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Preventing Impaired Driving Using IoT on Steering Wheels Approach

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Abstract

To drive safely, one must be attentive, coordinated, have good judgment, and be able to respond quickly to changing conditions. In certain countries, improving safety may depend largely on reducing the number of impaired drivers on the road. Therefore, solutions are required to reduce the risk that is posed on the road by drivers who have been consuming alcohol while driving. Previous research has proposed the use of sensors for detecting driver impairment caused by alcohol intoxication. However, relying on a gas sensor alone may not be appropriate for detection. To reduce drunk driving, this study proposes an Internet of Things (IoT)-based tool that measures heart rate and analyzes the breath of a driver for traces of alcohol. The tool represents a vehicle that is made up of a DC motor. In the circumstance that the tool detects a higher than resting heart rate in the driver as well as an amount of alcohol in the driver's breath sample, the tool will immediately power down the DC motor and send an SMS to the registered emergency contact with the driver's precise position using the GPS module. The initial prototype demonstrates the tool as a potential aftermarket accessory for vehicles. The implication of this paper is that the designed tool might be of practical use to researchers in their attempts to determine and obtain information on alcohol intoxication.

Keywords: Impaired Driver; Alcohol Intoxication; Internet of Things; Sensors.

1. Introduction

Road traffic accidents are a major cause of injury, impairment, and death across the world, and they are the top cause of mortality among those aged 15 to 29. Alcohol-impaired drivers are much more likely to be involved in an accident. Drunk driving is a major risk factor for 27% of all road injuries [1]. For example, alcohol-impaired driving is a major issue that poses a threat to road safety in China. The problem has been well documented by numerous studies and has been identified as a significant factor in the occurrence of road accidents [2]. Moreover, the E-Survey of Road Users' Attitudes (ESRA) conducted an online survey in 2018, gathering data from over 35,000 road users in 32 countries. The survey highlighted that driving under the influence of alcohol or drugs is one of the top four risky driving behaviors. However, it was also found that driving under the influence was the least commonly reported behavior among participants [3, 4].

Drivers' senses, i.e., hearing, vision, touch, smell, and even taste, are vital in providing crucial information about the road, traffic conditions, and the environment, enabling the driver to make informed decisions and respond appropriately to the situation. However, excessive consumption of alcohol impairs these senses, adversely affecting one's ability to

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perform these tasks. The effects of alcohol on the senses encompass reduced hearing acuity, blurred vision, diminished touch sensitivity, an impaired sense of smell, and a weakened sense of taste [5]. These impairments result in misjudging the surroundings and making poor decisions, endangering the individual and potentially others. This is because an impaired driver may fail to recognize hazardous situations or react too slowly to avoid them, leading to perilous or even life-threatening circumstances [6, 7]. Operating a vehicle under the influence of alcohol stimulates the senses and compels individuals to drive in an unsafe manner, thereby increasing the likelihood of accidents and unnecessary fatalities [5, 8]. Even at low blood alcohol levels, drivers experience difficulties maintaining focus, coordination, and identifying dangers on the road (World Health Organization, 2019). Studies have demonstrated that even a low blood alcohol content, as indicated by a Blood Alcohol Content (BAC) of 0.08%, can adversely affect an individual's sensory abilities, which are essential for safe driving [2]. Alcohol substantially impairs an individual's ability to function effectively, particularly regarding the central nervous system. When an individual chooses to drive under the influence of alcohol, the likelihood of a road accident significantly rises. In Malaysia, the legal limit for alcohol consumption while driving is regulated by the Road Transport Act 1987, stipulating that a person must not exceed 35 micrograms of alcohol per 100 milliliters of breath when operating a vehicle [9]. Therefore, drunk driving is not only a non-communicable disease but also a significant public health concern that impacts all road users.

Globally, to prevent and minimize alcohol-related impaired driving, a range of counter measures mainly based on deterrence theory, which will be successful only if drivers feel they will be caught and punished, are in place [2]. Most drivers perceived that there was a low probability of getting caught by authorities since, for many years, alcohol tests for intoxicated drivers relied on the testing of urine and blood among the drivers [10]. The authorities typically use the Field Sobriety Test to assess a driver suspected of being drunk [11, 12]. Hence, a non-profit organization in the United States of America known as Mothers Against Drunk Driving recommends that drunk driving prevention technology be mandated in newer vehicles in the year 2021. However, the technology should only make use of blood-alcohol content or identity recognition for a brief period to either disable a vehicle from being operated by an impaired driver or safely bring an in-motion vehicle to a safe stop [13].

Recent advancements in vehicle technology offer new possibilities for minimizing the occurrence of drunk driving [14], including driving performance monitoring systems, driver monitoring systems, and passive alcohol detection systems, as well as the application of the Internet of Things [15, 16]. While the driving performance and driver monitoring systems are aimed at detecting dangerous behaviors that lead to road accidents, the passive alcohol detection system employs sensors built into a vehicle to passively identify whether the driver is intoxicated. Preventing drunk driving is a critical issue that requires the attention and efforts of various organizations. For instance, the United States, the National Highway Traffic Safety Administration (NHTSA), and the Automotive Coalition for Traffic Safety (ACTS) have joined forces to develop a passive alcohol detection system known as the Driver Alcohol Detection System for Safety (DADSS). This innovative system was designed to prevent drivers from shifting their vehicles into gear if they attempt to operate the vehicle at a Blood Alcohol Content (BAC) above the legal limit [2].

Similarly, previous work on vehicle-based counter measures for driver alcohol detection systems utilized BAC to determine a person's alcohol level. BAC is typically considered the more accurate and reliable measurement, especially in legal contexts. For instance, Lukas et al. [17] reported the use of an Arduino Uno processor (ATMEGA 328) and an MQ3 alcohol sensor to determine a driver's BAC, while Nortajuddin [18] extended the work by incorporating safety measures through the BAC safe limit. If the BAC exceeds the prescribed safe limit, the engine will not start, and the driver's next of kin will be notified via a GSM module. Likewise, another project by Rosenberg [11] aims to ensure driver sobriety by cutting off the fuel supply to the engine and sounding an alarm sound in case of a high BAC. The system will also notify nearby authorities through an SMS message. In addition, an Intelligent Alcohol Detection System, as described by Ryan and Howes [19], is a comprehensive approach that not only assesses a driver's BAC but also their state of consciousness and driving ability. This system includes an eye blink sensor to detect drowsiness and a tilt sensor to monitor the vehicle's movement. If the BAC exceeds the safe limit, the vehicle's GPS information will be sent to the nearest police station, a message will be sent to a designated family member, and the engine will stop to prevent further driving.

Alternatively, the Breath-alcohol Concentration (BrAC) analyzer has advanced in recent years, with a growing interest in understanding the behavioral effects of alcohol and the impairments caused by even low to moderate alcohol consumption. This shift in focus has been further fueled by changes in traffic laws that lower the permissible BrAC limit for drivers across the nation [20]. Even though it is not as precise as BAC, it provides a lightweight, portable, quick, and non-invasive way to estimate alcohol levels by employing sensors to simultaneously measure both the alcohol and carbon dioxide concentrations present in a person's breath. Carbon dioxide levels in human breath serve as an indicator of breath dilution, which in turn allows for the accurate measurement of alcohol content in expired air. This non-invasive method provides a quick and efficient way to determine an individual's alcohol level, making it a valuable tool in preventing drunk driving [21]. The results obtained are thought to be accurate enough to be used in an alcohol intoxication conviction

[10]. Nevertheless, the distance between the breathalyzer and the person who is tested affects the data acquired. For instance, the MQ3 sensor detects less alcohol concentration when the distance is increased [22]. In a recent study, Wang et al. [23] proposed a two-step drunk driving detection frame for shared cars. Alternatively, other approaches include using photoplethysmography [24], radar systems [25], transfer learning [26], and blockchain [27, 28].

A recent study found that the more alcohol is consumed, the faster a person's heart rate rises. Hence, higher BrAC can increase heart rate [29]. An increase in heart rate can be considered an indicator of a driver's response to drunk driving [30], which may be caused by an increase in sympathetic activity or an increase in calcium entering cardiac myocytes. An adult's typical resting heart rate ranges between 60 and 100 beats per minute [29]. Tasnim et al. [31] discovered that having one normal drink raised the participants' heart rates by roughly five beats per minute over the next six hours. The rise in heart rate was larger with two or more drinks, and heart rates remained modestly raised up to 24 hours later. High-dose alcohol causes an increase in heart rate for up to 24 hours. In addition, a driving simulator experiment with 100 ml of alcohol found that a 10% rise in Breath Alcohol Concentration (BrAC) levels increased the response time of Greek drivers by 2% [32]. Furthermore, it was observed that a unit increase in BrAC increased response time by 0.3 in their trials on Chinese drivers using a 500-ml alcoholic beverage (orange juice combined with vodka containing 40% alcohol). The same study also found that a unit increase in BrAC resulted in a 0.2% rise in the standard deviation of lane position (SDLP) [33]. It is worth noting that the permissible BrAC limit varies from country to country, as seen in Table 1. Therefore, it is important for those using the BrAC analyzer to familiarize themselves with the specific regulations and guidelines set by their local authorities.

Table 1. BrAC limit by country

BrAC Threshold (mg/l)	Countries
0.10	Norway, Sweden, Estonia, Morocco
0.20	Mongolia
0.22	Scotland, Finland, Hong Kong, Belgium, Botswana, Malaysia
0.24	Slovenia, South Africa, Israel
0.25	Denmark, Germany, Cambodia, France, Greece
0.35	Brunei, Ghana, Kenya, Singapore
0.38	Malawi, Namibia, Swaziland
0.40	Austria
None	Thailand, Indonesia, India, Ireland

Therefore, this study demonstrates the work on detecting impaired driving based on BrAC and the heart rate of the driver using the Internet of Things (IoT). Combining BrAC measurements with heart rate data might enhance the accuracy of identifying drunk drivers. Alcohol consumption can affect heart rate, so monitoring both parameters could provide a more comprehensive picture of a driver's intoxication level. Since both BrAC and heart rate can be measured non-invasively, the tool can be easily integrated into vehicle systems for continuous monitoring and early detection, which could potentially prevent accidents and impaired driving to take place. The following section presents the C2A2 methodology applied in this study. Next, the results and discussion are provided. Finally, the conclusion section concludes the paper.

2. Research Methodology

The C2A2 (capture, communicate, analyze, and act) IoT lifecycle is employed in this study. First, a prototype was developed with the embedded system design methodology to capture data from sensors and transform it into a digital value. The embedded system design methodology was utilized to integrate hardware and software components optimally. The approach involved a strategic plan and execution to maximize the performance of the systems. The hardware assembly was given priority, with all essential modules and sensors gathered, installed, and programmed. Before proceeding, preliminary tests were performed to verify that all necessary data and sensors met the predetermined requirements. Once completed, the application and components were integrated by configuring and verifying data transfer between them. This ensured seamless system operation and met the desired outcomes. Then, during the Communicate stage, Wi-Fi telecommunication technologies link the IoT device with the central server. Afterwards, data from the device will be analyzed in real-time based on pre-determined rules. Finally, the act is the last stage, and depending on the results obtained in the previous step, notification is provided by analysis. Figure 1 illustrates the C2A2 IoT lifecycle, which corresponds to the IoT architecture layers.

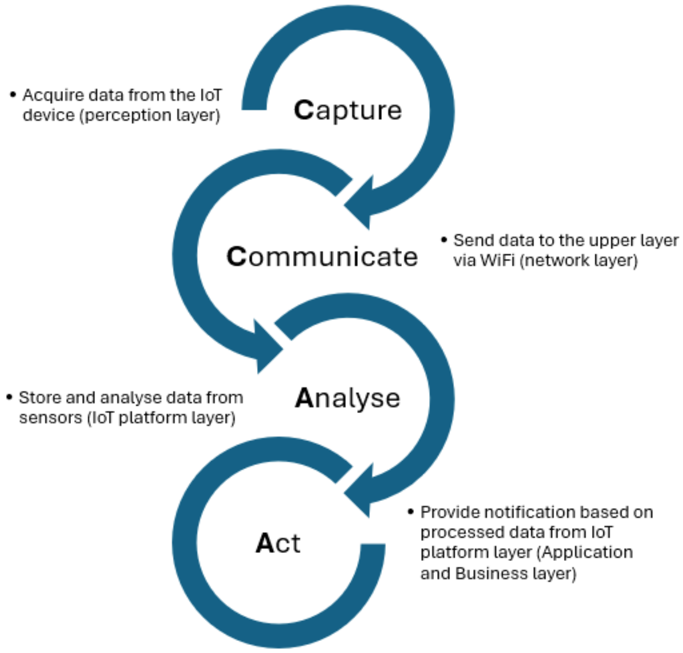

Figure 1. C2A2 IoT lifecycle

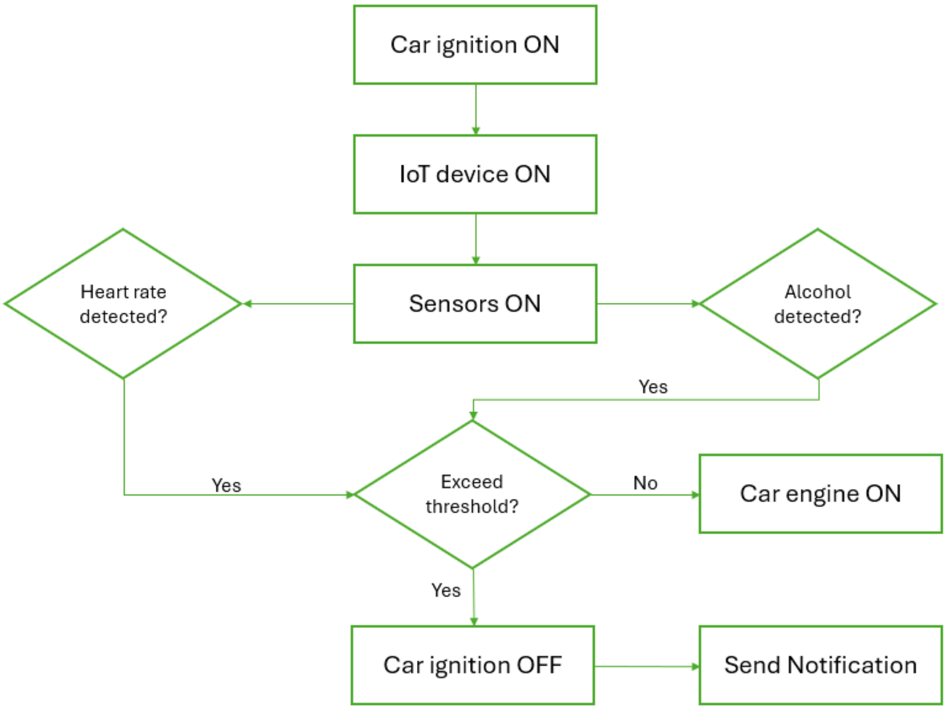

Figure 2. System flowchart

The flow chart shown in Figure 2 provides an illustration of the entire process flow for the alcohol detection system. The diagram depicts the sequential steps involved in the system, starting from the initiation of the process (Capture) and ending with the final output (Act). During the installation process, basic information like sex, gender, and weight needs to be provided. The values will be used to determine the threshold for heart rate and alcohol level. To power up the IoT device, the vehicle ignition needs to be on before sensors can begin detecting the driver's heart rate and alcohol level. The readings will be compared to the threshold values. Assuming a driver has alcohol on his breath and an elevated heart rate, the vehicle's engine will not start as a safety measure. The ignition will be disabled to prevent the driver from operating the vehicle while under the influence. To ensure the safety of the driver and others on the road, an SMS notification will be sent to the driver's emergency contact with their current location. This will allow the emergency contact to take appropriate actions, such as seeking assistance or arranging for a designated driver. If, however, the driver does not have traces of alcohol on their breath and their heart rate is normal, the vehicle's engine will start normally, and the system will shut down. This indicates that the driver is cleared to operate the vehicle safely.

The block diagram in Figure 3 represents the hardware connections and communication flow of the system, which includes various components such as an Arduino Uno microcontroller, MQ3 alcohol sensor, MAX30102 heart rate sensor, relay switch, L298N motor driver module, DC motor, GSM/GPS module (SIM9000A), and ESP8266 Wi-Fi module. The relay switch acts as the interconnecting device between all hardware components. The MQ3 alcohol sensor and MAX30102 heart rate sensor are connected to the Arduino Uno microcontroller in a unidirectional manner, meaning data can only flow from the sensors to the microcontroller. On the other hand, the GSM/GPS module (SIM9000A) has a bidirectional connection with the Arduino, allowing data to flow in both directions. The L298N motor driver module is connected to the DC motor, which represents the engine deactivation system, and starts functioning as soon as the system is initialized. The DC motor is connected to pin 9 of the microcontroller and operates with a voltage range of 1.5 to 6.0 volts. Finally, the sensor data is sent to the cloud using the ESP8266 Wi-Fi module. Prior to integrating all the components, each one was tested and assembled individually with the Arduino Uno and respective codes. This was done to ensure proper functionality and eliminate any errors before integration.

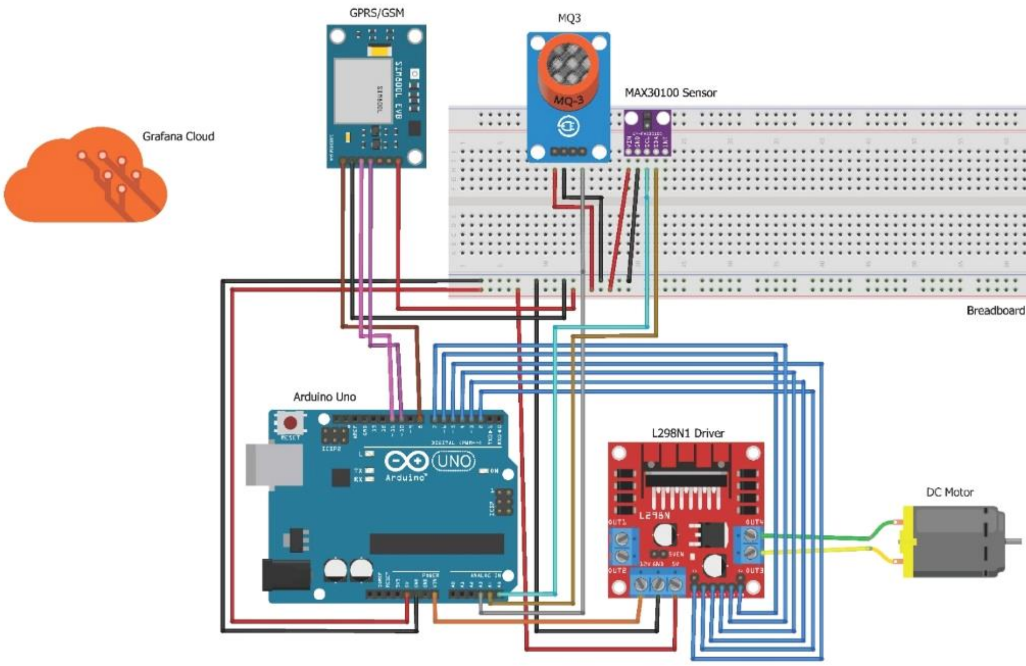

Figure 3. System block diagram

The MQ3 alcohol sensor was successfully integrated with the Arduino Uno microcontroller, allowing for efficient testing of alcohol detection within the system. The MQ3 sensor is commonly used to measure drivers' alcohol concentration when discussing vehicle-based counter measures. For example, Carranza et al. [34], Vignesh et al. [35], and Pravinth Raja [16] utilize the MQ3 sensor in their studies to detect alcohol levels. For first-time usage, the sensor must be fully warmed up for 24-48 hours to ensure maximum accuracy. Consecutive usage only requires around 3 minutes warm-up period. The sensor typically reads high and gradually decreases until it stabilizes. In addition, the MQ3 sensor has a detection range from 0.05 mg/L to 10 mg/L. For alcohol concentration in air, the recommendation for sensitivity adjustment is to calibrate for 0.4 mg/L. Since an Arduino analog input pin gives a reading between 0 and 1023, the real-time value acquired from the sensor is used to calculate the BrAC as in Equation 1.

$$BrAC = \frac{Real\ time\ value \times 0.4}{1023} \quad (1)$$

Moreover, 2100:1 is the standard conversion factor for estimating blood alcohol concentration, which indicates that 1 milliliter of blood contains 2100 times more alcohol than 1 milliliter of the lungs' air. The BAC is stated in grams of ethanol weighted by 210 liters of breath (Table 2). Hence, the BAC can be calculated using Equation 2.

$$\%BAC = \frac{BrAC \times 210}{1000} \quad (2)$$

Based on previous studies, the normal resting heart rate is usually 60–100 beats per minute. The target heart rate during driving is less than 20 beats per minute above the resting heart rate [36]. When a driver consumes alcohol, it is likely to show an increase in the heart rate [30]. However, if the normal heart rate for the driver is not provided, the system will refer to the average resting heart rate as in Table 3.

Table 2. BrAC to BAC values

Sensor value	BrAC		BAC	
	mg/L	mg/210	mg%	%BAC
128	0.05	10	10	0.01
256	0.10	20	20	0.02
358	0.14	30	30	0.03
486	0.19	40	40	0.04
563	0.22	46	46	0.046
614	0.24	50	50	0.05
742	0.29	60	60	0.06
844	0.33	70	70	0.07
972	0.38	80	80	0.08

Table 3. Average resting heart rate based on gender in beats per minute

Age (years old)	Male	Female
18-25	70-73	74-78
26-35	71-74	73-76
36-45	71-75	74-78
46-55	72-76	74-77
56-65	72-75	74-77
65+	70-73	73-76

3. Results and Discussion

This study aims to prevent accidents using vehicle-based counter measures using an Internet-of-Things approach to detect driver impairment based on a combination of the driver's heart rate and alcohol level from the driver's breath. For testing purposes, a higher heart rate was induced by doing a 5-minute cardio exercise prior to placing the finger on the heart rate sensors. If the heart rate is beyond the threshold (more than 100), the red LED will light up. The MQ3 sensor is placed in the middle of the steering wheel, which is about 30 cm from the mouth of a 160 cm-tall driver. Because the MQ3 sensor reacts to any type of substance with a high concentration of ethanol, it cannot distinguish between alcohol molecules, fragrances, or hand sanitizers. Due to dietary restrictions, authors cannot consume alcohol for the purpose of testing. Alternatively, this test was performed by applying alcohol to two fingers and gently rubbing them near the sensor. The alcohol source used in the test was obtained from a perfume bottle that had a composition of 38% alcohol by volume in every 100 ml. One spray of the perfume bottle (4 ml) produced 0.0152 mg of alcohol, and to obtain a higher concentration, approximately 20 sprays were utilized, resulting in a total of 0.3 mg of alcohol. In addition to the perfume bottle, the sensor was also tested using hand sanitizer, which has a high concentration of ethanol (90%). This test was performed to further validate the accuracy and reliability of the sensor in detecting and measuring alcohol concentrations in the air and calculating the Blood Alcohol Concentration (BrAC) value.

An integration test was conducted to assess the compatibility and functionality of the MAX30102 heart rate sensor, MQ3 alcohol sensor, Arduino Uno, and the GPRS/GSM module. This test was crucial in determining the success of the integration process and the overall performance of the system. The GPRS/GSM module plays a crucial role in the system as it serves as the communication module responsible for sending SMS text messages to the driver's emergency contacts in case of drunk driving. To simulate this scenario, the program was temporarily modified to respond to approximately 0.3 mg of alcohol. The threshold for the alcohol sensor was set at 550 analog values, which represents 0.22 mg/L of BrAC as regulated in Malaysia. Additionally, the heart rate sensor's threshold was set at 100 beats per minute (bpm). If both the alcohol concentration and heart rate exceed the set thresholds, the system is programmed to send an SMS and turn off the DC motor, representing the vehicle. The results of the integration test were successful, with the SMS notification being transmitted to the emergency contact through the GPRS/GSM module and confirmed by the receiving end, as shown in Figure 4. The results of the integration test were captured in Table 4.

Figure 4. SMS notification

Table 4. Testing results

Condition	Components	Value	Results
Heart rate detection, no exercise	MAX30102	≥ 60 and ≤ 100	Normal heart rate
Heart rate detection, post exercise	MAX 30102	≥ 101	High heart rate
20 Sprays from perfume bottle (~0.3mg of alcohol)	MQ3 Sensor	≥ 551.00, ≤ 672.00	Alcohol detected
Hand sanitizer 90% ethanol	MQ3 Sensor		Alcohol detected
Heart rate detection, post exercise and perfume	MAX30102, MQ3, Arduino Uno and SIM900A GPRS / GSM Module	≥ 101 heart rate and ≥ 550 alcohol	DC motor stop; SMS sent
Heart rate detection, post exercise and hand sanitizer	MAX30102, MQ3, Arduino Uno and SIM900A GPRS / GSM Module	≥ 101 heart rate and ≥ 550 alcohol	DC motor stop; SMS sent

Figure 5 shows an image captured in a vehicle cabin to further demonstrate the potential of the prototype. For this purpose, the integrated circuit is placed in a PVC enclosure box with LEDs as visual indicators for the driver. The pulse sensors are placed at the 3–9 position of the steering wheel based on the assumption that the driver will be holding the steering in the recommended position. The MQ3 sensor is placed at the center of the steering wheel. The yellow LED will light up when the car ignition is turned on, and once the sensors are in a ready state, the green LED will light up. If the alcohol level and heart rate exceed the limit, the red LED will light up, and the car ignition will be turned off.

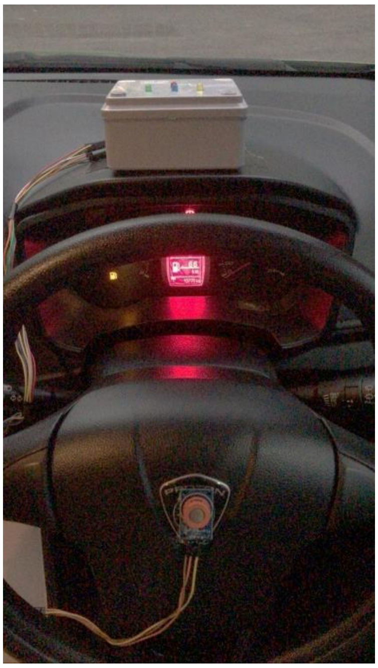

Figure 5. Prototype

This IoT approach allows the driver's heart rate and alcohol concentration levels to be monitored at the same time. The sensor data is also sent to the Grafana cloud. It is important to note that the alcohol concentration in a vehicle cabin can be affected by other factors. Changes in the heart rate may increase the reliability of the assessment of the driver's impairment when it is related to the alcohol concentration in the driver's breath. Moreover, preventive measures on the driver's ability to operate the vehicle safely are triggered by disabling the vehicle ignition and notifying the driver's state to his close contacts. This approach avoids possible accidents based on the driver's state.

4. Conclusion

This paper presents the development of an IoT-based alcohol detection system for drivers that utilizes IoT technology and the C2A2 IoT lifecycle. The tool was designed with the integration of an Arduino Uno microcontroller, a heart rate sensor, an MQ3 sensor, a GSM module, and a DC motor. The sensor data was uploaded to the cloud using a Wi-Fi module (ESP8266) connected to a microcontroller. This connectivity allows the data to be accessed and analyzed remotely, providing valuable insights into a driver's condition. This study considers a driver's heart rate increase to supplement the alcohol concentration in the air, which is detected using the MQ3 sensor. As a preventive measure, when the tool detects that sensor data exceeds the threshold, the vehicle ignition will be disabled, and a notification will be sent to the driver's close contact. This study offers promising advancements in assessing driver impairment. However, it is important to acknowledge several limitations in the approach. The accuracy and reliability of heart rate measurements may be affected by various factors, including environmental conditions, sensor placement, and individual physiological differences among drivers. Factors such as hand position on the steering wheel, driving style, and vehicle vibrations could introduce noise or variability in heart rate readings, potentially impacting the overall effectiveness of the system. Interpreting the sensor data in the context of driver impairment requires careful consideration of individual baseline heart rates, medical conditions, and other factors that may confound the analysis. Therefore, to ensure that it is suitable for use in a passenger vehicle, further development and improvement are necessary. This may include identifying the strategic placement of the tool to ensure accurate measurement of the driver's breath and alcohol concentration level. An extensive investigation is needed to ensure compliance with established global standards for vehicle interiors to ensure safety and regulatory compliance. Education and public acceptance of the vehicle-based counter measures should also be emphasized. Additionally, careful redesigning is needed to ensure compatibility with existing steering wheel mechanisms and ergonomics.

5. Declarations

5.1. Author Contributions

Conceptualization, S.F.A.R. and S.Y.; methodology, S.Y.; investigation, A.U.; writing—original draft preparation, S.F.A.R., S.Y., and A.U.; writing—review and editing, S.F.A.R. and S.Y.; funding acquisition, S.F.A.R. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

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5.4. Acknowledgements

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5.5. Institutional Review Board Statement

Not applicable.

5.6. Informed Consent Statement

Not applicable.

5.7. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6. References

[1] W.H.O. (2019). SAFER: A World Free from Alcohol Related Harms. World Health Organisation, New York, United States. Available online: https://www.who.int/publications/i/item/9789241516419 (accessed on March 2024).

[2] Liu, L., Chui, W. H., & Deng, Y. (2021). Driving after alcohol consumption: A qualitative analysis among Chinese male drunk drivers. International Journal of Drug Policy, 90. doi:10.1016/j.drugpo.2020.103058.

[3] Pires, C., Torfs, K., Areal, A., Goldenbeld, C., Vanlaar, W., Granié, M. A., Stürmer, Y. A., Usami, D. S., Kaiser, S., Jankowska-Karpa, D., Nikolaou, D., Holte, H., Kakinuma, T., Trigoso, J., Van den Berghe, W., & Meesmann, U. (2020). Car drivers' road safety performance: A benchmark across 32 countries. IATSS Research, 44(3), 166–179. doi:10.1016/j.iatssr.2020.08.002.

[4] Kumar Yadav, A., & Velaga, N. R. (2021). A comprehensive systematic review of the laboratory-based research investigating the influence of alcohol on driving behaviour. Transportation Research Part F: Traffic Psychology and Behaviour, 81, 557–585. doi:10.1016/j.trf.2021.07.010.

[5] Love, S., Rowland, B., & Davey, J. (2023). Exactly how dangerous is drink driving? An examination of vehicle crash data to identify the comparative risks of alcohol-related crashes. Crime Prevention and Community Safety, 25(2), 131–147. doi:10.1057/s41300-023-00172-6.

[6] Fang, C., Zhang, Y., Zhang, M., & Fang, Q. (2020). P300 measures and drive-related risks: A systematic review and meta-analysis. International Journal of Environmental Research and Public Health, 17(15), 1–14. doi:10.3390/ijerph17155266.

[7] Kloft, L., Monds, L. A., Blokland, A., Ramaekers, J. G., & Otgaar, H. (2021). Hazy memories in the courtroom: A review of alcohol and other drug effects on false memory and suggestibility. Neuroscience and Biobehavioral Reviews, 124, 291–307. doi:10.1016/j.neubiorev.2021.02.012.

[8] van Dijken, J. H., Veldstra, J. L., van de Loo, A. J. A. E., Verster, J. C., van der Sluiszen, N. N. J. J. M., Vermeeren, A., Ramaekers, J. G., Brookhuis, K. A., & de Waard, D. (2020). The influence of alcohol (0.5‰) on the control and manoeuvring level of driving behaviour, finding measures to assess driving impairment: A simulator study. Transportation Research Part F: Traffic Psychology and Behaviour, 73, 119–127. doi:10.1016/j.trf.2020.06.017.

[9] Zainal, E. S. (2020). Drunk Driving in Malaysia_ Heavier Punishments vs Stricter Laws. Malaysian Litigator. Kuala Lumpur, Malaysia. Available online: https://malaysianlitigator.com/2020/08/10/drunk-driving-in-malaysia-heavier-punishments-vs-stricter-laws/ (accessed on March 2024).

[10] Yousif, E., Alali, D., Aldakhl, S., & Zohdy, M. (2021). Use of vehicle breathalyzers in the reduction of DUI deaths. 2021 IEEE International IOT, Electronics and Mechatronics Conference, IEMTRONICS 2021 – Proceedings, Toronto, ON, Canada. doi:10.1109/IEMTRONICS52119.2021.9422629.

[11] Rosenberg, E. (2015). A Study of the Accuracy and Precision of Selected Breath Alcohol Measurement Devices (Breathalyzers). Report TUW CTA 2015/27EN, 1–45.

[12] Smith, R. C., Robinson, Z., Bazdar, A., & Geller, E. S. (2016). Intervening to decrease the probability of alcohol-impaired driving: Impact of novel field sobriety tests. Journal of Prevention and Intervention in the Community, 44(3), 199–212. doi:10.1080/10852352.2016.1166817.

[13] MADD. (2022). 10 Things to Know About the Impaired Driving Prevention Technology Provision in the Infrastructure Law. Mothers Against Drunk Driving, Texas, United States. Available online: https://madd.org/press-release/10-things-to-know-about-the-drunk-driving-prevention-technology-provision-in-the-infrastructure-bill/ (accessed on March 2024).

[14] NHTSA. (2023). Advanced Impaired Driving Prevention Technology. National Highway Traffic Safety Administration, Department of Transportation, Washington, D.C., United States.

[15] Kingsley, K., da Silva, F. P., & Strassburger, R. (2023). In-vehicle technology to prevent drunk driving: Public acceptance required for successful deployment. Transportation Research Procedia, 72, 2433–2440. doi:10.1016/j.trpro.2023.11.741.

[16] Pravinth Raja, S., Blessed Prince, P., & Jeno Lovesum, S. P. (2023). Smart Steering Wheel for Improving Driver's Safety Using Internet of Things. SN Computer Science, 4(3), 277. doi:10.1007/s42979-022-01636-6.

[17] Lukas, S. E., Zaouk, A., Ryan, E., McNeil, J., Justin Shepherd, M., Willis, M., Neeraj Dalal, B., & Kelly Schwartz, B. (2017). Driver Alcohol Detection System for Safety (DADSS)-Preliminary Human Testing Results. 25th International Technical Conference on the Enhanced Safety of Vehicles (ESV), 1–11.

[18] Nortajuddin, A. (2020). Drunk driving on the rise in Malaysia. The ASEAN Post, Kuala Lumpur, Malaysia. Available online: https://theaseanpost.com/article/drunk-driving-rise-malaysia (accessed on March 2024).

[19] Ryan, J. M., & Howes, L. G. (2002). Relations between alcohol consumption, heart rate, and heart rate variability in men. Heart, 88(6), 641–642. doi:10.1136/heart.88.6.641.

[20] Dubowski, K. M., & Essary, N. A. (1999). Measurement of low breath-alcohol concentrations: Laboratory studies and field experience. Journal of Analytical Toxicology, 23(6), 386–395. doi:10.1093/jat/23.6.386.

[21] Ferguson, S. A., & Draisin, N. A. (2021). Strategies for accelerating the implementation of non-intrusive alcohol detection systems in the vehicle fleet. Traffic Injury Prevention, 22(1), 13–19. doi:10.1080/15389588.2020.1836367.

[22] Uzairue, S., Ighalo, J., Matthews, V. O., Nwukor, F., & Popoola, S. I. (2018). IoT-enabled alcohol detection system for road transportation safety in smart city. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Springer Verlag, Vol. 10963 LNCS. doi:10.1007/978-3-319-95171-3_55.

[23] Wang, F., Bai, D., Liu, Z., Yao, Z., Weng, X., Xu, C., Fan, K., Zhao, Z., & Chang, Z. (2023). A Two-Step E-Nose System for Vehicle Drunk Driving Rapid Detection. Applied Sciences (Switzerland), 13(6), 3478. doi:10.3390/app13063478.

[24] Sanguansri, P., Apiwong-Ngam, N., Ngamjarurojana, A., & Choopun, S. (2022). Development of non-invasive alcohol analyzer using Photoplethysmographytle. Journal of Physics: Conference Series, 2145, 12059. doi:10.1088/1742-6596/2145/1/012059.

[25] European Society of Cardiology. (2018). Drinking alcohol makes your heart race. ScienceDaily, Maryland, United States. Available online: www.sciencedaily.com/releases/2018/03/180319124246.htm (accessed on March 2023).

[26] Ye, Y., Ma, L., Liu, J., Zhang, Z., Gu, C., & Mao, J. F. (2022). A Novel Non-Contact Drunkenness Monitoring Technique Based on A 24-GHz Interferometric Radar System. 2022 IEEE MTT-S International Microwave Biomedical Conference, IMBioC 2022, 296–298. doi:10.1109/IMBioC52515.2022.9790121.

[27] Kumar, A., Kumar, A., Singh, M., Kumar, P., & Bijalwan, A. (2022). An optimized approach using transfer learning to detect drunk driving. Scientific Programming, 2022(1), 8775607. doi:10.1155/2022/8775607.

[28] Farooq, H., Altaf, A., Iqbal, F., Galán, J. C., Aray, D. G., & Ashraf, I. (2023). DrunkChain: Blockchain-Based IoT System for Preventing Drunk Driving-Related Traffic Accidents. Sensors, 23(12), 5388. doi:10.3390/s23125388.

[29] Soner, S., Litoriya, R., & Pandey, P. (2022). Integrating Blockchain Technology with IoT and ML to Avoid Road Accidents Caused by Drunk Driving. Wireless Personal Communications, 125(4), 3001–3018. doi:10.1007/s11277-022-09695-x.

[30] Chen, H., Yuan, X., Ye, H., Chen, L., & Zhang, G. (2019). The effect of alcohol on the physiological performance of the driver. International Journal of Crashworthiness, 24(6), 656–663. doi:10.1080/13588265.2018.1511226.

[31] Tasnim, S., Tang, C., Musini, V. M., & Wright, J. M. (2020). Effect of alcohol on blood pressure. The Cochrane database of systematic reviews, 7(7), CD012787. doi:10.1002/14651858.CD012787.

[32] Christoforou, Z., Karlaftis, M. G., & Yannis, G. (2013). Reaction times of young alcohol-impaired drivers. Accident Analysis and Prevention, 61, 54–62. doi:10.1016/j.aap.2012.12.030.

[33] Li, Y. C., Sze, N. N., Wong, S. C., Yan, W., Tsui, K. L., & So, F. L. (2016). A simulation study of the effects of alcohol on driving performance in a Chinese population. Accident Analysis and Prevention, 95, 334–342. doi:10.1016/j.aap.2016.01.010.

[34] Carranza, H., Carranza, A., & Tito, E. (2023). IoT and Cloud Computing Integration to Minimze Drunk Driving Accidents. International Conference of Control, Dynamic Systems, and Robotics. doi:10.11159/cdsr23.213.

[35] Vignesh, R. S., Sankar, R., Balaji, A., Kumar, K. S., Sharmila Bhargavi, V., & Anusuya, R. (2023). IoT Assisted Drunk and Drive People Identification to Avoid Accidents and Ensure Road Safety Measures. Proceedings of the 2nd IEEE International Conference on Advances in Computing, Communication and Applied Informatics, ACCAI 2023, Chennai, India. doi:10.1109/ACCAI58221.2023.10200809.

[36] Razak, S. F. A., Tong, Y. J., Yogarayan, S., Ismail, S. N. M. S., & Sui, O. C. (2024). Driver-centered pervasive application for heart rate measurement. International Journal of Electrical and Computer Engineering, 14(1), 1176–1184. doi:10.11591/ijece.v14i1.pp1176-1184.