A Car Blackbox System that Uses the Heterogeneous In-vehicle Network

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ABSTRACT
Recently, many electronic control units (ECUs) are being installed in vehicles to ensure safety and convenience using IT. The ECU transmits its data to the OBD II network, and its multimedia data to the MOST network.
In this paper, a car blackbox system was proposed to ensure vehicle safety and to maximize its role as a blackbox. To supplement the problems of existing blackboxes, the new multimedia car network MOST and the standard OBD II car network were used to collect the ECU data and thereby, to identify the current vehicle condition and provide information.

Keywords: blackbox, in-vehicle blackbox, MOST, OBD, in-vehicle network

I . INTRODUCTION

Blackboxes were first used in aircrafts to store the flight records and use them to determine the causes of accidents. This technology was recently applied to vehicles, and is being used to identify the causes of vehicle accidents. The purpose of the car blackbox is to store the driving video, vehicle location, and time information related to an accident as objective data, and to identify their causal relationships with the accident. The car blackbox can also record hit-and-run cases during driving or parking accidents to protect the driver's propery. With the increase in the importance of the car blackbox, it has been made obligatory for all vehicles in Europe in 2010, and for all 4.5-ton-or-less vehicles in the U.S. in 2011. Between 2010 and 2013 in Korea (12/29/2009, Ministry of Land, Transport and Maritime Affairs), business vehicles started to be required to be equipped with a digital driving recorder. In November 2007, the Korean Agency for Technology and Standards established the national standard (KS) for the car accident recorder (KSR5076) to provide regulatory support for its technical development and for its use in relevant industries. According to the KS blackbox standards, video data are important, but the driving data (vehicle speed, brake condition, seatbelt fastening status, GPS, ABS, tire pressure, air bag condition, etc.) are also necessary in actual car accidents. Most car blackboxes in the market, however, meet the KS video data standards, but do not comply with the requirement for the vehicle condition data. In actual car accidents, video data are not enough to accurately identify the accident cause[1][5].

In this paper, video data were stored; the vehicle conditions, including the RPM and speed, were stored using the OBD-II protocol, which is widely used for in-vehicle networks; and the vehicle multimedia information were stored using the media-oriented systems transport (MOST) protocol, which is widely used for vehicle multimedia networks, to realize an integrated blackbox that provides accurate information for actual accident analysis.

II . RELEVANT STYDIES

II -1. OBD-II Network

Vehicles are equipped with sensors for measurement and control, and these devices are controlled by the electronic control unit (ECU). The original purpose of developing the ECU was to control the core functions of the engine, including the ignition timing, fuel injection, variable valve timing, idling, and limit setting; but with the development of vehicle technologies and computer performance, the ECU now controls almost all parts of the vehicle, including the automatic transmission, drive system, brake system, and steering system. Due to the continuous development of the electronic diagnosis system, it has recently been established as the standard diagnosis system, called the "on-board diagnostics system version II (ODB-II)." In the OBD network, data on the main systems or failures that are transferred from the sensors to the ECU can be seen from a vehicle console or other external device using the serial communications feature[3][4].
All vehicles that use the OBD-II network adopt the standard diagnostic trouble code (DTC) and connection interface (ISO J1962), but there are five different electronic signals, as follows: SAE-J1850 (VPW-PWM); ISO 15765 and SAE-J2234 (CAN communication); and ISO 1941-2 and ISO 14230-4 (ISO method). According to the regulations, however, all vehicles sold in the U.S., which is the world's largest car market, have had to use CAN (ISO157654) since 2008. Accordingly, it is expected that the European and Asian markets will adopt CAN (ISO15765-4), and that CAN's interfaces will be unified into one type.
When a fault occurs in a vehicle, OBD-II describes the fault information using the five-digit diagnostic trouble code. The trouble types and codes are also standardized. General car maintenance agencies use the trouble codes based on the OBD-II standard to detect abnormalities in vehicles and to

repair them.
CAN (ISO15765 and SAE-J2234) was designed for stable operation in a noisy environment. Because the CAN bus is basically the broadcasting type, all its nodes can detect all messages, but can process only the messages for themselves. The bus supports a transfer speed of 125 kbit/s at a distance of 500 m. CAN is stronger against noise and has a faster transfer speed than other standard protocols. The message frame has the priority information,
and the frame with a higher priority is transferred first. The message is very short (8 bytes), and CRC-15 is used to handle errors and corrections (Fig. 1).

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Fig. 1. CAN message frame

II -2. MOST Network
MOST is the high-speed integrated multimedia system communication protocol that enables transfer of high-capacity multimedia data, which include digital image, voice, and control data, at a speed of up to 150 Mbps. The fiber-optic cable that is formed in the ring network is used.
MOST is the multimedia networking technology that is optimized for vehicles and other applications. High-quality audio and video packet data for vehicle multimedia services can be transferred at the same time, and a single transmission medium can be controlled in real time. The protocol is available using the physical layer of a plastic optical fiber or an electrically non-shielded or shielded stranded wire, which meet vehicle environment requirements. At present, there are MOST25 (25 Mbps bandwidth), MOST50 (50 Mbps bandwidth), and MOST150 (150 Mbps bandwidth). It is expected that these will be unified into MOST150, which has the largest bandwidth.
The frame length that is defined in MOST150 is 3,072 bits (384 bytes) in all. Twelve bytes are used for management purposes, and the remaining 372 bytes are used for the user data.
The user data area is largely divided into the synchronous area (streaming) and the asynchronous area (packets). The user data area can be freely changed at multiples of four bytes.

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Fig. 2. MOST150 frame

III. Configuration of the Integrated Blackbox System

The integrated blackbox in this study consists of the transmitter and receiver for communication with the MOST network; the transmitter and receiver for communication with the OBD-II network and the external memory for data storage (USB and SD memory); GPS for collecting time and vehicle location information; and a notebook computer for operating the integrated blackbox.
As shown in Fig. 3, the video data while driving, the multimedia data from the MOST network, the driving condition data from the OBD-II network, the GPS reception time, and the vehicle location data are stored in the notebook computer's main memory and then in the external memory every five minutes[2].


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Fig. 3. Configuration of the integrated blackbox

IV. Design of the Integrated Blackbox System

The core function of this blackbox system is the timing synchronization between networks by reading the data of the OBD-II and MOST networks. To ensure the blackbox's performance of this core function, an algorithm was designed for the synchronization of the communication between the OBD-II network, the MOST network, the GPS, the CAM, and the PC.

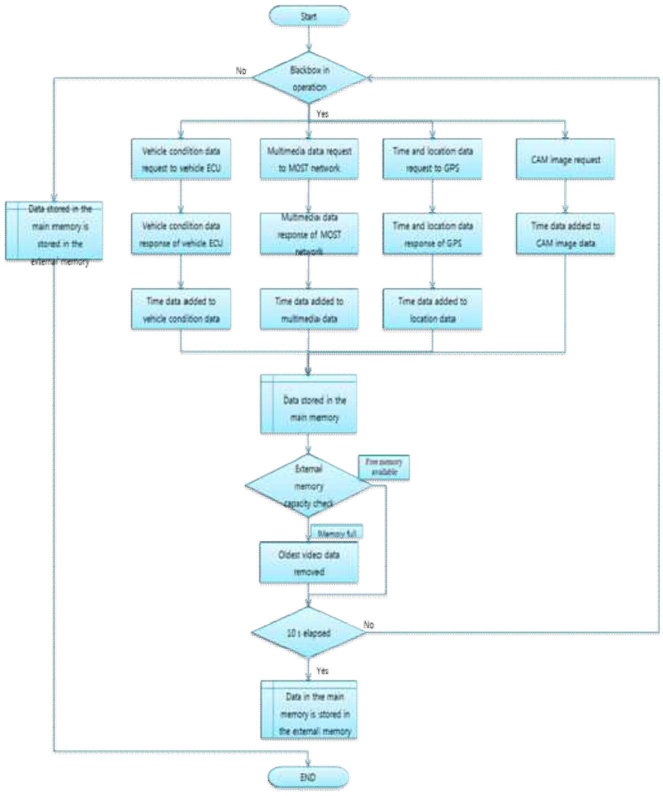

Fig. 4. Flowchart of the integrated blackbox

Fig. 4 shows the flowchart of the integrated blackbox. The blackbox creates four threads and simultaneously conducts four tasks; and the GPS processor, which retrieves the global time to write time information on each data, serves as the main processor. The time and location data are received from the GPS. After the time information is retrieved, three processors operate.

First, the blackbox requests the driving data (vehicle speed, RPM, travel distance, tire pressure, etc.) according to the PID of the appropriate sensor (Table 1) by connecting the OBD-II network via an OBD connector (OBD-Link). When each PID is requested from the vehicle, the appropriate sensor that is connected to the OBD-II network responds[6].

Table 1. PID for OBD-II

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

In the second processor, the driving data, including the sharp curve, the abrupt deceleration, and the school zone are received from the virtual navigation that is connected to the MOST network via the MOST PCI interface.

The third processor stores the CAM frame, and OpenCV processes the frame. OpenCV is the strong image-processing library that was manufactured by Intel. The OpenCV() library is used to store the images in the main memory at a resolution of 320*240 and a frame rate of 30 fps using the MPEG-4 codec. A resolution of up to 640*480 is available, but it was set at 320*240 considering the external memory capacity. The time information from the GPS is added to the image data before they are stored. The blackbox system checks the external memory before storing the data, removes the oldest image data when the memory is full, and stores the data every 10 seconds.

The fourth processor retrieves the GPS data. The basic protocol of GPS is the National Marine Electronics Association (NMEA) data format. There are many NMEA protocols, but $GPRMC, which is basically used in GPS, was used in this study.

Fig. 2 shows the structure of $GPRMC

Table 2. $GPRMC structure

	Field	Example
1	Sentence ID	$GPRMC
2	UTC time	92204.999
3	Status	A
4	Latitude	4250.5589
5	N/S indicator	S
6	Longitude	14718.5084
7	E/W indicator	E
8	Speed over ground	0
9	Course over ground	0
10	UTC date	211200
11	Magnetic variation	
12	Checksum	*25
13	Terminator	CR/LF

After the GPS satellite data are received, they are stored after the time information is added to them for thread synchronization. The blackbox receives and stores the data other than the image data (the driving condition, multimedia, and GPS data) at a rate of 1 fps. When the system actually starts its operation, the GPS time information is additionally stored to synchronize the data in three threads. The data that is stored in the main memory is in turn stored in the external memory every 10 seconds.

V. Design of the Integrated Blackbox System

The system development environment was Windows XP on a desktop computer, and a USB was used as the external memory device.

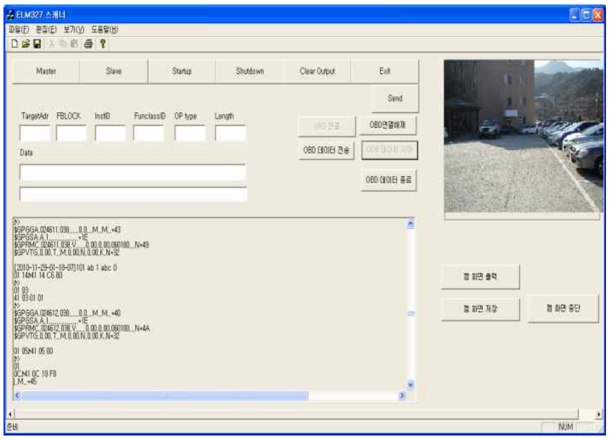

Fig. 5. Car blackbox system implementation

The main window of the blackbox system program has three areas: the OBD-II, MOST, and GPS data reception area; the blackbox control area; and the CAM image display area (Fig. 5).

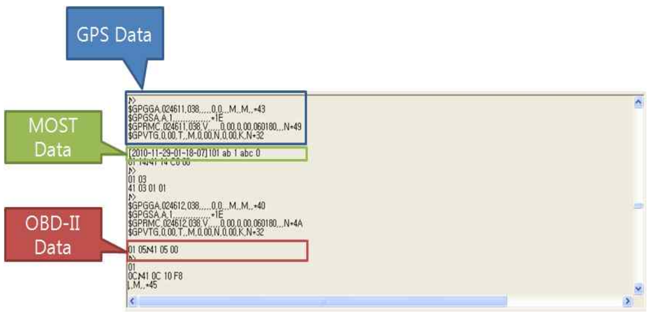

Fig. 6. GPS, MOST, and OBD-Ⅱ data outputted

Fig. 6 shows the window wherein the OBD-II, MOST, and GPS data are outputted according to each event.

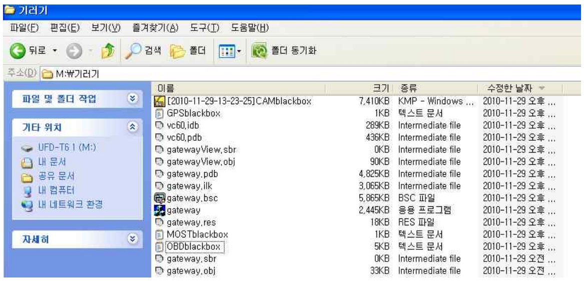

Fig. 7. GPS, MOST, OBD-Ⅱ, and CAM data stored in the external memory

Fig. 7 shows the window wherein the OBD-II, MOST, and CAM data are stored in the external memory. When the blackbox starts its operation, the external images are outputted and stored in five-minute sections. When the external memory is full, the oldest image data are removed. If an accident happens or the Store button is pressed, the external images (CAM) are stored in a separate space (USB memory), and the time information is used as the image data name.

The stored data are analyzed via simulation so that users can easily understand them (Fig. 8).

Fig. 8. Simulation window

VI. Conclusion

The car blackbox is mounted on vehicles to track the situation and cause of a car accident. It enables accurate determination of the causes of traffic accidents by providing critical clues to such causes, and legally protects drivers against unfair disadvantages. With the increasing demand for the car blackbox and the development of car electronics, it is expected that the blackbox technology will continue to be developed and will become a part of vehicle standards in a few years.

Current blackboxes store only image and voice data. A driver can be disadvantaged if an accident occurs due to an internal trouble in the ECU. In this study, to realize an advanced car blackbox and to reduce the driver's potential disadvantage, a CAM camera was used to collect driving images, and a GPS module was used to collect the time and vehicle location. In addition, an OBD-II driving interface was used to check the current driving conditions, and the MOST network interface was used to monitor the multimedia device conditions, to accurately find out the cause of a car accident. Further studies will be conducted to transfer the data to an external server via an external network (3G or WIFI) in case the blackbox is damaged in a car accident. In addition, a better blackbox system will be realized in terms of the actual installation of the blackbox by embedding.

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