Smart and Safe Vehicle Monitoring with Fuzzy Integral and Haar-like Features

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Abstract: An on-board Android-based smart and safe vehicle monitoring system is presented. The on-board monitoring system (OMS) performs important monitoring functions: Record, Report and Alert (RRA). The Record function records front images of a moving vehicle. During the recording, any accidents or other emergency conditions will be automatically reported via the Report function for an emergency rescue operation. For the detection of shocks or accidents, we use acceleration based shock sensors that utilize fuzzy integral algorithm. The OMS also focuses on drowsiness that is largely regarded as the main cause of most accidents. The Haar-like feature is used to detect any sign of drowsiness and the Alert function is performed to alert the driver. All the vehicle-borne information is stored at a remote server via wireless communication links for later use or post-processing. A test bed has been developed and verified thoroughly for its accurate operations. The proposed smart and safe vehicle monitoring system offers advanced safety features and is expected to substantially reduce fatigue related accidents.
Keywords: Fatigue, Haar-like, Monitoring, Vehicle Safety.

1 Introduction

Over the last half-decade, smartphones have evolved dramatically and would soon behave like laptops. Most mobile devices are nowadays integrated by a smartphone as convenient infrastructure and intelligent functionality has been built to further users ultimate convenience [1]. For example, transport machine industry, particularly vehicle industry, provides vehicle-borne information via a car navigation system. Even various driving environment information, not to mention information about driving itself, is provided to the driver. However, conventional devices or modules are focused on data storage and do not offer any drowsiness related safety features. Thus, technologies in mobile and vehicle telematics need to be developed further and also necessitate advanced safety-oriented modules. In particular, a fatigue related accident prevention feature must be sought together with basic monitoring functions, e.g. recording of vehicle data and images incorporated with GPS for track-down and investigation of any accidents occurred.

This paper addresses a smart and safe vehicle monitoring issue. The system is based on an Android mobile device, offering advanced monitoring capability of the recording of vehicle-borne data and image, GPS data and accelerator sensors for automated alarm function. Also, it offers an alertness function to prevent fatigue related accidents using the Haar-like algorithm [1, 2].

2 Design and Structure of OMS

The proposed system is composed of a microcontroller (MCU) module, an Android device and database server. Fig. 1 shows a block diagram of the system. Basically, the camera fitted on the mobile device will monitor and record front images. The accelerator sensor will detect shocks or any accidents occurred through the fuzzy integral algorithm [3]. These recorded images

will be saved in the SD memory of the mobile device. When required, these will be stored in a remote server via wireless links from the SD memory. When an accident occurs or an emergency condition exists, a rescue message will automatically be sent to next of kin. The Android-based mobile development is based on Google Android 2.3 Operating System [4] and some Google libraries have been used to implement the proposed functions. The top menu consists of three submenus: Camera View, Map View and Accelerometer View.
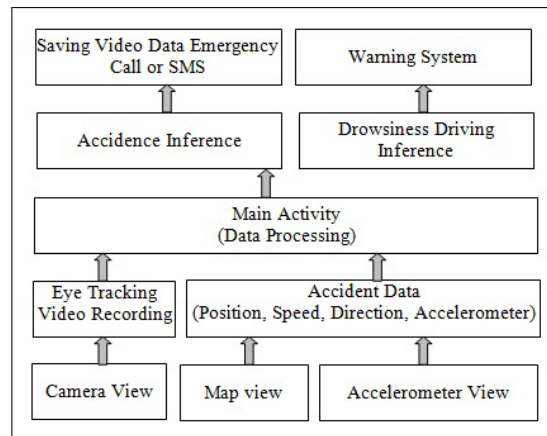

Figure 1: Block diagram of the proposed system

2.1   Camera view

Camera View is implemented with a periodical recording function. Various Google libraries are used. For example, recInstallize() is defined for image formatting, encoding modes and the length of recording, whereas fileOutStream() creates camera recorded image files and chkAccident() detects an occurrence of accident and recPrepare() sets up a saving route for the files. Once recorder.start() is invoked, the image recording will begin for the pre-defined time. When recorder.stop() is invoked, the files will be stored at the SD memory.

During this main activity, if the MCU and accelerator sensor receive any data for the possible detection of accidents or shocks, an alarm dialogue will be sent out and the associated file will be automatically saved with a file extension of Accident.To control an overflow issue, old files are sequentially deleted while any files with the extension of Accident remain stored.

2.2   Map view

To obtain location information, a few more libraries are utilized such as onCreate() and getBestProvider() for the best provider of the information (Wi-Fi, 3G or GPS satellite). As location changes, LocationListener() moves its position and updates its latitude and longitude. With the assumption that the power is supplied from the vehicle, setPowerRequirement() and setAccuracy() are set to ACCURACY-FINE and POWER-HIGH for a fine collection of the data. All collected data are stored as a text file and transmitted to a remote database server. The location of the vehicle will be displayed on Google Map online.

2.3   Accelerometer view

Sensors applied in this development are accelerator sensors, gyroscope and proximity sensors. For the detection of accidents (or shocks), accelerator sensors and GPS speed data as well as shock sensors located inside MCU are employed. Fig. 2(a) shows the directions of vehicle from

the perspective of a mobile placed upright, where Y axis indicates left and right, and Z axis the front and rear, respectively. Figs. 2(b) and 2(c) show the response of the accelerator sensor when two shocks are applied in front and another two from the rear.
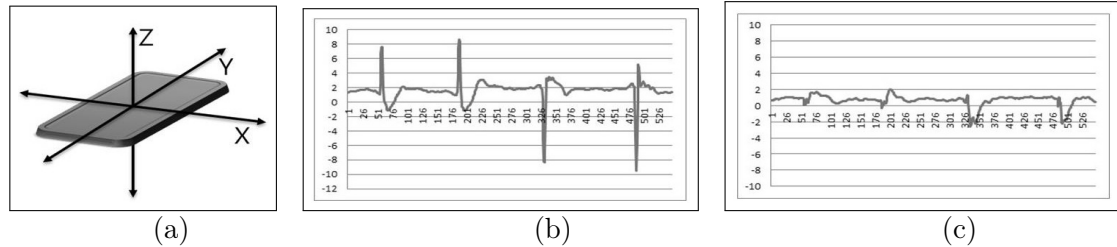

Figure 2: Accelerometer View: (a) Definition of vehicle direction (b) and (c) Values of the accelerometer sensor under shock conditions

Although this method of shock detection provides a degree of accuracy, it needs to enhance its accuracy further, particularly when the vehicle is attacked diagonally or at different angles other than basic four directions. This drawback would result in inaccurate detection of accident. In order to address this ambiguous situation, the study has employed the fuzzy logic and integral algorithm by treating this condition as fuzziness. Fig. 3 shows accelerator values and its scope ranging from S1 up to S8. Values of Y and Z axes and rule-base of accelerator are shown in Fig.4.
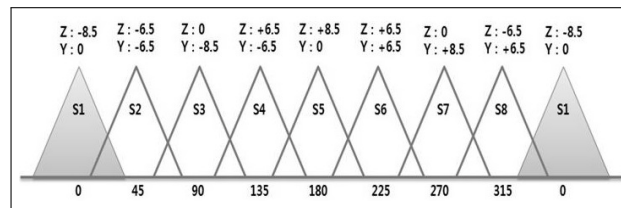
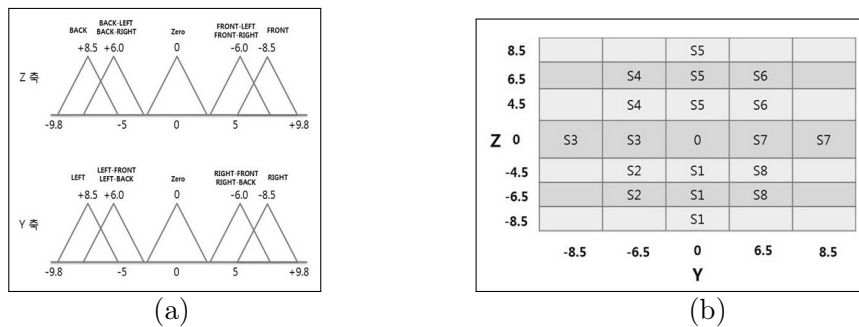

Figure 3: Block diagram of the proposed system

Figure 4: (a) Values of Y and Z axes (b) Rule-base of accelerator

We first define variables for Y and Z axes and each accelerator value will undergo fuzzification and defuzzification. Then, by making use of the center of gravity, the angle of vehicle shock can be determined. Fig. 5 shows how to find the angle of shock using this method.

2.4 Methodology of drowsiness detection

In order to reduce or prevent accidents due to driving under drowsiness, a detection mechanism of drowsiness has been developed. An eye tracing algorithm known as Haar-like feature
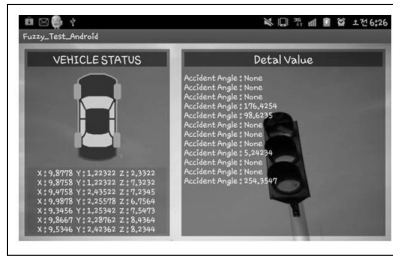
Figure 5: Method of finding the angle of shock

[5] has been used to determine if a driver is in a drowsy condition. The Haar-like features are digital image features used in object detection and recognition [2, 5]. The method first identifies face and eye features and adds pixel values within that area. Then, some weighting factors are multiplied to find a final value. For this reason, this feature is useful in moving pictures rather than still images.

To detect drowsiness, we have used eye closure. This method is well known and widely used for detecting drowsiness [6]. When the camera fitted shows an image of a driver, the detection algorithm starts to find face. Once the face is recognized, the detection for eyes begins to initiate the eye closure based drowsiness procedure. The method assumes that the drivers eyes are closed if eyes are not detected. In detecting the eye closure, blink count increments and timer starts to measure the time during which eyes are closed. Therefore, PERCLOS [6] is computed as follows:

$$PERCLOS = \frac{Eye\ closure\ time}{Measurement\ time} X100$$

According to the values of PERCLOS, we determine if the driver is under drowsiness. The detailed procedure of the method is shown in Fig. 6.
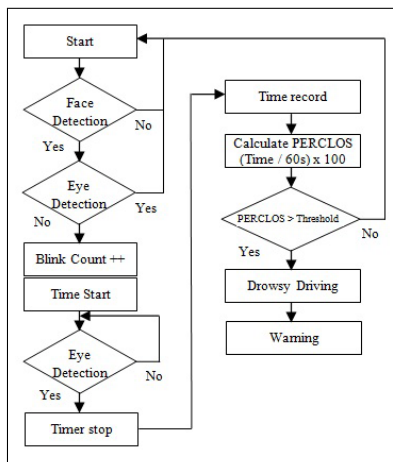

Figure 6: Flow chart of drowsiness detection

3   Verification of OMS

The OMS has been under rigorous verification for its all functions. As mentioned previously, we first evaluate the main menu composed of the front image, Google Map and accelerator sensor

as shown in Fig.7 (a). When the vehicle is in motion, the accelerator sensor is in operation for detecting any shocks or accidents. If accidents or shocks occur, an alarm dialog window appears as shown in Fig.7 (b). In order to avoid any false alarm situations, the dialog window allows users to tap OK button to continue the driving, otherwise it regards as an emergency condition to initiate rescue operations, e.g. call initiation to next of kin as shown in Fig.7(c). In addition, the recorded image files before and after that moment of the emergency condition are stored with GPS location information into the SD card memory of the mobile device and transmitted to a remote database server via wireless links, e.g. Wi-Fi or 3G. These files can be viewed anytime as indicated clearly with an extension of Accident. Figs.7 (d) and 7(e) show the file storage and GPS data.

While the vehicle is in motion, the drivers eyes are continuously monitored. If the value of PERCLOS is higher than the predefined threshold value, the system is set to send out a warning message and an alarm sound also goes off to alert the driver for the prevention of any possible accidents. Fig.8 (a) shows the detection of face and eyes subsequently. The eye closure detection is then performed and PERCLOS is computed to determine if the driver is in a drowsy condition as shown in Fig.8 (b).

The verification process demonstrates that the OMS operates the proposed functions accurately as designed.
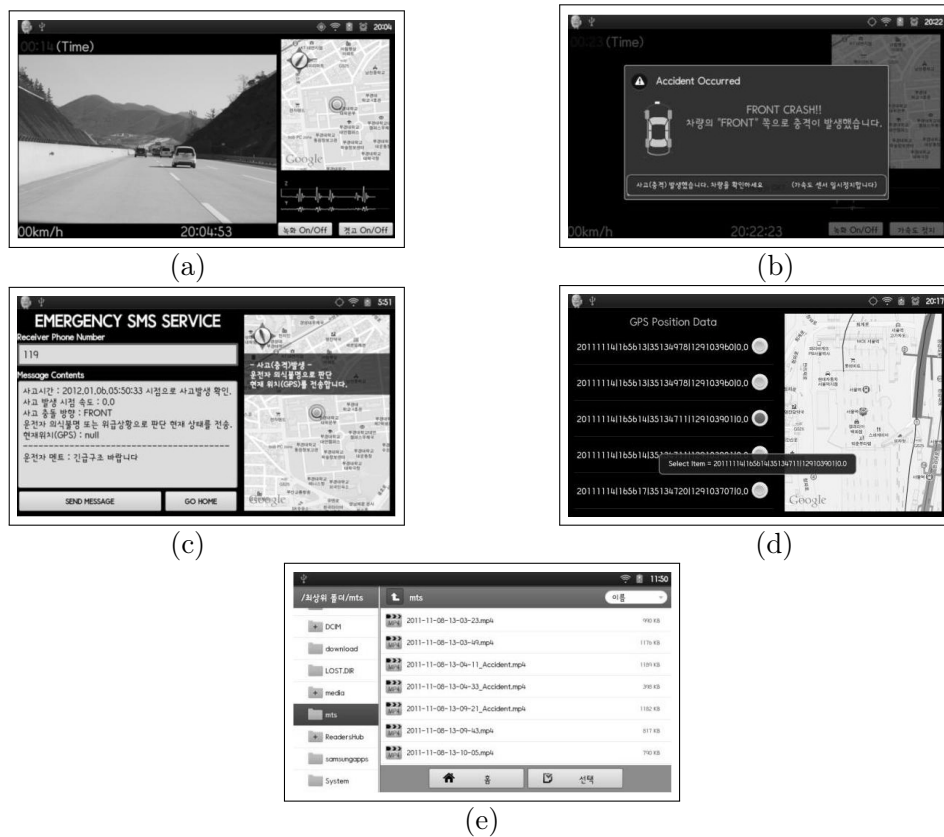

Figure 7: Verification of OMS functions

Figure 8: (a) Detection of face (b) Eye detection for drowsiness

4   Conclusions

Fuzzy integral and image processing techniques integrated on a smartphone are employed to provide the enhanced safety of vehicle. In addition to providing monitoring functions such as the Record and Report functions, an advance warning system for fatigue related accidents is developed using the Haar-like feature. The test bed comprising hardware and associated software has been evaluated through its verification process. The system shows its accurate and correct operations on possible driving scenarios. Also, the drowsiness of a driver is successfully detected using PERCLOS. It is therefore expected that the developed vehicle monitoring system will play an essential role in providing enhanced safety feature to transportation machine to reduce vehicle-borne accidents significantly.

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