Vehicle Inside Information Recording System Using GPS and In-Vehicle Network

Sung-Hyun Baek and Jong-Wook Jang

Abstract Vehicle black boxes that have similar functions as airplane black boxes are currently being used due to the loss of many lives and properties arising from vehicle accidents. Both black-box products and Event Data Recorder (EDR) systems are currently available in the market. Most of the existing in-vehicle black boxes, however, record only external videos and images and cannot show the vehicle's driving status, whereas EDR products record only the driving status and not external videos. To address the problem of black boxes that can record only videos and images and that of EDR systems that can record only driving data, an integrated vehicle diagnosis recording system that uses Media-oriented System Transport (MOST), a new vehicle multimedia network, and Onboard Diagnostics II (OBD-II), a current standard of electronic-control network, was realized in this study to collect data from the electronic-control devices. The system uses external sensors such as camera (CAM) and global positioning system (GPS) to collect video, time, and location data that will be needed to make a judgment on the vehicle's current status.

Keywords Vehicle black box · OBD-II · Global positioning system (GPS) · Wi-Fi · Media-oriented system transport (MOST) · In-vehicle network introduction · External sensor · Event data recorder (EDR)

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1 Introduction

The existing Event Data Recorder (EDR) systems are used as diagnostic tools to discover what inflates vehicle airbags. Moreover, vehicle black boxes, just like their airplane counterparts, are introduced to verify the cause-and-effect relation by recording and securing objective data related to accidents, such as driving video, location, and time. They also help protect the driver's property loss or damage by recording hit-and-run cars, parking accidents, and runaway vehicles.

The importance of such system drove the European Union (EU) to establish a policy that makes it mandatory for all vehicles to be equipped with black boxes by 2010, and drove the U.S. to make it mandatory for vehicles under 4.5 tons to likewise be equipped with such black boxes beginning this year (2011). South Korea also announced that all business vehicles should have a digital EDR from 2010 to 2013 (December 29, 2009, Ministry of Land, Transport, and Maritime Affairs). In November 2007, the Korean Agency for Technology and Standards set up a national standard (KS) on a vehicle accident recording device (KSR5076) to provide institutional support to black-box technology development and the related industries [1–4].

According to the black-box standard, video data are important for accident analysis, but also essential are the driving status data [speed, brakes, seatbelt, global positioning system (GPS), automatic braking system (ABS), tire pressure, airbag status, etc.]. While most black boxes, however, meet the national standard (KS) with regard to video data, they cannot meet the national standard (KS) with regard to status data.

For actual vehicular accidents, status and video data are both essential for accident analysis. Witness testimony plays a critical role in accident analysis in most cases, and these video and status data take the place of the witness. The existing EDR products, however, use only vehicle status data, and black boxes, only video data. The absence of either vehicle status data or video data makes it difficult to establish the exact cause of an accident [5].

To overcome the limitations of the existing black boxes and EDR systems, and to provide more accurate information regarding a vehicular accident, a Wi-Fi data-transfer-available OBD-II connector was used in this study to record video, an important factor in black boxes, with GPS data. The OBD-II protocol, an in-vehicle network for recording vehicle status data such as revolutions per minute (RPM) and speed, and the MOST protocol, a vehicle multimedia network for recording a vehicle's multimedia and virtual navigational information, were also used to finally realize an Vehicle Inside Information Recording System.

2 Relevant Studies

2.1 OBD-II

Vehicles are equipped with various measurement and control sensors, which are controlled by the electronic-control unit (ECU). The original purpose of ECU was to provide accurate control of the engine's key functions, such as ignition timing, fuel injection, variable valve timing, idling, and boundary condition setup, but with the development of vehicles and computers, ECU now controls almost all the systems of the vehicle, including the automatic transmitter and the driving, braking, and steering systems. These electronic diagnosis systems underwent repeated development, and a standardized diagnosis system called "ODB-II" was established for the diagnosis of the ECU. The OBD-II network has the function of relaying information on the vehicle's major systems, or the trouble information gathered by the ECU from the in-vehicle sensors, to the vehicle's display console or external devices, via the serial communication function [6, 7].

All vehicles using the OBD-II network adopt the standardized diagnostic trouble code and connection interface (ISO J1962), but there exist five different electronic signals: VPW-PWM (SAE-J1850), CAN communication (ISO 15765, SAE-J2234), and ISO type (ISO 1941-2, ISO 14230-4). It was stipulated, however, that all vehicles to be sold in the U.S., the world's biggest vehicle market, should use control area network (CAN) beginning in 2008. This will certainly unify the future EU and Asian markets with CAN [8].

Figure 1 shows a block diagram of the in-vehicle devices connected to the OBD-II connector. Various in-vehicle electronic-control devices receive the vehicle's status data from the sensors located in each part of the vehicle, and these data can be collected externally through the ODB-II connector (J1962) [9].

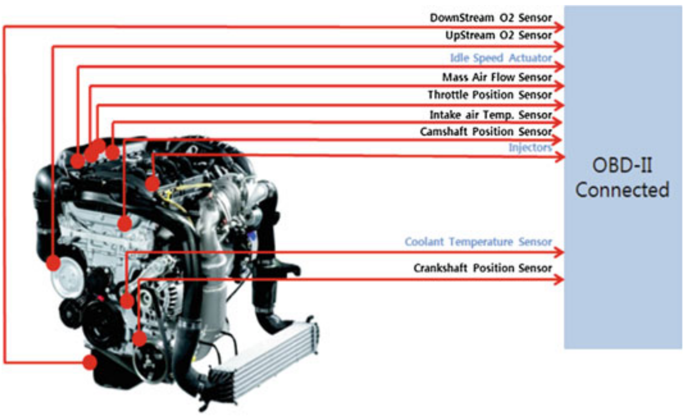

Fig. 1 OBD-II system diagram

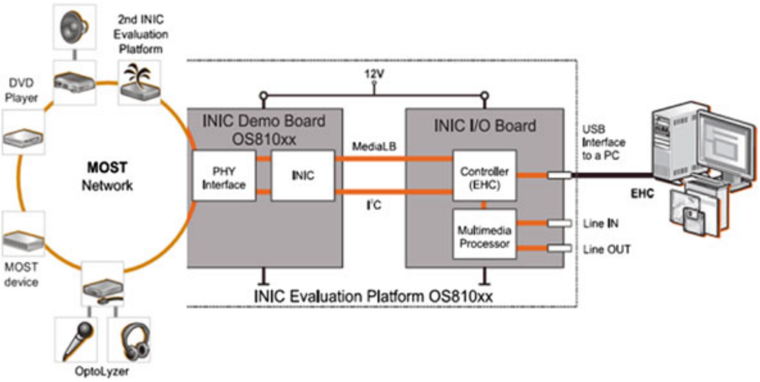

Fig. 2 MOST system diagram

2.2 Media Oriented Systems Transport (MOST)

MOST is a high-speed integrated multimedia system communication protocol that enables high-capacity multimedia data transfer of a maximum of 150 Mbps of digitized video/audio and control data. It consists of a ring-type network and uses fiber-optic cables. MOST is an optimized multimedia networking technology for use in vehicles and other applications. It is a communication technology for vehicles that can transmit high-quality audio and video packet data at the same time for the vehicle's multimedia service, and that can control a single transferred media on a real-time basis. MOST can be used in physical layers of plastic fiber optics, an electrically shielded or unshielded cluster of cables, which is a common condition in a vehicle. Currently, there are MOST25, which uses a 25 Mbps bandwidth, MOST50 (50 Mbps bandwidth); and MOST150 (150 Mbps bandwidth). MOST150, which uses the largest bandwidth, is expected to unify all these.

Figure 2 shows a block diagram of the in-vehicle MOST networks connected to a laptop. The status data of the in-vehicle multimedia electronic-control device are transferred, and these data can be collected externally via the MOST evaluation platform [10, 11].

3 Existing System Analysis and the Proposed System Composition

3.1 Comparison of Proposed and Existing Methods

The importance of the scientific analysis of accidents is drawing more attention as the number of vehicular collision accidents is increasing. Moreover, it is interesting to find out the exact circumstances of an accident through the investigation

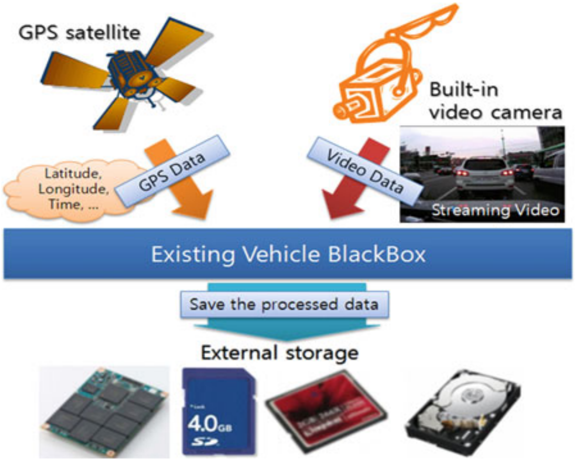

Fig. 3 The existing black-box system

and analysis of all the factors involved in the accident, such as the humans, vehicle, and environment, which data can also be used to prevent further vehicular accidents.

The existing vehicle black boxes have been trying to provide precise analyses and simulations of vehicular accidents using vehicle collision accident simulation programs with video and GPS data (Fig. 3), and the existing EDR systems also tried to provide precise analyses and simulations using vehicle accident simulation programs with vehicle driving data (Fig. 4).

However, this method contains various uncertain elements regarding road situations, car situations, etc. making it inadequate for reliable scientific analysis. To scientifically identify the causes of traffic accidents, it is important to reconstruct the accident occurrence course, and to that end, it is essential to secure dynamic behavior data such as car speeds and acceleration before and after the accident, the driver's car operation situations, and road and surrounding environments.

Vehicle diagnosis and state monitoring methods are categorized into the method of using OBD-II and collecting data via car communication, and into the method of connecting via wire with and using the car engine room's systems, car speeds, RPM, etc. The latter method is difficult for ordinary people without expertise to use, and data are difficult to verify due to absence of legalized regulations. Also, the diagnosis method using OBD-II requires the installation of a separate monitoring device, or provides only operation information, making it inadequate for defining the causes of car trouble and faults.

The proposed system uses an OBD-II connector enabling the Bluetooth communication transmission and reception and enables the confirmation of the real-time vehicle state data, namely, OBD-II data. It can also utilize MOST navigation information using the MOST network, and check the current road situations and surrounding environment situations. Using this system, a black box data backup system using the Wi-Fi network was implemented in order to identify the causes of traffic accidents.

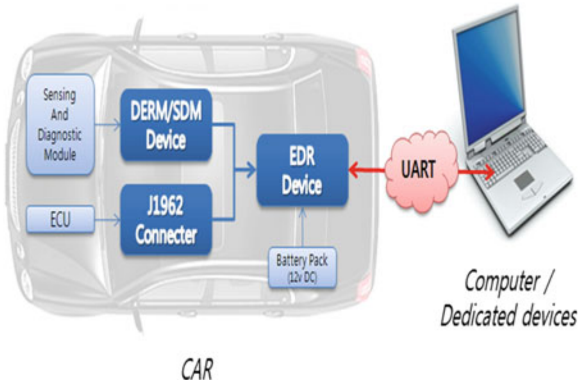

Fig. 4 The existing EDR system

These systems, however, operate in different products, making it difficult to reorganize the course of an accident to scientifically establish its cause. For this purpose, integrated data are required, which shall include all the necessary data, such as driving-related data like the vehicle speed and acceleration before and after the accident, the driver's vehicle operation status, and the environmental data (e.g., the road conditions). The Vehicle Inside Information Recording System that was realized in this study is crucial for this purpose.

There are two ways of carrying out vehicle diagnosis and status monitoring in the existing EDR systems: by collecting data through the vehicle communication system, using OBD-II; and by establishing a direct connection with engine room devices to find out the vehicle speed, RPM, etc. In the latter, general users without expertise experience difficulties, and data verification is also difficult due to the absence of regulations. OBD-II service is also weak with regard to vehicle trouble or malfunction because it requires an additional terminal for monitoring, and because it provides only driving-oriented data.

The Vehicle Inside Information Recording System proposed in this study makes it possible to check the road conditions prevailing during a vehicular accident, and the circumstances surrounding such accident, through a Wi-Fi-available OBD-II connector, which provides OBD-II, a real-time vehicle status data, and through the MOST network, which provides MOST navigation data. A data back-up system of the integrated vehicle diagnosis recording system with a Wi-Fi network was realized using these systems, to enable the scientific examination of the cause of the accident.

3.2 Composition of the Proposed Vehicle Inside Information Recording System

The system that was realized in this study consists of the following: a transmitter–receiver for communication with the MOST network, a computer to execute the

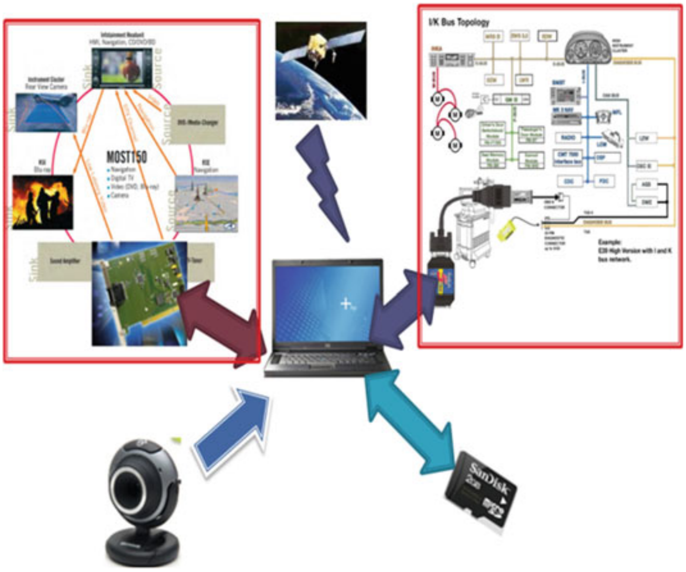

Fig. 5 Diagram of the proposed system

system. Figure 5 shows video data obtained during driving, multimedia data received from the MOST network, vehicle driving status data received from the OBD-II network using a Bluetooth-enabled OBD-II connector, and storage of the time and vehicle location data obtained from the GPS in the main memory of the laptop, with external-memory backup every 5 min and black-box data backup to the server using the Wi-Fi network.

3.3 Composition of the System

For the proposed system, timing synchronization between the OBD-II and MOST networks is the key function. For this function, an algorithm for communication synchronization among the OBD-II network, MOST network, GPS, CAM, and PC was designed in this study. When the black-box system operates, it generates four threads at the same time, leading to four simultaneous operations, while the GPS processor acts as the main processor, receiving the global time to apply time data for each data. When the GPS receives time and location data, three processors operate to read the vehicle driving, multimedia, and CAM data.

With the first processor, which is connected to the vehicle through an OBD-II connector called "OBD Link," the black box requests for the vehicle's driving data (speed, RPM, driving distance, tire pressure), matching the PID (Table 1) of the applied sensor. With these PID requests, each sensor connected to the OBD-II network responds with its value as data. At this time, the GPS time data are

Table 1 PID of OBD-II

Mode	PID	Returned data bytes	Description
01	00	4	PIDs support
	01	4	DTC clear
	03	2	Fuel system status
	05	1	Engine coolant temperature
	0C	2	Engine RPM
	0D	1	Vehicle speed
	0F	1	Intake air temperature
	51	1	Fuel type

additionally stored for the synchronization of the data from the three aforementioned threads.

With the second processor, the black box requests for data from the multimedia ECU, which is connected to the MOST network through the MOST evaluation interface. At this time, the requests match the FblockID of the applied multimedia. With these requests to the ECUs, the ECUs make appropriate responses, and the black box additionally stores the GPS time data for the synchronization of the data obtained from the three aforementioned threads(FblockID : run block that MOST of functions). If your paper deviates significantly from these specifications, our Publishing House may not be able to include your paper in the Proceedings. When citing references in the text of the abstract, type the corresponding number in square brackets as shown at the end of this sentence [1].

The third processor stores CAM images using OpenCV, a powerful image-processing library made by Intel. A setup of 30 frames per second in MPEG-4 codec using the OpenCV library and storage in the main memory is designed. An up to 640 × 480 resolution is possible, but considering the capacity of the external memory, it has been set to 320 × 240. When storing video data, the time data from the GPS are also stored. When storing, the black-box system checks the external memory, and if it is already full, the black box deletes the oldest video data and performs storage every 10 s [12].

The fourth processor receives data from the GPS. The basic protocol of GPS uses the NMEA data format.

There exists various sub protocols in the NMEA protocol, but this paper basically uses the $GPRMC protocol, which is currently widely used for GPS.

After receiving the GPS satellite data, the time data are stored for the synchronization of each thread. The proposed system receives and stores data (vehicle driving status, multimedia, and GPS data) in one frame per second, except for video data. When the system operates, it checks the time every 5 min to transfer the main memory storage to the external memory. If the capacity of the external memory is not enough for the transfer, it deletes the oldest video data and stores the new data.

4 Realization of the Proposed System

For the system requirements, this study uses a laptop with Windows XP as OS and USB memory as external memory.

The main screen of the proposed integrated vehicle diagnosis recording system consists of three areas: a receiving area of OBD-II, MOST, and GPS data; an area for black-box control; and a CAM image display area.

Figure 6 is an actual image of a PC screen showing the proposed integrated vehicle diagnosis recording system. When the black box operates, the left screen shows the OBD-II, MOST, and GPS data coming from the vehicle, and storage is executed together with the time data, and is a screen where the received OBD-II, MOST, and GPS data are being printed, matching each event.

The actual data stored in this way will be analyzed and displayed via simulation, for user recognition (Fig. 7).

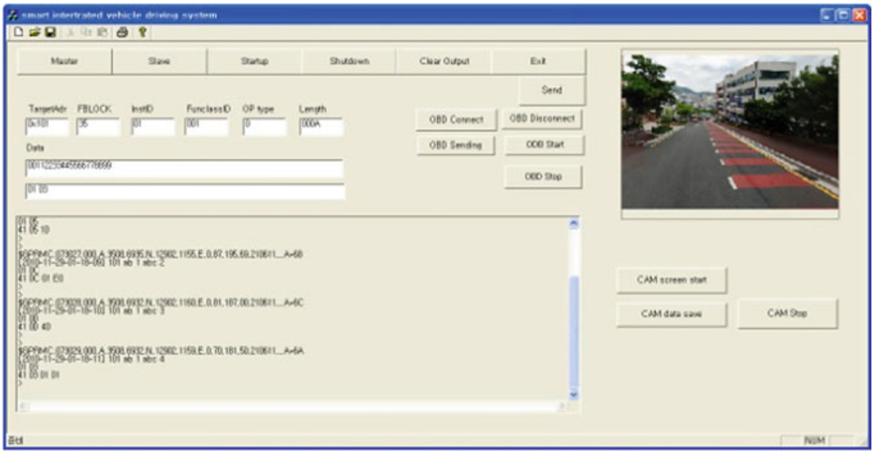

Fig. 6 Realized screen image of the proposed system

Fig. 7 Simulation screen using each data

5 Conclusion

Generally, vehicle black boxes and event data recorder (EDR) systems are mounted in vehicles and are used for traceback the courses and causes of vehicular accidents. They play a vital role in the analysis of the causes of vehicular accidents and protect drivers from suffering unfair life and property losses by coming up with an accurate judgment of the causes of such accidents. The recent black boxes have been designed to store only a vehicle's video and audio data, whereas the EDR system stores only a vehicle's driving data. This separate realization of functions by separate systems provides split vehicle driving and video/image data, which makes it difficult to achieve an accurate analysis of the situation prevailing during a vehicular accident. To overcome this shortcoming, an integrated vehicle diagnosis recording system was realized in this study, which uses CAM to collect the vehicle's overall driving video and a GPS module to collect the current time and vehicle location data. In addition, the use of an OBD-II interface to check the current vehicle's driving status, and a MOST network interface to check the status of the multimedia device, helps achieve a more accurate analysis of the cause of a vehicular accident when it happens. The proposed system, however, is open to further technical developments.

Today's increasing demand for vehicle black boxes and EDR systems will get such devices mounted in more vehicles as electronic devices and technology continuously develop, and such devices will become standard systems in a few years.

The future research subjects include the realization of data transfer to an external server using an external network (3G, Wi-Fi) in the case of black-box loss due to a vehicular accident, and of a more perfect the proposed system in the form of an embedded system for actual mounting in vehicles.

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