Smart-Steering: An IoMT-Device to Monitor Blood Alcohol Concentration using Physiological Signals

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***Abstract*—Accidents on road are severe unavoidable incidents that have been exponentially increasing every year in the United States. Statistics show that among the total accidents, 40% are due to driving intoxicated or under influence. With the growth in science and technology, robust solutions with improved, reasonable, feasible mechanisms should be proposed. Smart-Steering strives to solve this issue with a scope of reduction in the increasing rate of road accidents. This proposes a smart "thing" which can convert the regular steering to smart steering with the help of the Internet of things. This device works with the touch of the human driver, collects and analyses the physiological data of the person and performs the analysis in a microcontroller. With the help of the analyzed data, the decision of sobriety of the human is made and sent to the car's infotainment as a notification. This data is also sent to the cloud server for storing purposes. The blood alcohol prediction is made with an exact level of the concentration present in the human body with an accuracy of approximately 93%.**

***Index terms*—** Internet of Things (IoT), Smart Cars, Smart Healthcare, Alcohol Level Detection, Blood Alcohol Concentration (BAC), Driving Under Influence (DUI), Driving While Intoxicated or Impaired (DWI)

I. Introduction

Driving Under Influence (DUI) or Driving While Intoxicated or Impaired (DWI) is a serious offense. Though these two terms have different meanings, the offense committed by the driver is the same. The alcohol's effects on the human body starts the moment someone consumes their first sip. Prolonged alcohol consumption effects not only involves behavioral changes, blackouts, slurred speech, fatigue, malnutrition, infertility, addiction, and numbness but also involves damage in vital organs such as the liver, the heart, and can cause diabetes and lung infections. The immediate effect of alcohol on the human body include slurred speech, drowsiness, vomiting, headaches, loss of consciousness, memory lapse and distortion of senses and perception [1].

The alcohol percentage in a person's bloodstream is known as Blood Alcohol Concentration (BAC). As BAC increases, the level of intoxication of a person increases. BAC of 0.08% is determined as the legal limit a person can drive in most states of the US. BAC of 0.10% indicates that the blood supply in an individual contains one part of alcohol for every 1000 parts of blood. The number of drinks, amount of time in which they are consumed, body weight, age, and sex are among the various factors that are considered in calculating BAC [2].

Road accidents are increasing at a significant rate every year. There are nearly 40,000 fatal car accidents recorded in the United States per year. There are more than 90 Americans dying in car accidents per day. Out of these 40,000 accidents, 40% are due to drunk driving, 30% are due to speeding and 33% are due to irresponsible driving [3].

It is important to improve traditional methodologies in detecting DUI cases. We propose Smart-Steering, an edge-level solution through the IoT. The Internet of Things (IoT) is defined as a network of interrelated, connected devices, mechanical, digital machines, or objects that are provided with a unique IP address for easy exchange of information without requiring human-to-human or human-to-computer interaction [4], [5].

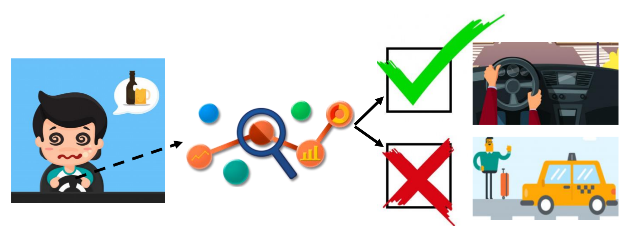

Fig. 1. Schematic Representation of Smart-Steering

The idea behind Smart-Steering is to minimize the requirement for humans to check if the driver is in a stable mind to drive or not. This works as Smart-Steering is an automated device which automatically monitors the physiological signal data of the driver every time he/she touches the steering. By analyzing the physiological data, the decision whether the driver is capable of driving or not is made and actions are taken accordingly. The schematic picture of Smart-Steering is represented in Fig. 1.

This paper is divided into the following sections: the novel contributions of Smart-Steering are outlined in Section II, a broad perspective is presented in Section III, related prior work is summarized in Section IV, the architectural design flow along with feature extractions and data acquisitions of the model are explained in Section V, the experimental setup of the device model is presented in Section VI and conclusion with future scope is presented in Section VII.

II. Novel Contributions

In a motivation to propose a novel method in detecting whether the driver is intoxicated or not, we propose a significant change in the traditional method of detection. The conceptual device prototype of Smart-Steering is shown in Fig. 2. We propose Smart-Steering which has the following novel features:

- A non-invasive, automated real time monitoring system which is activated by human touch.
- An advanced method which doesn't require human-to-human interaction.
- A system which determines the state of the person by monitoring physiological parameters and decides if the person can drive by the measured physiological parameters.
- A system that predicts BAC and checks if the driver is in inebriated or not through out the driving period so as to eliminate any scope of accidents.
- A system that detects the exact BAC with 5 intervals in order to educate the driver of his driving capability.
- The analyzed physiological signal data is saved to the cloud for future reference and the notification is displayed on the infotainment.

Fig. 2. Device Prototype of Smart-Steering

III. Smart-Steering: BAC Predicting System through the IoT

The main objective of smart-steering is to predict the BAC before the driver starts driving rather than in the process of driving. Any regular system can be made in to a smart system by adding this add-on device proposed. This system is optimized as the physiological signal check is done during the driving period only. Once the physiological signal is obtained, it is sent to cloud database for storing purposes. After the analysis, the decision is displayed on the car's infotainment system. The broad perspective of smart-steering is represented in Fig. 3.

IV. Related Research Overview

The impact of growth in science and technology has led to car companies attempting to incorporate an alcohol level detection system in smart cars that automatically determines the BAC and whether the person is able to drive. However, these companies have used the touch technology but this is limited to a certain point with no real time continuous monitoring providing a chance of misuse of the technology. On the other hand, there are wearables that are available in the market in order to test the alcohol consumption but that depends solely on the driver [6], [7]. There are smart phone application based works presented in the literature which do not help to stop accidents [8], [9].

A photoplethysmogram (PPG) signal based approach has been proposed in [10] for the blood alcohol level detection. The PPG signal data from four different individuals was obtained and was analyzed to detect the blood alcohol concentration. However, this research only had the capability of detecting the blood alcohol concentration greater or less than the 0.08%, the limit for driving in most of the states. With this, the driver's ability to drive is stated but the analyzation of stability of driver's consciousness cannot be predicted. In Smart-steering we have proposed the method which is capable of just detecting if BAC is less than or greater than 0.08% but also detect the exact level of BAC as that can be useful in order to analyze the mental ability of the driver.

Detecting the blood alcohol concentration of a person is determined by using biometric scan as the key in [11]. This biometric scan can be used in Smart-Cars as the original pupil diameter and redness in the eye can be used as baseline information for the comparison. The decision of blood alcohol concentration is not solely dependent on biometric scan but also dependent on blood pressure data for more accurate results [12]. The dependency on just the physiological signals is highlighted in Smart-Steering, which helps in developing more robust, simplified and less costly solutions to the same problem.

V. System level modeling of Smart-Steering

The architectural flow of the system is shown Fig. 4. Whenever the driver touches the steering wheel, the physiological signal data is taken, pre-processed and is compared with the baseline information. The data is then analyzed in the microcontroller and the decision to allow the driver to drive or not is determined and is displayed on the car's infotainment center. The IoT cloud is used as storage for the collected data and the decisions made by the system. The microcontroller acts as a "thing" as it is the key part for any car to turn it into a smart-car.

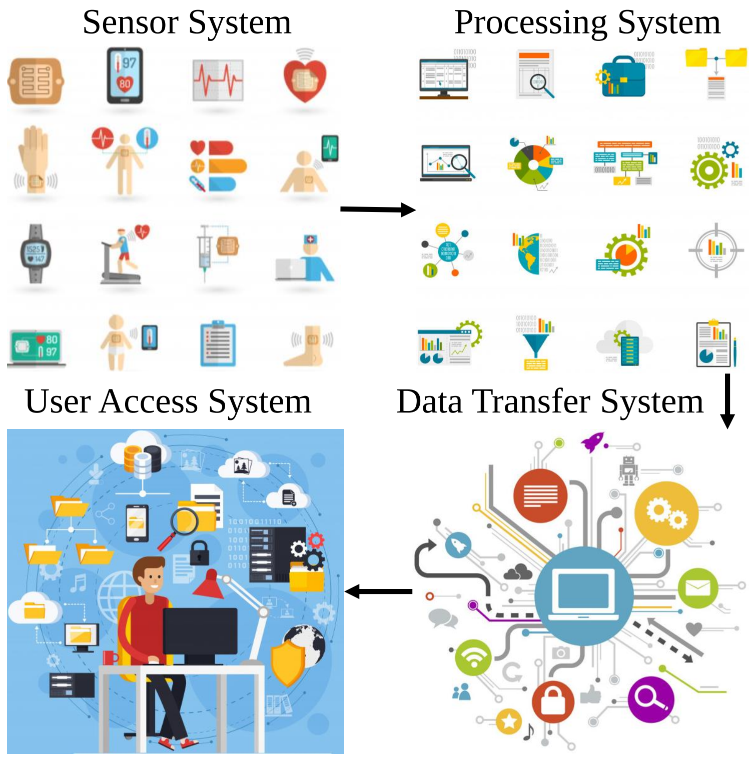

Fig. 3. Perspective of Smart-Steering

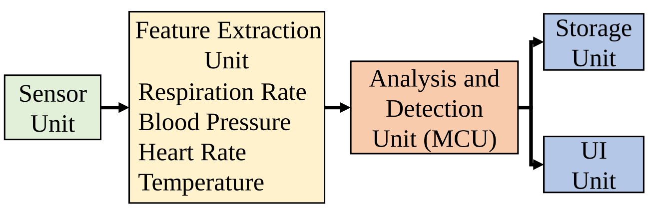

Fig. 4. Architecture Flow of Smart-Steering

A. Working Principle of the Smart-Steering System

When the driver starts the engine, the touch of his hand on the steering wheel activates the sensors that are incorporated in it. The physiological data is gathered at this state. The gathered data is analyzed in the microcontroller unit which can either be placed on the steering or anywhere in the car. This way, the microcontroller acts like a part of the network. After the data is analyzed, the decision if the driver is sober or not is made and is sent to the infotainment. If the driver is sober, he/she is allowed to drive but if the driver is not sober, the engine is locked to prevent accidents. The process of gathering the physiological data and analyzing it is done throughout the driving period in order to prevent any misuse of technology. The gathered, analyzed data will be sent to database for storage. The flow of detection mechanism is shown in Fig. 5.

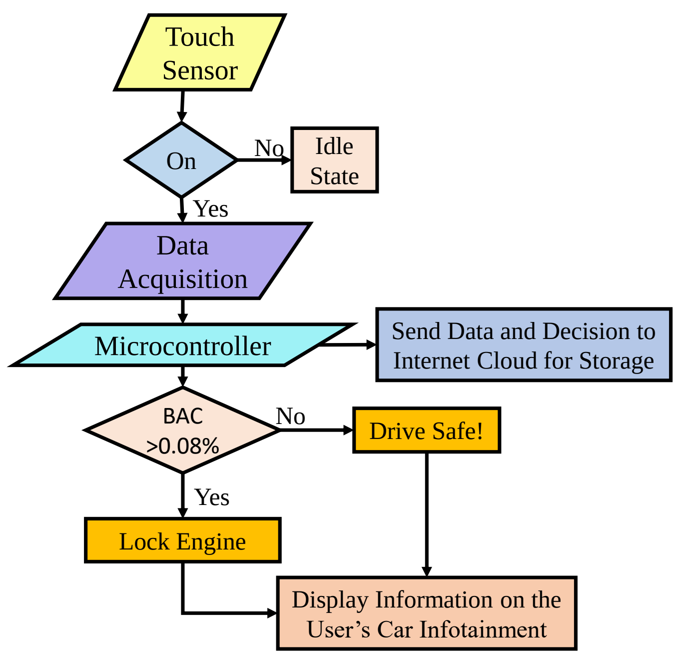

Fig. 5. Design Flow of Smart-Steering

B. The Extraction of Features for Smart-Steering System

The parameters of the physiological signals that are considered in Smart-Steering along with their relationship with alcohol consumption are presented in this Section. The parameters include the following:

- Temperature
- Respiration Rate
- Heart Rate and
- Blood Pressure

The immediate effects of alcohol that have short-term impact on the human body with blood alcohol consumption $\geq 0.08\%$ include increase in blood pressure, blood oxidation content along with an increase in heart rate [13]–[15]. Increase in alcohol consumption may result in very irregular, short and slow bursts in breathing which effects the rate of respiration of the person [16], [17]. The increase in the content of blood alcohol also have impacts on the temperature of the body. The temperature rises because of the distribution of heat in the body and it makes the body feel warm [18], [19].

C. Physiological Signal Data Acquisition

Photoplethysmogram (PPG) signal data was observed for respiration and blood pressure. The observed results also had a relationship with the intake of alcohol typically till the level reached 0.08% of BAC. The established relationship with the BAC content to the PPG signal data is represented by the following expression [10]:

$$m * nl \quad > \quad m * nh \tag{1}$$
$$m * nl \quad < \quad m * nh, \tag{2}$$

In the above, Eqn. (1) represents low alcohol consumption level, i.e. BAC$<$ 0.08%, Eqn. (2) represents high alcohol consumption level i.e., BAC$>$ 0.08%, m is the PPG signal data, nl is the low alcohol consumption level.

The temperature and heart-rate are obtained using literature-published data. The normal body temperature and resting heart-rate of the human body are 97-99°F and 60-100 bpm respectively. If there is a difference in the measured values to the baseline values, the person is assumed to be consuming alcohol. The sensor signal calibration data are represented in Table I while the classification of BAC levels is represented in Table II.

VI. Implementation and Validation of Smart-Steering

For the system implementation, the dataset based on Table II is taken and is executed in MATLAB. The comparison of traditional PPG technique to Smart-Steering is shown in Fig. 6 through the GUIDE interface. The 0.02 here not only represents if the person has exceeded the state rule of BAC but also determines the exact percentage of BAC so as to observe his/her behavior.

The system has been implemented using NodeMCU or ESP8266 along with the physiological sensors as shown in Fig. 7. The analyzed outputs are directly sent to the Cloud

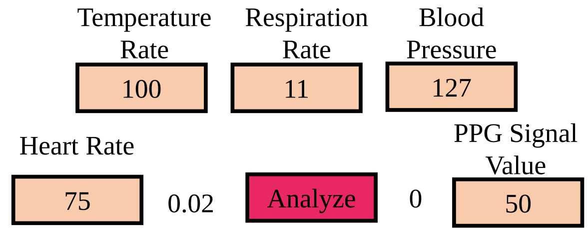

Fig. 6. GUIDE View of Smart-Steering

for storage. The temperature, respiration, blood pressure, and heart rate sensors are used to obtain the sensor information and the system analyzes the data with an average delay of 10ms. The decision is represented in the infotainment center using the LED display. The system has produced an accuracy of approximately 93% when trained with set of 256 rules which have various combinations of the four physiological signal data.

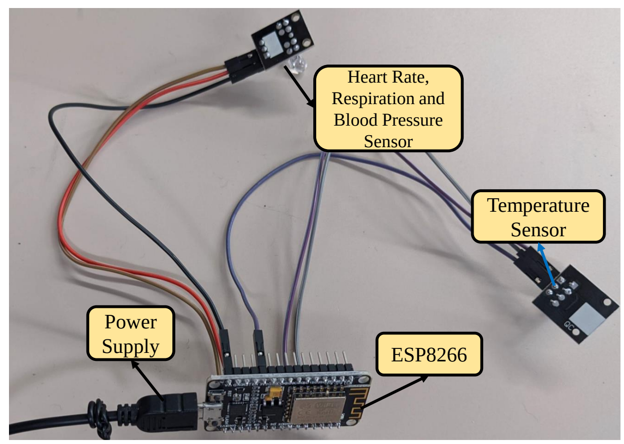

Fig. 7. Hardware Implementation of Smart-Steering

For the cloud connectivity, ThingSpeak, an IoT Analytics tool, was used where the data collected in the cloud can be analyzed using MATLAB®. The combined intoxicated and sober signal data along with the time of occurrence is represented in ThingSpeak in a 2-D graphical format. The graphs obtained from each individual sensor are in Fig. 8.

The brief comparison of the wearables and articles that propose the BAC detection are represented in Table III. From Table Table III and Fig. 6, it can be observed that the alcohol consumption detection depending on only one sensor signal data, produces the results with noticeably less accuracy. Also, in most of the articles, the results are produced in such a way that the user knows if the blood alcohol concentration is above or below the driving limit i.e., 0.08%. Through Smart-Steering, by using more than one physiological signal data, the proposed system not only identifies the individual level of alcohol blood concentration but also states if the user is sober.

TABLE I
SENSOR SIGNAL CALIBRATION

Sensor/Signal Type	Feature Considered	Baseline Condition	BAC Conditions
Heart Rate Sensor	Heart Rate	60-90 beats/min	$>$ 90 beats/min
Temperature Sensor	Temperature	97-99°F	$>$ 99°F
PPG Signal Data	Respiration Rate, Blood Pressure	12-20 breaths/min, 110/70 to 120/80	$m*nl>/<m*nh$

TABLE II
BAC LEVEL REPRESENTATION

PPG Signal Data	Respiration Rate (breaths/min)	Blood Pressure	Heart Rate (beats/min)	Temperature	BAC (%)
nl= 0.994, nh= 0.966	12-20	110/70-120/80	60-90	97-99	0 - Sober
nl= 0.248, nh= 0.2415	10-12	120/80-125/85	90-100	99-101	0.02
nl= 0.497, nh= 0.483	9-10	125/85-130/85	100-105	101-102	0.04
nl= 0.745, nh= 0.724	5-9	135/85-140/90	$>$105	$>$102	0.06
nl= 0.994, nh= 0.966	$<$5	$>$140/90	$>$105	$>$102	0.08

(a) Heart Rate

(b) Respiration Rate

(c) Blood Pressure Rate

(d) Temperature Rate

Fig. 8. Signal Analysis Smart-Steering.

VII. CONCLUSIONS AND FUTURE RESEARCH

Smart-Steering has proposed and implemented the idea of detecting blood alcohol concentration level of a person through a smart device before the process of driving starts. This device can turn a regular device to smart device by connecting to the Internet to store the data. As soon the driver touches the steering wheel, the physiological sensors get activated and collect the initial data of the driver. This obtained data is checked with the regular baseline information and a decision of the driver's sobriety is made. If the driver is sober, he is allowed to drive but if he is not, the car will automatically lock the engine along with the blood alcohol concentration information being displayed on the infotainment. The exact blood alcohol concentration present in the human body is also determined. The information is processed in a microcontroller with an approximate accuracy of 93% and the data is sent to an Internet of things analytic tool which can be accessed by the user later.

The future directions of this research will be expanding the impact of physiological signal data by observing the changes in physiological parameters during various chores of a person. Also, the type, amount and time of food consumption, the average sleep score, the physiological parameter changes during these actions to make a significant improvement not only in the detection of blood alcohol consumption but also to analyze person's behavior is one of our important aspects

TABLE III
COMPARISON WITH EXISTING RESEARCH

Research	Prototype	Sensors/Things	Accuracy	Cost	BAC classification(%)
Liu, et al. [20]	Device	NIR	NA	High	2
WrisTAS [6]	Wearable	Touch sensor	NA	NA	2
BACtrack [8]	Device	Breathe Analyzer	NA	High	5
Floome [9]	Device	Breathe Analyzer	75%	High	5
Chen, et al. [10]	NA	PPG	85.71%	Moderately High	2
Rachakonda, et al. [11] (Donot-DUEye)	Device	Biometric Scan and BP	95%	Moderate	2
Smart-Steering (Current Paper)	Device	Heart rate, temperature, respiration and blood pressure	93%	Moderately Low	5

of research. Combining vision along with this data to create a more robust smart healthcare models to monitor, analyze and educate the users is the main research focus.

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