Developing a Driver Alert and Alarm System for High Quality Driving Supports

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***Abstract*—Prevention and vigilance plays a key role in preventing threatening risks and potential dangers when one is driving. In other to achieve the goal of averting danger when driving, people need valid and up to date information about: driving behavior, driving environment and vehicle status. There are a lot of factors that needs to be considered in order to keep a driver safe. Drunk driving, blind spots, bad driving habits, fatigue driving, and vehicle status are all factors that needs to be taken into account if safety is to be improved. Driving comfortability greatly depends on vehicle's status and driver's behavior. To evaluate the comfort level for a particular ride, we developed a number of formulas for evaluating various variable like vibration which has their base from the ISO. Rules for detecting these factors like fatigue driving, blind spot collision, etc., were set in this study, each of which has a threshold that shouldn't be exceeded. In this paper, we introduce an in-car monitoring system for driving safety and provide alert and alarm functions using Android device connected to the car's on-board diagnostics system(OBD-II) and the in-car module.**

Keywords: In-Car Monitoring System, Driving Safety, On-Board Diagnostics System, Driver Alert, Alarm System

I. INTRODUCTION

The major motivation of this study is to develop asystem for helping people to monitor their driving to ensure safety and prevent any potential danger that could be threatening.

The goal of this study is to build an on-board alert and alarm system, and driving events record system for various information collected and processed while driving. Included in this list of information are; the driving environment, driving behavior, vehicle's status and road situations. These data collected are all related to driving safety.

There are a lot of factors that needs to be considered in order to keep a driver safe. Drunk driving, blind spots, bad driving habits, fatigue driving, and vehicle status are all factors that needs to be taken into account if safety is to be improved. Driving comfort ability greatly depends on vehicle's status and driver's behavior. To evaluate the comfort level for a particular ride, we developed a number of formulas for evaluating various variables like vibration which has their base from the ISO. Rules for detecting these factors like fatigue driving, blind spot collision, etc., were set in this study, each of which has a threshold that shouldn't be exceeded. All these criteria, threshold and information analysis were the foundation of our information system and application that was developed in this study.

Development of such system was built with certain criteria like low cost, quick response, low maintenance effort, and ability to produce continuous measurements. Although the drivers are driving on the road, they still can access the real time information by using smart devices.

This real time driving safety and monitoring system procedures are described as follows: To monitor the parameters we use specific sensors. All the readings produced by the sensors will be sent to the smart devices by a Zigbee modem. For this purposes, we designed a WSN for driving environment, safety and road situation monitoring system using Zigbee modem for car.

We believe that this kind of system and the monitoring method is the future trend of Intelligent Transportation System (ITS) and Advanced Vehicle Control and Safety System (AVCSS).

In this paper, section 1 is the introduction of this research. Section 2 is the research background. In section 3 we proposed the research method, in section 4 the system architecture of this research is presented in detail. The section 5 discusses the high quality driving issues. Then in Section 6 a focus on the explanation of the module 3 of the system including the contents, data flow and data transmission.

II. RESEARCH BACKGROUND

The history of vehicle evolution shows that car manufacturers have long since been in pursuit of high-performance and high energy-saving capability. But the above goal is slightly related to

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the driving safety, unfortunately, a high performance measure is inversely proportional to safety. The "safety" here includes: driving behavior, driving environment status, vehicle status, etc.

The On-board diagnostic system (OBD-II) can provide malfunction information of the vehicle, and warning to the driver. Also the mechanic may perform repairs quicker using error codes provided by this system.

Driving fatigue phenomenon occurs when a driver stays longer in the car and the air quality goes bad. This can cause drowsiness, dizziness, and one also may lose concentration which is a major cause of accidents. Since a car is a closed environment, when the AC is not turned on, fatigue may easily occur. Quality of air may also be affected by concentration of harmful gases like Carbon Monoxide as well as high concentrations of CO_2.

Drunk Driving occurs quite often than usual. When a driver is drunk, it's totally hard for them to recognize and make good judgment on road situations. Blind spots are also a possible course of accidents. A car basically has 4 blind spots and drivers find it hard to see them while driving.

All the above courses involve the drivers and to prevent such event from happening over and over to save lives is an important issue. In this study, we developed an alert and alarm system to monitor the situation of a car which will alert the driver when a specific occur.

III. RESEARCH METHOD

In order to achieve the goal of safety driving, we developed an "Alarm & Alert" system, which can monitor the driving safety factors while driving. We used a variety of sensors to monitor driving safety such astemperature and humidity sensor for environmental comfortability evaluation, and the motion sensor data of smart devices was used to analyze driving behavior. We also applied the On-Board diagnostics (OBD) adapter for monitoring the vehicle's status and complex driving behaviors.We set some thresholds of these observed data to provide alerts and alarms when these thresholds are exceeded.The difference in alarm and alert is the degree of emergency. Alarms are provided for serious events like drunk driving, while alerts warnings to bring the driver's attention to events that are not extremely serious.

System Architecture

The developedsystem consists a monitoring center (Android tablet), an in-car module and outer car module, and a remote server. The architecture is shown in figure 3-1:

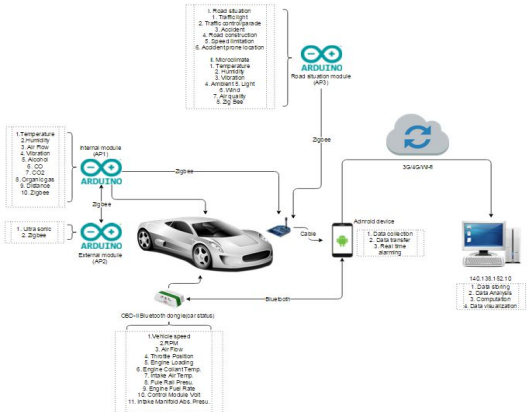


Fig. 3. 1: System Architecture

There are 6 Components in this System;

Android Mobile Device: To achieve real time alerting and data transmission, we choose Android Tablet which has several sensors like 3-axis Gravity sensor, Gyroscope sensor and GPS sensor. It is connected to OBD-II via Bluetooth, and connects Xbee chip for receiving data from AP1, AP2 and AP3.

OBD-II Bluetooth Adapter: in order to obtain vehicle's information, we used this device and developed an Android based application to connect OBD-II.

Vehicle Inner Module: we monitored driving safety and comfort ability by using various sensors and Arduino MCU.

Vehicle Outer Module: we used an ultrasonic distance measurer, Arduino MCU and a Xbee modem for data transmission for this module.

*Road Situation and LBS Module***:** Road situation information like LBS may also be needed by drivers.

XBee modem: Two kinds of Zigbee modules are organized as a network for driving safety and monitoring system. The first Zigbee module is Zigbee coordinator modem. Zigbee coordinator module or ZCM is responsible for maintaining other devices on the network and collecting data from other devices. 3 modules developed in this study; (1) in-car module, (2) outer module and (3) road situation and location information module.

Vehicle Inner Module (AP_1)

In order to monitor driving safety and driving comfortability using sensor approach, a vehicle inner module (AP1) has been developed. User should connect a Xbee modem to Android device, which helps in monitoring vehicle's inner environment, including temperature, humidity and various kinds of gases, and transmit data by Xbee chip. The block diagram is shown infigure 3-2.

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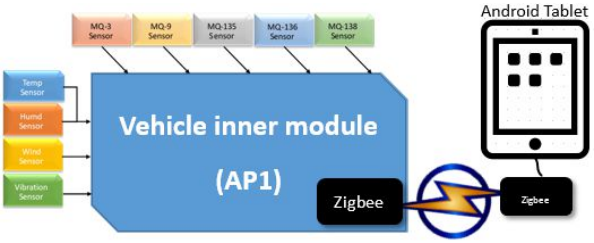


Fig. 3. 2: Block Diagram of AP1

Vehicle Outer Module (AP2)

A blind spot detector was developed which could measure the distance between car body and obstacles.When detected distance is too close, an alarm then be triggered.

Road Situation and Location Information Module (AP3)

When driving on the road, driver may need the information of road situation and other LBS information, such as accidents, traffic control, speed limit, road construction, accident prone locations, etc., toachieve this feature, a prototype of road situation and location information module has been developed.It canmeasure somemicroclimate information and transmit this information to the vehicles as road situation. It's possible to assign some constants into the module directly, like speed limit, accident prone location. The block diagram is as shown infigur 3-3.

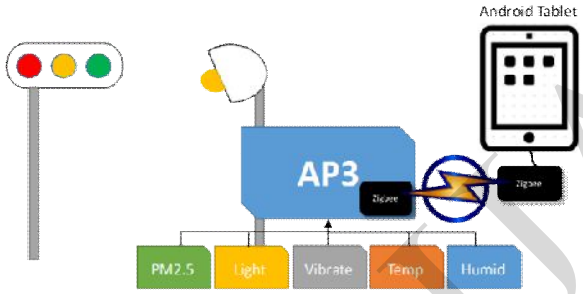


Fig. 3. 3: Block Diagram of AP3

IV. SYSTEM ARCHITECTURE

This on-board high quality driving monitoring system has 5 components, which are: Android tablet, Inner module (Arduino), Outer module (Arduino), Location based information module (Arduino) and an OBD-II Bluetooth adapter, the function and architecture shown as figure 3-5.

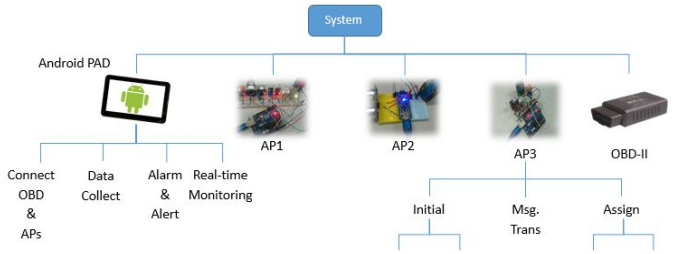


Fig. 3. 4: System Architecture

First, the application developed in this study which provides monitoring of driving conditions and sets of alarms and alerts should be installed on the Android device. This application will connect OBD-II adapter and the APs via Bluetooth and Zigbee. All the received data will be synched to a remote database. Because of the current wireless communication of mobile devices is without Zigbee, so it needs a data transfer cable to connect Zigbee chip to mobile dev**ice.**

V. HIGH QUALITY DRIVING ISSUES

Driving safety comprises of several factors; (1) Driving healthy, (2) Driving comfortable, (3) Driving behavior and (4) Vehicle status.

5.1 Healthy Driving

We use sensors and microcontroller to monitor a driving environment. It consists of gas sensors, wind sensor, vibration sensor, temperature and humidity sensor and ambient light sensors.

If the air quality is bad, drivers will become drowsy, dizzy, and will lose focus, which is a major reason of accidents. Some drivers need to in the vehicle hours (≥ 40 min), an example is the commercial drivers.

Table 5.1: Factors of Healthy Driving

Warning program	Index
Alert of Carbon dioxide	Density of CO2 is >= 500 ppm.
Alert of Carbon monoxide	Density of CO>= 150 ppb.
Alert of Organic gas	Density of Organic gas >= 100 ppm.
Alert of Hydrogen sulfide	Density of H2S>= 50 ppm.
Alert of Sulfur dioxide	Density of SO2>= 100 ppm.
Alert of Nitrogen Oxides	Density of NOx>= 25 ppm.

5.2 Comfortable Driving

Driving Comfortability is also affected by environmental factors such as temperature, humidity, ventilation, vibration, ambient light, pressure and so on; these factors will indirectly affect driving safety. By extending the ISO standard we could generate a formula to evaluate the driving comfort ability index (DCI), shown as follow:

$$DCI = w_1|PMV| + w_2V + w_3DB$$

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Note: the "PMV" here is an evaluated value from ISO 7730, and the "V" here denotes evaluated value from ISO 2631-1, the "DB" is evaluated value generated from this study, and the w_x is the weighted value, which could be assigned by user. The following is the evaluation formula of ISO 7730, where the w_x here is the weighted value, it is modifiable by the factors from user's requirement, e.g. a newbie driver may set the w_3 as the highest (driving behavior).

The "DCI" here was not only considered the vibration, but the other environmental factors like temperature, humidity, ambient light ventilation and specific gases. The provided monitoring list is as follows in Table 5-2.

Table 5.2: Factors of comfortable driving

Warning program	Index
Alert of Ventilation	Detected status of ventilation is FALSE.
Alert of Temperature	Detected temperature >= 28 ℃.
Alert of Humidity	Detected humidity >= 70 %.
Alert of vibrations	Instant acceleration is greater than 0.8m/s2
Alert of Ambient light	Detected temperature <= 300 lm

The evaluated formula of ISO 2631-1, ISO 7730 and their reference values shown as follows:

PMV

The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions, the formula of ISO 7730 (show as follow) could derive the value of PMV in various environments.

$$PMV = |(0.303e^{-0.0036M} + 0.028) * \{M - 3.05 * 10^{-3} * (5733 - 6.99M - P_a) - 0.42 * (M - 58.15) - 1.7 * 10^{-5} * M * (5867 - P_a) - 0.0014 * M * (34 - t_a) - 3.96 * 10^{-8} f_{cl} * [(t_{cl} + 273)^4 - (t_r + 273)^4] - f_{cl} * h_c * (t_{cl} - t_a)\}|$$

$$t_{cl} = 35.7 - 0.028 * M - I_{cl} * \{3.96 * 10^{-8} f_{cl} * [(t_{cl} + 273)^4] + f_{cl} * h_c * (t_{cl} - t_a)\}$$

$$h_c = 2.38 * (t_{cl} - t_a)^{0.25} \quad for\ 2.38 * (t_{cl} - t_a)^{0.25} > 12.1(v_{ar})^{0.5}$$

$$12.1(v_{ar})^{0.5} * (v_{ar}) \quad for\ 2.38 * (t_{cl} - t_a)^{0.25} < 12.1(v_{ar})^{0.5}$$

$$f_{cl} = 1.00 + 1.29 I_{cl} \quad for\ I_{cl} \le 0.078 m^2 k/w$$

$$1.05 + 0.645 I_{cl} \quad for\ I_{cl} > 0.078 m^2 k/w$$

$$P_a = (RH / 100 * e^{-(18.6686 - 4030.18/(TA + 235))}) / 0.00750062$$

The different symbols are as follows; M: Metabolism amount (W/m2), W: External influences the energy of the human body (W/m2), Icl: Clothing isolation degree (m2K/W), fcl: Clothing area factor, ta: Temperature (°C), tr: Mean radiant temperature (°C), var: Relative wind speed (m/s), Pa: Water vapor pressure (Pa), h_c: Convective heat transfer coefficient (W/ (m2K)) and t_{cl}: Clothing surface temperature (°C).

The result of this evaluation formula will form 7 different heat levels ranging from 3 hot, to -3 cold. An evaluation from ISO-7730.

5.2.1 V (Vibration)

A driver must sustain certain amount of vibrations when driving. If the human body is continuously exposed to whole-body vibrations, it is possible that the body will have adverse effects from the whole body vibrations. The formula of ISO 2631-1 (show as follow) is used to evaluate the value of vibrations.

$$V_c = \sqrt{\frac{(G_x)^2 + (G_y)^2 + (G_z)^2}{3}}$$

A value less than 0.315 is considered a normal environmental value. Representations of other values are shown in Table 5-3.

Table 5.3: Evaluated result of ISO-2631-1

Calculated value(VC)	Level of Comfort	Evaluated value(V)
< 0.315 m/s2	Normal	0
0.315 m/s2~0.63 m/s2		1
0.5 m/s2~1 m/s2	Slight Uncomfortable	2
0.8 m/s2~1.6 m/s2	Uncomfortable	3
1.25 m/s2~2.5 m/s2	Very Uncomfortable	4
> 2 m/s2	Extremely Uncomfortable	5

The driving behavior is the evaluation factor considered in this study. Some driving behavior will make passengers afraid or nervous; it is driving comfort ability issue. By a particular formula shown as follow (to count the specific driving behaviors (refer to Ch. 5.4 - hazardous driving behavior) in unit distance (1 km))

$$DB_c = \frac{\sum specific\ driving\ behavior(times)}{mileage(km)}$$

Table 5-4 evaluated values using this formula.

Table 5.4: Evaluated result of driving behavior

Calculated value(DBC)	Level of Comfort	Evaluated value(DB)
≤ 1 times/km	Normal	0
1~5 times/km	Comfortable	1
5~10 times/km	Slight Uncomfortable	2
10~15 times/km	Uncomfortable	3
15~20 times/km	Very Uncomfortable	4
≥ 20 times/km	Extremely Uncomfortable	5

The DB is generated by counting the times of specific driving behaviors (refer to Ch. 5.4), and dividing it by mileage, if the value exceeds the assigned threshold, then give corresponding DB.

Driving on the mountainous road will make passengers feeling uncomfortable or dizzy, even motion sickness. We derived a formula (show as follows) to calculate the rotation angle in unit time. Both the angle and time are modifiable from user's requirement.

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Calculated value(C)	Level of Comfort	Evaluated value(V)
Frequently turning $\mathbf{ft}(Azi) = \sum_{i=1}^{30} \lvert Azi_i \rvert$	$\mathbf{ft}(Azi) > 600$: **Frequently turning**	**3**

There is another driving comfort ability factor which is altitude. Because the barometric pressure will decrease along with altitude. The relationship is: for each 12-meter altitude, there is a decrease of 1mm-Hg.

5.2.2 Evaluated Results

Applying the above driving evaluation formula, we can get the evaluation result of each driving. For PMV, we can get information from result: PMV has high correlation with temperature and ventilation, and the temperature is affected by the seasons, so the experiment result of table5-5 shows the temperature of Spring is "warm", "slightly warm" and "neutral". After the evaluated result of ISO-2631-1, we can find that if driving on the normal road, the vibration values will not be too large. The driving behavior depends on the drivers, so the value is not stable.

5.3 Safer Driving

Driving behavior data consists of the driving trend(s) and driving habit(s) from long term driving data observation.

Drunk Driving: For drunk driving detection, we used alcohol sensor to detect the density of alcohol and then implemented necessary alarm functions. When the alcohol density is greater than or equal to 300 ppm an alarm is triggered.

Blind Spot Detection: This is achieved by measuring the distances between the car and obstacles. When the distance is less than or equal to 100 cm, an alarm is then triggered.

Fatigue Driving: Driving time and driving comfortability: to calculate the evaluated value (DCI), we can obtain this value by the formula we derive in this study. The larger number denotes a bad environment, and a bad environment will drain a driver's physical strength. By a timer alerting, we can set up like continuous driving t/2t/3t minutes, then trigger the alert. On the contrary when driving in a better environmental condition, the value of tcan be set larger (the value of 't' can be modified by user.)

OBD-II and sensors: by the OBD-II, we can judge the driving behaviors from sensor readings (vehicle speed, throttle position, variation of speed, etc.).

5.4 Hazardous Driving Behavior

The OBD-II data and motion sensor data can be used to analyze the driving behaviors, which includes: going over speed limits, acceleration (emergency), deceleration and turning, the provided alert function includes:

- Vehicle speed: if vehicle speed is greater than 100 km/h, triggers alert (speed too high).
- Acceleration: if the Delta vehicle speed > 10 km/h, triggers alert (Emergency acceleration).
- Acceleration: Delta throttle position > 30%, triggers alert (Emergency acceleration).
- Deceleration: Delta vehicle speed < -10 km/h, triggers alert (Emergency deceleration).
- Engine RPM: if RPM > 3,000, triggers alert. (Prevent Engine RPM too high.)

We applied various rules for detecting certain driving behaviors. Sometimes a driver may perform some behaviors in responds to emergency, for example, accelerating, turning, and deceleration. Alarms and warnings are triggered for these events. For acceleration if the speed < 40 km/h, and the G sensor reading ≥ 2.353596 m/s2 (0.24g). For deceleration, if the speed < 40 km/h, and the G sensor reading ≤ -3.432327 m/s2 (-0.35g).The detection rule of emergency turning is analyzed by acceleration and angular velocity. The high speed turning may cause larger lateral G values

5.5 Compound Driving Behavior

By extended detection method of hazardous behavior, we can judge compound hazardous driving behavior, the considered driving behaviors and the rules for detection includes the following; (1) Emergency brake and lane changing, in an unprepared situation, a driver may encounter such scenario it may other to hit the rear end of the car. (2) Emergency acceleration and lane changing, (3) Emergency turning and emergency brake. (4)Zigzag (Frequently lane changing). Either of these emergencies are unprepared scenarios that may cause the driver to change his/her behavior which might consequently have effects.

VI. ALERT BY ROAD SITUATION AND VEHICLE STATUS INFORMATION

6.1 Vehicle Status

The OBD-II data can provide the detailed vehicle information in real time. Such as fuel temperature, engine temperature, etc. We will use these data to provide the alarm of malfunctioning of the vehicle. The values monitored are as follows;

6.2 Road Situation and Location-Based Service

The information of road status is important on traffic system. If the driver can get the road status in real-time, the traffic congestion situation can be reduced. The LBS information is important too, like microclimate (temperature, humidity, wind, air quality, etc.).

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In order to get the information of road status, we developed a sensor rich platform to get information, such like microclimate, road status, traffic status, etc.

The Ripple Algorithm

This algorithm is applied on data transmission, the detailed steps shown as follow:

First, we need to assign each module a specific serial code, the format is like: (Rid, Rid_list, Counter, Info.). The "Rid" denotes the serial number of road section in the road network design by ourselves, and the Rid_list is a list that stores the fixed information interconnecting roads of Rid, the third one. Counter is the times of data transfer, larger number will make the information transfer farther (to more modules), the last one

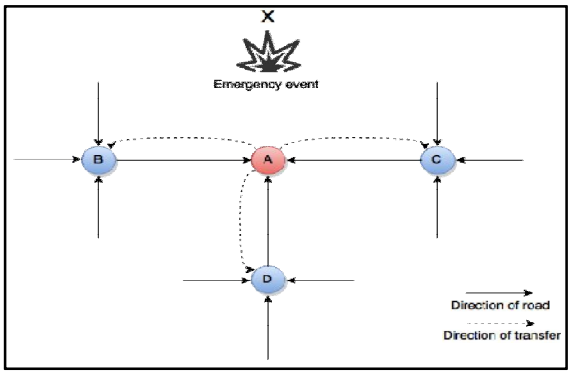


Fig. 6.1: Data transmission architecture

"Info" is an information on specific event.

This algorithm will stop if:

(1) The counter = 0

(2) Rid' not equal to Rid or not in Rid_list.

Figure 6-1 shows an example, and the following is the description:

Once the emergency occurs (figure 6-1 X point), the related unit is obtained and the message is set to coordinator module (figure 9-A point). Then the message will follow the counter to broadcast to neighbor modules (figure 9-B, C, D points), and keep passing to nearby modules repeatedly until counter = 0. This algorithm will reset the information in modules after specific times. (Decided by the importance of event)

VII. CONCLUSIONS

This on board real time monitoring system which successfully measures driving behavior and environmental information which includes the concentration of Alcohol, CO, CO2 can be detected. Also included in the collected data are air condition, then the right alerts and alarms are made to driver for appropriate measure to be taken to solve the situation, like switch on the A/C, open the window, stop and rest for a while and so on. In the information system, we made this data available to user. The system utilized visualization tools and statistical methods for data presentation to user in the form of graphs presented on devices like smart device.

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