Driving Physiological State Monitoring Based on IoT Sensing Architecture

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Abstract: In clinical practice, alcoholic beverages will have imaging effects on the autonomic nervous system. Common reactions of the human body after absorbing alcohol include unsteady walking, rapid heartbeat, and reddening of the face. In this case, humans are usually unable to fully rely on self-consciousness to manipulate the body, and consciousness tends to become blurred. In recent years, the incidents of drinking and driving have emerged in an endless stream. Although there are laws and regulations, they cannot effectively prevent and control drunk driving. Therefore, this study intends to develop an alcohol lock that can monitor the physiological state of driving.
The architecture proposed in this study uses the pulse oximeter to obtain the PPG signal and then analyzes the autonomic nervous system and uses the MQ-3 alcohol sensor to detect the air alcohol content in the cockpit. The two signals are sensed by ESP32 and sent to the base station outside the car by LoRa through the IoT architecture. Finally, the driving physiological information will be sent to the server for centralized display.

Keywords: ANS, PPG, Alcohol lock, LoRa

1. Introduction

In Taiwan, drinking is a common thing, whether it is a dinner, wedding banquet or entertainment, alcohol is a source of stress or happiness for adults, but alcohol will have an effect on the central nervous system, resulting in unstable gait, loss of self-restraint ability of drinkers, as the concentration in the blood increases, and even there will be a decrease in nerve reflexes or a decrease in blood pressure leading to coma. In this case, there are many people who insist on driving home after drinking, when driving alcohol concentration of 0.25 milligrams per liter, or blood alcohol concentration of more than 0.05%, even if it violates the law, even if there are often signs on the road "drive without drinking, drink without driving", but the number of people drinking on the road has not seen a significant decrease.

According to Taiwan's Ministry of Communications, the total number of traffic accidents from last year to April this year was 481,056, of which 14,469 were killed or injured by drunk driving. According to Figure 1, the peak at the end of 110 resulted in 1,178 deaths and injuries, and the number of deaths and injuries caused by drunk driv-ing fluctuated without any decrease. Drunk driving has seriously endangered other passers-by, causing not only casualties but also property damage, and people also believe that drunk driving is an unforgivable act. According to the regulations, first-time offenders riding motorcycles are fined 15,000 TWD ~ 90,000 TWD, drivers of cars are fined 30,000 TWD ~ 120,000 TWD, if it causes serious injury or death, they will not enter the vehicle, and their driver's license will be revoked and they will not be allowed to obtain it, and repeat offenders will be fined more than once, with no upper limit. However, regulations alone cannot effectively prevent drunk driving, and drunken car accidents are still endless, so this study hopes that through the alcohol locks promoted by the government, it is expected to be effectively used in various situations, such as driving cars or operating large machinery on factory sites (forklifts, excavators, etc.), and preventing more accidents or occupational safety accidents through alcohol locks.

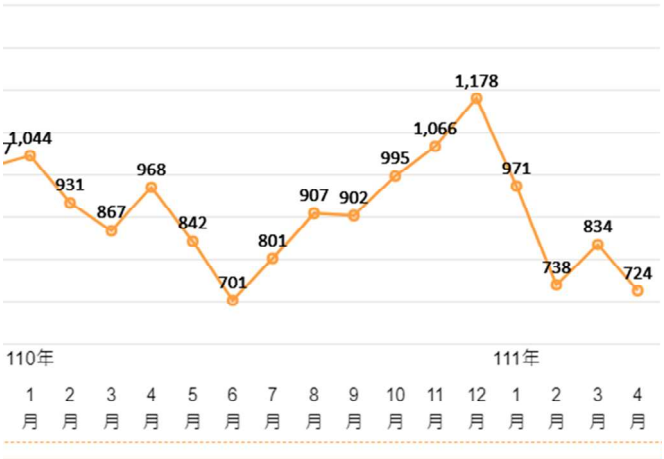

Fig. 1. Statistics on the number of deaths and injuries caused by drunk driving from last year to April this year

1.1 Research Questions

According to the Taiwan government, if drunk driving repeat offenders want to drive on the road, they must install alcohol locks on the vehicle, but the alcohol lock products on the market are expensive, ranging from thousand to 200,000. The traditional alcohol lock only has the function of a wine detector, the main process is: blowing - if it exceeds the standard - it cannot automatically open the vehicle, and there is no automatic upload or recording function to the cloud, but the data is stored in the control box, and the data needs to be returned to the factory for maintenance to download the data, but this will cause trouble for users, if the user still forcibly starts after drinking, the police cannot immediately prevent the regret from happening. The existing alcohol lock combines the cloud or Bluetooth function, as long as the user blows, the wine tester information will be uploaded to the cloud, so that the industry can instantly view the location of the car owner through the APP or web page, and whether there is a alcohol test. However, there are many old cars that cannot be installed with alcohol locks, and the price of alcohol locks is high, which makes the installation effect poor.

TABLEIWine Tester Comparison

	Police alcohol detectors	Simple alcohol detectors
Accuracy	High	Low
Price	Expensive	Cheap
Installation cost	Expensive	Cheap

Generally, the police use the best alcohol detectors, comparing simple alcohol detectors with police alcohol detectors, simple types are cheaper, affordable to the public, but the accuracy rate is lower, on the contrary, it is higher. The police alcohol detector will only measure the alcohol content in the body, if there is residual alcohol in the mouth, the instrument can quickly distinguish it, while the simple alcohol detector is simply to analyze the gas spit out of the mouth, there is still a difference between the two. Although the accuracy of the police device is relatively high, if it is to be installed on vehicle or large machine, the cost will be too high. Therefore, this study replaced alcohol testers with PPG and MQ-3 to measure drinkers.

2. Methods

Figure 2 is the system flow chart of this study, PPG will first be used to test the user's wine, and determine whether the user's alcohol measurement value exceeds the standard, if it does not exceed the standard, it can be unlocked and started; If it exceeds the standard, the unlocking action cannot be carried out, then determine whether the user forcibly unlocks, if not, end the action, if yes, immediately use GPS positioning, and notify the police in the jurisdiction for control to avoid serious damage or casualties.

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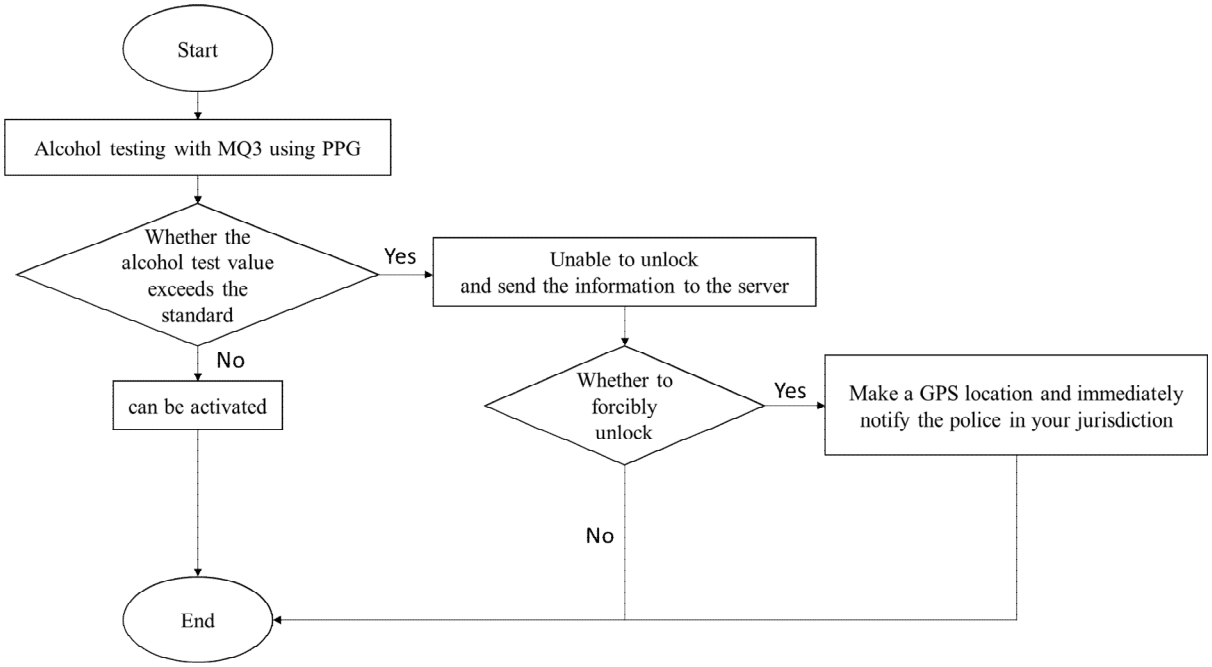

Fig. 2. Flow Chart

The system architecture diagram of this study is shown in Figure 3, which mainly includes PPG monitoring, ESP32 control board, and wireless devices. Through ESP32 plus wireless equipment to control the vehicle, and at the same time use PPG and nozzle MQ-3 alcohol sensor for detection and monitoring, and then the sensed data is sent to the base station through LoRa, and finally the driving information is sent to the service desk and displayed through the Internet service.

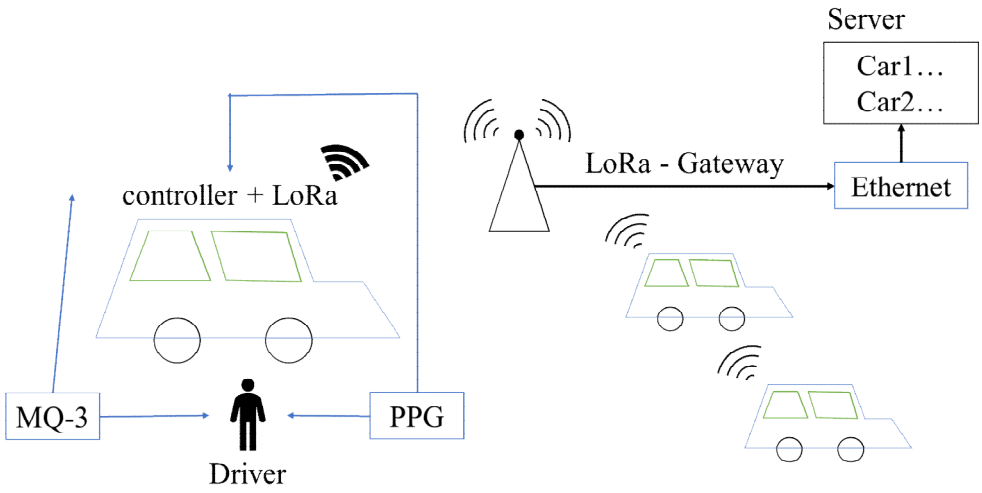

Fig. 3. Architecture Diagram

2.1 ESP32

ESP32 can be called a microcontroller or MCU for short, MCU integrates ROM, RAM, CPU and I/O in the same chip, is a very low cost and Wi-Fi IOT control chip with a complete TCP/IP protocol, and combined with du-al-mode Bluetooth, it can support a variety of compatible development environments, greatly reducing the entry threshold for its programming development. ESP32 has rich hardware interfaces, can support GPIO and infrared transmission, etc., suitable for various IoT applications. The main functions of this study include serial oral trans-mission, GPIO.

Serial oral transparent transmission: transparent transmission of the intention of transparent transmission, in the process of data transmission, through wireless transmission, the process of data will not change in any form, while ensuring the quality of transmission, transmission reliability is good.

GPIO: This pin was used to control the PPG sensor as well as the MQ-3 alcohol sensor.

2.2 MQ-3

The gas-sensing material used in the MQ-3 sensor is a low conductivity SnO2, and when alcohol vapor is present in the environment, the conductivity of the sensor increases with the increase of alcohol concentration in the air. MQ-3 only needs to use a simple circuit to convert the change of conductivity into an output signal corre-sponding to the gas concentration, and MQ-3 is very sensitive to alcohol, will not be interfered by gasoline, smoke or water vapor, and the market price does not exceed 100 TWD, is a low-cost sensor [1].

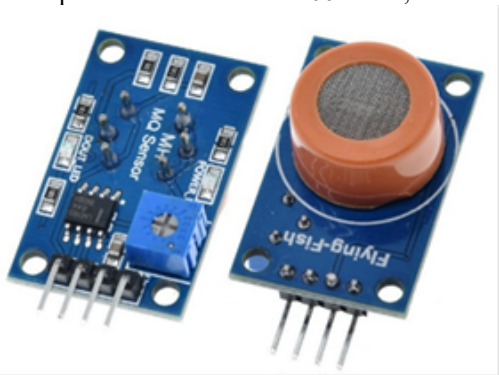

Fig. 4. MQ-3

2.3 Arduino IDE

An open source embedded hardware platform for users to create interactive embedded projects. Software programming usually uses C/C++ programming language. The Arduino Software IDE is a programming language and integrated development environment derived from the Wiring project. It is designed to introduce programming to artists and those unfamiliar with programming, featuring a text editing interface, graphical controls, common toolbars, automatic indentation, one-click compilation and burning executables to the Arduino hardware editor. A program written using the Arduino IDE is called Sketch. There are many functions in the Arduino IDE system menu, including many commonly used function libraries. Developers can use the functions provided by the function library as long as they are familiar with the parameter settings in the function library. There are hardware development board and serial port settings under the toolbar. This function is convenient for beginners to understand the relationship between Arduino IDE and hardware, and get started quickly [2].

2.4 PPG

Photoplethysmography, also known as PPG, is an optically obtained organ plethysmogram that can be used to detect changes in blood volume in the micro vessels of human tissue. During each heartbeat cycle, the heart pumps blood throughout the body. Because blood flow to the skin is susceptible to various physiological systems, PPG can also be used to monitor respiration, hypovolemia, and other circulatory conditions. Based on the study [3], the researchers classified the general population and those with alcohol dependence and recorded differences in heart rate (HR) and heart rate variability (HRV) between the two groups. Alcohol-dependent individuals were found to have greater variability in heart rate (HR) and heart rate variability (HRV) and were more likely to have cardio-vascular disease. The main characteristic parameters of PPG are shown in TABLE II:

TABLEII PPG Characteristic Parameters

Characteristic Parameters	Definition
Heart Rate (HR)	Heartbeats per minute (Heart Rate)
Heart Rate Variability (HRV)	Heart Rate Variability

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Heart rate (HR) refers to the rate at which the heart contracts and beats and the number of beats per minute. A normal heart rate at rest is 60-100 beats per minute. Heart rate is controlled by the autonomic nervous system. When the sympathetic nerves are strengthened, the heart rate increases. In addition, the heart rate is also affected by body temperature. For every 1 degree Celsius increase in body temperature, the heart rate will increase by 12 to 18 beats.

Heart rate variability (HRV) is a measure of the degree of continuous heart rate variability. The calculation method is mainly to analyze the heartbeat time series and heartbeat interval obtained by pulse measurement. Heart rate variability analysis is most used to calculate R waves in an electrocardiogram. By measuring the time interval between RRs, it becomes a series of numbers for further calculation and analysis. Its modes can be analyzed in the time domain and frequency domain [4].

The PPG signal may be disturbed by external noise during acquisition. Interference sources include external ambient light sources or motion artifacts [5]. Therefore, the noise can be filtered out by means of filters, etc., and the PPG signal can be kept clean and intact. The PPG signal consists of two parts. Normally, when the heart contracts, there are continuous cyclical changes in pressure and blood flow in the blood vessels in the body. When the heart relaxes, the pressure in the blood vessels decreases relatively. Therefore, a complete PPG signal including systolic and diastolic phases is also affected by the autonomic nerve and vascular flow state. The complete PPG signal is shown in Figure 5:

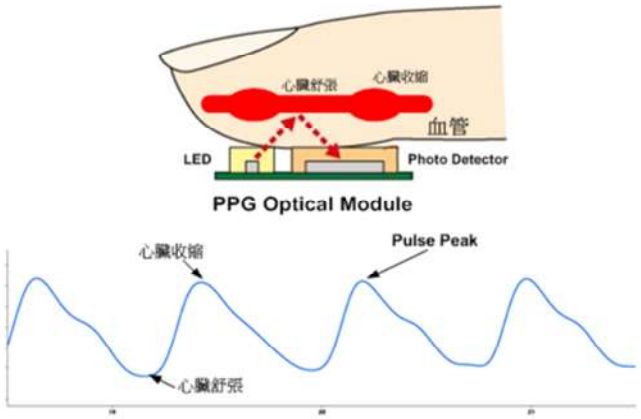

Fig. 5. PPG Complete Signal

The autonomic nervous system can be divided into the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system almost covers the heart and controls the conduction and con-traction systems of the heart. The parasympathetic nervous system mainly innervates the conduction system of the atrioventricular node (AVN) and sinoatrial node (SAN). When the sympathetic nerves are excited, it causes the heart rate to increase, blood vessels to constrict, and blood pressure to rise. Sympathetic and parasympathetic nerves form a symmetrical and balanced relationship, controlling and regulating physiological functions such as breathing, heartbeat, and gastrointestinal motility. After drinking alcohol, the heartbeat will speed up to a certain extent, mainly because the brain will be excited after the alcohol enters the human body, the sympathetic nerve will be tense when excited, and the heartbeat will become faster. Drinking alcohol can cause a rapid heartbeat, be-cause alcohol contains ethanol, which is converted into acetaldehyde during metabolism, and acetaldehyde has the effect of dilating capillaries, so extensive capillary dilation occurs after drinking alcohol, which leads to lower blood pressure. Because telangiectasia is equivalent to increasing the volume of blood vessels without changing the total amount of blood, this results in a state of hypotension and hypoperfusion. To improve this state of hypo-tension and hypoperfusion, the heart must make up for the relative lack of volume by beating faster.

Through the above, it can be observed that the diastole and contraction of the heart are related to drinking. Therefore, PPG can be used to measure whether the alcohol concentration exceeds the standard.

3. Result and Discussion

In this study, 20-year-old adult females were used as experimental subjects to measure the changes in

physiological status before and after drinking alcoholic beverages.

3.1 Before drinking alcoholic beverages

Figure 6 focuses primarily on LF/HF values. LF/HF refers to the ratio of high and low spectral power and is a valid measure of sympathetic and parasympathetic interactions for processing time series.

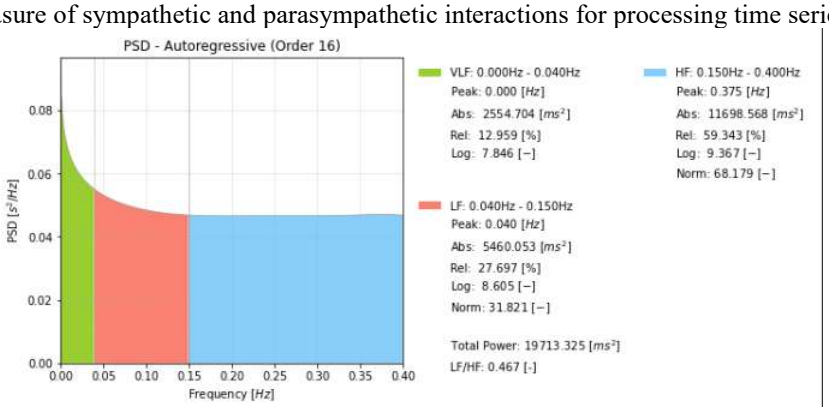

Fig. 6. Frequency Domain PSD Analysis Results

Figure 7 is a Poincare plot, the dots are scattered and not concentrated, and are presented in the upper right corner, indicating a slow heartbeat.

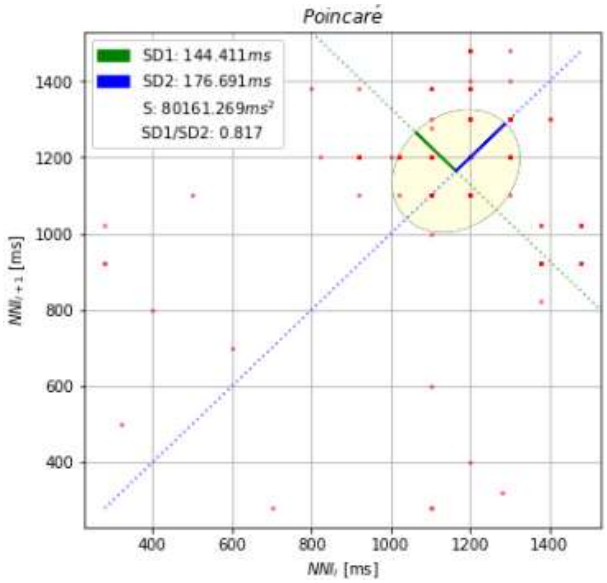

Fig. 7. Poincare Plot

3.2 After drinking alcoholic beverages

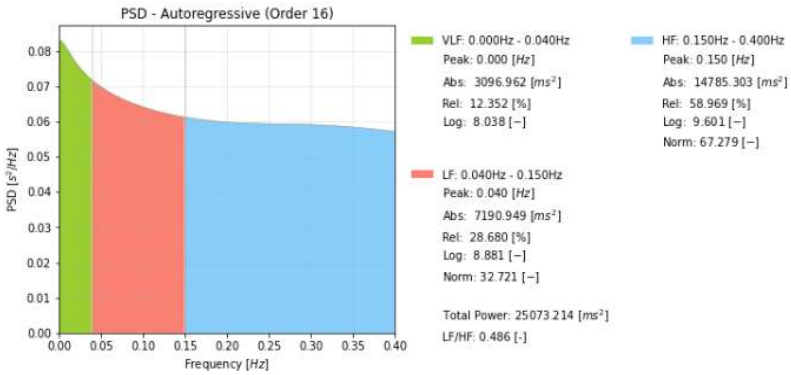

Fig. 8. Frequency Domain PSD Analysis Results

In Figure 9, it can be observed that the points are concentrated in the lower left corner, and the closer to

the lower left corner, the faster the heartbeat.

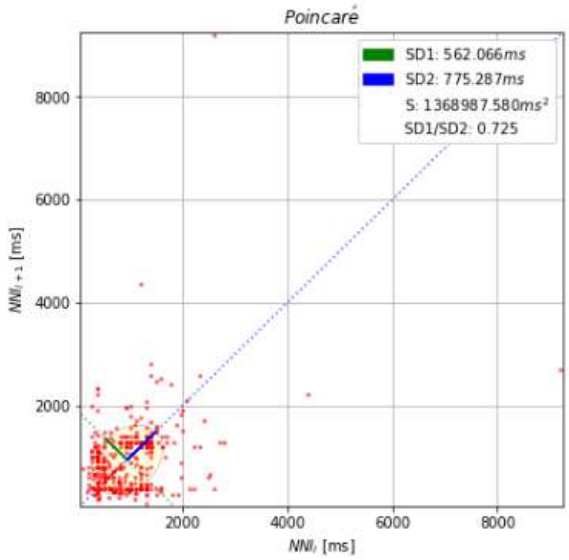

Fig. 9. Poincare Plot

4. Conclusions

According to the experimental results, before drinking alcoholic beverages, Fig. 6 mainly focuses on the LF/HF values. LF/HF refers to the ratio of high and low spectral power, which is an effective indicator to measure the interaction of sympathetic and parasympathetic nerves. Figure 7 clearly shows that the dots are scattered everywhere and in the middle, tending to the middle means that the heartbeat is stable, after drinking alcoholic beverages, it can be clearly observed in Figure 9 that the dots are concentrated to the lower left corner, and the difference before and after drinking can be seen. Therefore, this study will use PPG for the application of alcohol lock device.

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