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Development of smart IoT based biomedical heart rate oximeter for driving safety

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Abstract: *This paper presents a novel approach for predicting a driver's risk of developing smart IoT based biomedical heart rate oximeter using artificial intelligence and deep learning techniques. The use of wearable medical devices has increased significantly in recent years, with a focus on monitoring vital signs such as heart rate and oxygen saturation levels. In the automotive industry, car-driving safety has become a major concern, and integrating these medical devices with the Internet of Things (IoT) technology can provide real-time monitoring of drivers' vital signs for safer driving. In this study, we present a guideline for the development of a smart IoT-based biomedical heart rate oximeter for car-driving safety. The device is designed to monitor the heart rate and oxygen saturation levels of drivers in real-time and transmit the data wirelessly to the cloud for analysis. The device is also designed to integrate with the IoT technology to provide real-time alerts to drivers, passengers, and emergency services in case of any abnormalities in vital signs. The device is developed with a focus on accuracy, reliability, durability, ease of use, and regulatory compliance. The guideline outlines the research, design, prototyping, testing, and refining process for the device, with emphasis on IoT integration for car-driving safety. The development of this device has significant implications for improving car-driving safety, reducing accidents, and improving overall health outcomes for drivers.*

Keywords: *IoT, MAX30102, smart sensor, car-driving-safety*

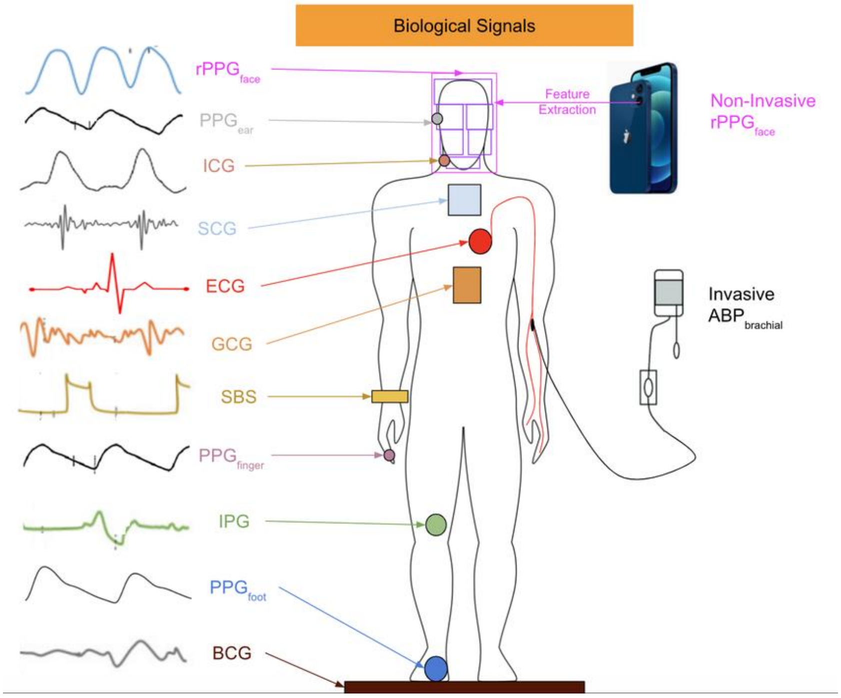
1. Introduction

The integration of wearable medical devices with IoT technology has opened new avenues for healthcare and safety in a variety of settings as shown in Figure 1. In the automotive industry, car-driving safety has become a major concern, with accidents caused by driver fatigue, heart attacks, and other health-related issues on the rise. The development of a smart IoT-based biomedical heart rate oximeter for car-driving safety has the potential to provide real-time monitoring of drivers' vital signs and improve car-driving safety.

Wearable medical devices have gained popularity in recent years, with a focus on monitoring vital signs such as heart rate and oxygen saturation levels. These devices have been shown to have positive impacts on health outcomes, and their integration with IoT technology provides new opportunities for real-time monitoring and analysis of vital signs [1]. In the automotive industry, the integration of these devices with IoT technology can provide real-time monitoring of drivers' vital signs, alerting drivers, and emergency services in case of any abnormalities in vital signs.

The development of a smart IoT-based biomedical heart rate oximeter for car-driving safety requires careful planning, research, and testing. The device must be designed with a focus on accuracy, reliability, durability, ease of use, and regulatory compliance. It should be capable of real-time monitoring of the heart rate and oxygen saturation levels of drivers and transmitting the data wirelessly to the cloud for analysis. The device using steering wheel to monitor driver’s health condition should also integrate with the IoT technology to provide real-time alerts to drivers, passengers, and emergency services in case of any abnormalities in vital signs [2].

In this study, we present a guideline for the development of a smart IoT-based biomedical heart rate oximeter for car-driving safety [3]. The guideline outlines the research, design, prototyping, testing, and refining process for the device, with emphasis on IoT integration for car-driving safety. The development of this device has significant implications for improving car-driving safety, reducing accidents, and improving overall health outcomes for drivers.



https://www.researchgate.net/figure/Biological-signals-from-various-parts-of-the-body/

Figure 1: Biological signals from various parts of the body [1]

2. Analysis

Hypoxia refers to a condition in which the body's tissues are deprived of oxygen, leading to a lower-than-normal concentration of oxygen in the blood. To determine if blood oxygen concentration is lower than normal, a blood oxygen machine measures blood oxygen saturation (SpO2), which is the ratio of oxygenated hemoglobin to total hemoglobin in the blood. The typical blood oxygen concentration in human arteries ranges from 95% to 100%. If the value drops below 90%, it is considered hypoxemia, which can damage vital organs such as the brain and heart if it drops below 80%. Heart diseases such as myocardial infarction and new coronary pneumonia are particularly susceptible to invisible hypoxia. Since hypoxia does not cause discomfort or pain, it may go unnoticed, making it essential to continuously monitor blood oxygen concentration in the body in real-time using a blood oxygen machine. To this end, the aim is to develop a "smart, IoT heart rate blood oxygen machine" that automatically measures blood oxygen concentration in the car and even online for emergency automatic driving or long-term cloud statistics. Additionally, the system will link with Line, Email, and APP to immediately send emergency notifications when the value exceeds the standard, creating an exclusive real-time heart rate oximeter in the car.

Photoplethysmography (PPG) is a non-invasive detection method for detecting changes in blood volume in living tissue by photoelectric means. Due to the light intensity, it is necessary to measure at a thin test site with sufficient blood perfusion (such as a finger or an earlobe), so that the light energy can penetrate the tissue as smoothly as possible. As shown in Figure 2, when a light beam of a certain wavelength is irradiated on the skin surface of the fingertip, the contraction and expansion of the blood vessel will affect the transmission of light (such as in the transmission PPG, the light passing through the fingertip) or the reflection of light (such as in the reflection PPG, from light near the face of the watch). When the light passes through the skin tissue and then reflects to the photosensitive sensor, the light will be attenuated to a certain extent. The absorption of light by muscles, bones, veins, and other connecting tissues is basically unchanged (provided that the measurement site does not move significantly), but blood is different. Because there is blood flow in the arteries, the absorption of light is naturally changed.

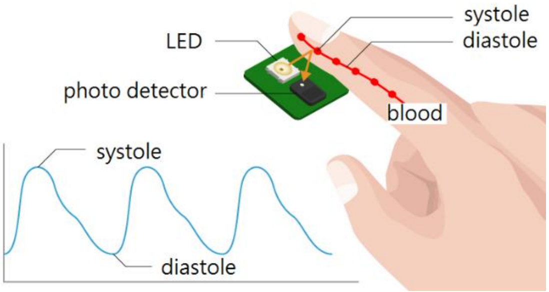


Figure 2: Photoplethysmography (PPG) sends specific wavelengths of light to tissue and uses the contraction and dilation of blood vessels with each heartbeat.

When we convert light into electrical signals, it is precisely because the absorption of light by arteries changes and the absorption of light by other tissues is basically unchanged, the obtained signals can be divided into direct current DC signals and alternating current AC signals. By extracting the AC signal, the characteristics of blood flow can be reflected as the contraction (systole) and dilation expansion (diastole) of the blood vessels during each heartbeat to determine the blood oxygen concentration by changing the absorbance (Figure 3).

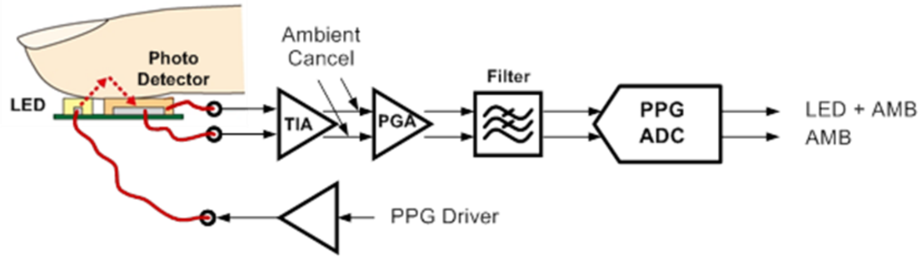


Figure 3: PPG measurement circuit.

The MAX30102 (Figure 4) is a sensor developed by Maxim Integrated to measure heart rate and blood oxygen with very low standby power consumption. This time, the ESP32 integrates the MAX30102 blood oxygen sensor module to provide a more complete appearance and structure, and the sensing circuit design considers avoiding interference from ambient light during the measurement. Using I2C communication, as long as two lines can be connected to multiple sensor devices and CAN bus on the car

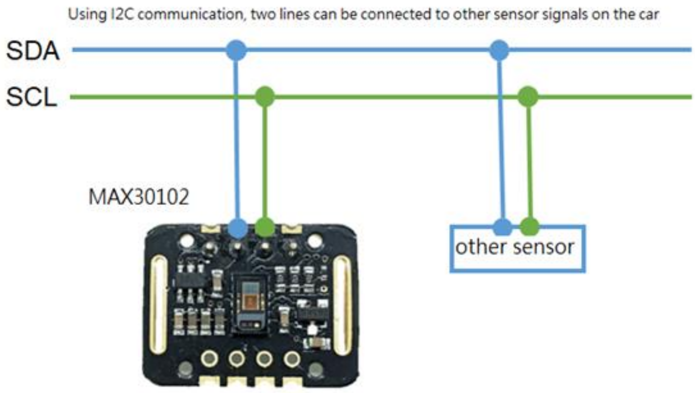


Figure 4: Train loss and validation loss.

RT1025 (Figure 5) is a highly integrated front-end circuit for measuring heart rhythm and ECG signals. RT1025 integrates low-noise voltage and current amplification circuits, so it can measure ECG and PPG signals at the same time. The RT1025 has a dynamic input range greater than 100dB when measuring ECG signals and provides high-precision acquisition rates from 64Hz to 4kHz. Through highly integrated circuit design, only a few external parts are needed, and it can be designed for low power consumption medical grade PPG, fitness, and wearable products. The RT1025 contains 4kB SRAM for data buffering. The reference clock is provided through an external crystal oscillator. It can use I_2C or SPI to communicate with the microprocessor to transmit information.

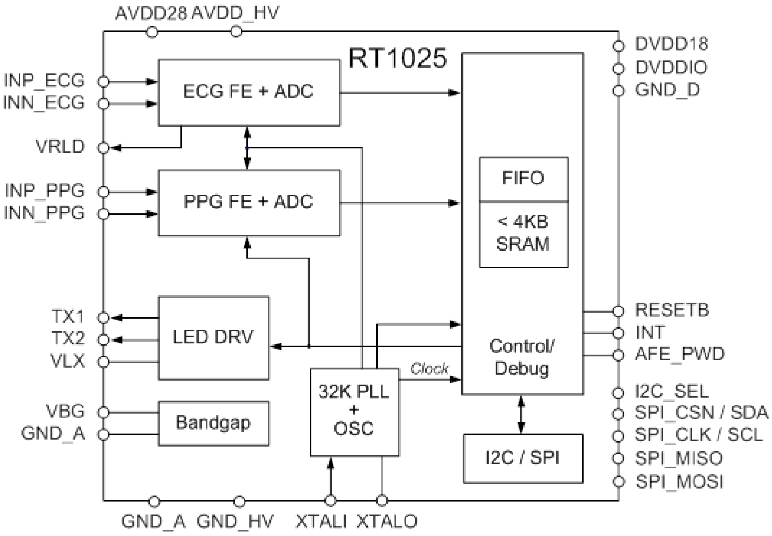


Figure 5: RT1025 Circuit.

Heart rate measurement-PPG signal AC component: Figure 6 shows the "DC" and "AC" components in the PPG signal. The DC component detects light signals reflected by tissues, bones and muscles, and the average blood volume of arterial and venous blood. The AC component represents the systolic and diastolic periods of the cardiac cycle. The blood volume changes between periods can be obtained by continuously measuring the peak systolic time of the AC component.

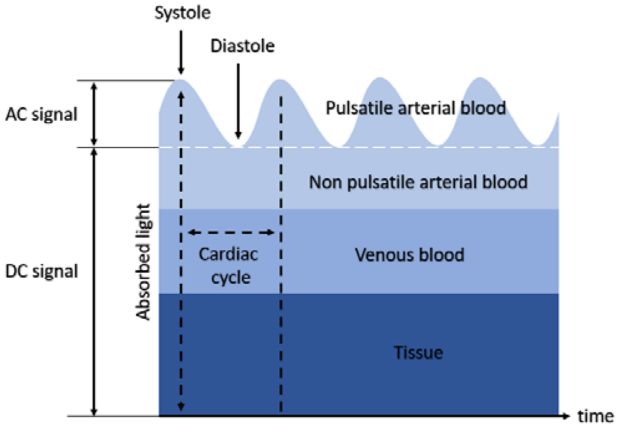


Figure 6: PPG AC, DC component.

Blood oxygen (SpO2) measurement: The hemoglobin without oxygen is called deoxy hemoglobin (deoxy Hb), and hemoglobin containing oxygen is called oxyhemoglobin (oxy Hb). Oxygen saturation refers to the available hemoglobin carrying oxygen Percentage (generally, the blood oxygen saturation of normal people should be 95~100%). Only one of the LEDs is needed to measure the heart rate, but two LEDs with different wavelengths are needed to measure the blood oxygen. The red light is 660nm, and the infrared light is 940nm. "Oxygenated hemoglobin absorbs more infrared light than red light, and deoxygenated hemoglobin absorbs more red light than infrared light", that is, oxyhemoglobin and deoxygenated hemoglobin absorb light of different wavelengths in a specific way. By comparing blood absorption. How much red and infrared light is used to calculate oxygen saturation as follows:

$$SpO_2 = \frac{HbO_2}{Total\ Hb} \tag{1}$$

The ratio between the two wavelengths is called "R", and R is proportional to SpO2, R is defined by the following equation, I_{AC} is the AC component in the PPG signal, λ_1 is the 650nm wavelength, and λ_2 is the 950nm wavelength light.

$$R = \frac{\log(I_{AC})*\lambda_1}{\log(I_{AC})*\lambda_2} \tag{2}$$

With the R value, we can estimate the SpO_2 value by curve approximation or table look-up and get a linear approximation formula based on the experience of many subjects collected from big data, age, skin color, and overall health.

$$SpO_2 = 110 - 25 * R \tag{3}$$

Figure 7 shows the relationship between SpO_2 and R value after many tests. It can be found that the present measured blood oxygen concentration is as low as 70% and then it is linear.

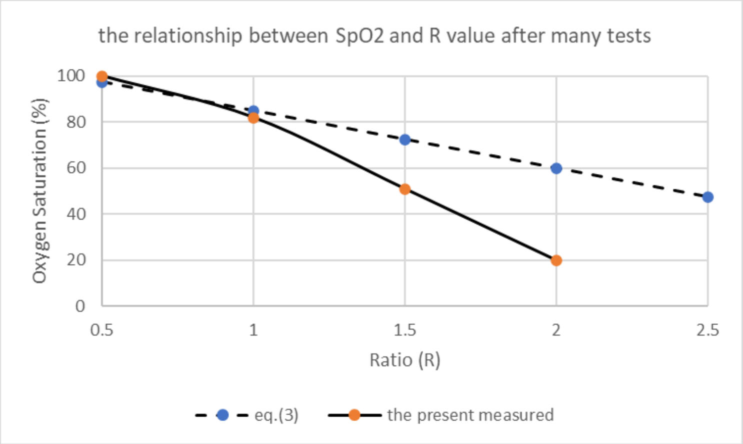
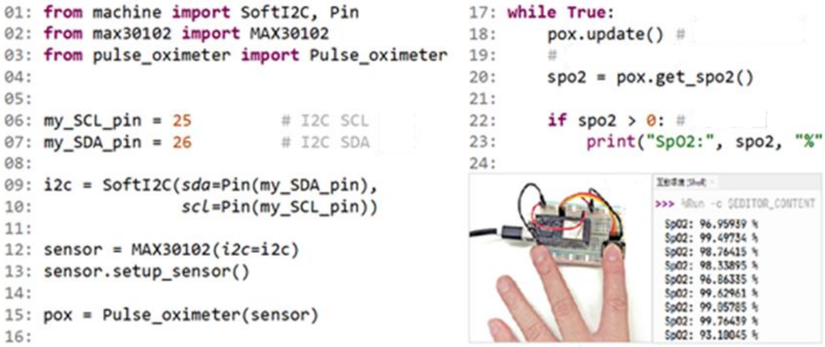


Figure 7: Relationship between SpO2 and R value after many tested.

The image depicted in Figure 8 indicates that the bottom section of the fingernail is positioned over the red LED, and the execution of the "pox=Pulse oximeter (sensor)" code yields the blood oxygen concentration value in percentage.



```python
from machine import SoftI2C, Pin
from max30102 import MAX30102
from pulse_oximeter import Pulse_oximeter


my_SCL_pin = 25          # I2C SCL
my_SDA_pin = 26          # I2C SDA

i2c = SoftI2C(sda=Pin(my_SDA_pin),
              scl=Pin(my_SCL_pin))

sensor = MAX30102(i2c=i2c)
sensor.setup_sensor()

pox = Pulse_oximeter(sensor)

while True:
    pox.update() #
    #
    spo2 = pox.get_spo2()

    if spo2 > 0: #
        print("SpO2:", spo2, "%")

```

```
>>> %Run -c $EDITOR_CONTENT
 SpO2: 96.95939 %
 SpO2: 99.49734 %
 SpO2: 98.76415 %
 SpO2: 98.33895 %
 SpO2: 96.86335 %
 SpO2: 99.62961 %
 SpO2: 99.05785 %
 SpO2: 99.76439 %
 SpO2: 93.10045 %
```

Figure 8: Python program to get the blood oxygen concentration value.

3. Result

The results of the development of the smart IoT biomedical heart rate oximeter for car-driving safety should include a working prototype of the device that accurately monitors vital signs and provides real-time alerts in case of any abnormalities. The device should be designed with a focus on accuracy, reliability, durability, ease of use, and regulatory compliance. The integration of the device with IoT technology should ensure seamless communication between the device and other systems, providing an added layer of safety for drivers and passengers. Future development of the device can include enhancements to the accuracy and reliability of vital sign monitoring, the integration of additional sensors, and the development of algorithms for predictive analysis of vital signs.

4. Conclusions

In conclusion, the development of a smart IoT-based biomedical heart rate oximeter for car-driving safety has significant implications for improving car-driving safety and reducing accidents caused by driver fatigue and other health-related issues. The guideline presented in this study provides a comprehensive framework for the research, design, prototyping, testing, and refining of the device, with emphasis on IoT integration for real-time monitoring of drivers' vital signs. The contribution of this study lies in the development of a device that can accurately monitor vital signs and provide real-time alerts in case of any abnormalities. The device's integration with IoT technology also ensures seamless communication between the device and other systems, providing an added layer of safety for drivers and passengers. Future development of the device can include enhancements to the accuracy and reliability of vital sign monitoring, the integration of additional sensors, and the development of algorithms for predictive analysis of vital signs. Overall, the development of a smart IoT-based biomedical heart rate oximeter for car-driving safety has the potential to revolutionize the automotive industry, making car-driving safer and improving overall health outcomes for drivers.

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