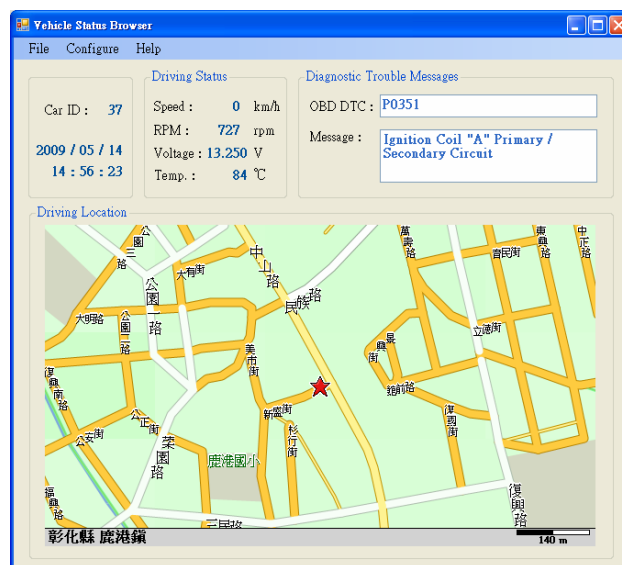

Fig. 11 Vehicle status browser

VII. CONCLUSION

This paper has successfully integrated the 3G mobile network, GPS and OBD system to develop a remote on-line diagnostic system while the complete system is comprised of three major elements: on-board computer, vehicle monitor server, and vehicle status browser. According to the results of experiments, the remote on-line diagnostic system proposed in this paper is able to allow the user to know the real-time driving status, malfunction message, and location of a moving car at a remote place. The remote on-line diagnostic system proposed by this paper offers a highly applicable value in the fleet management, remotely automotive diagnosis or the initiative service notification of a maintenance/repair shop.

In the future, the linking between the vehicle status browser and vehicle monitor server in the system will use the HTTP (Hypertext Transfer Protocol) protocol. Thus, without mounting the vehicle status browser, the user can execute the Web Browser from a computer, mobile phone or handheld device to inquire about the real-time information of a car in moving. Consequently, the convenience of using the remote on-line diagnostic system is further upgraded.

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