2023 Synopsys ARC AIoT Design Contest

Project Proposal

Project Topic-心動安全方向盤

Presenter- Shih-Hung Huang、BO-HAO CHEN

2023/07/08

Agenda

- Abstracts
- Challenge and Innovation
- Design and Implementation
- Project Progress
- Test Result
- Overall Summary

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- **Abstracts**
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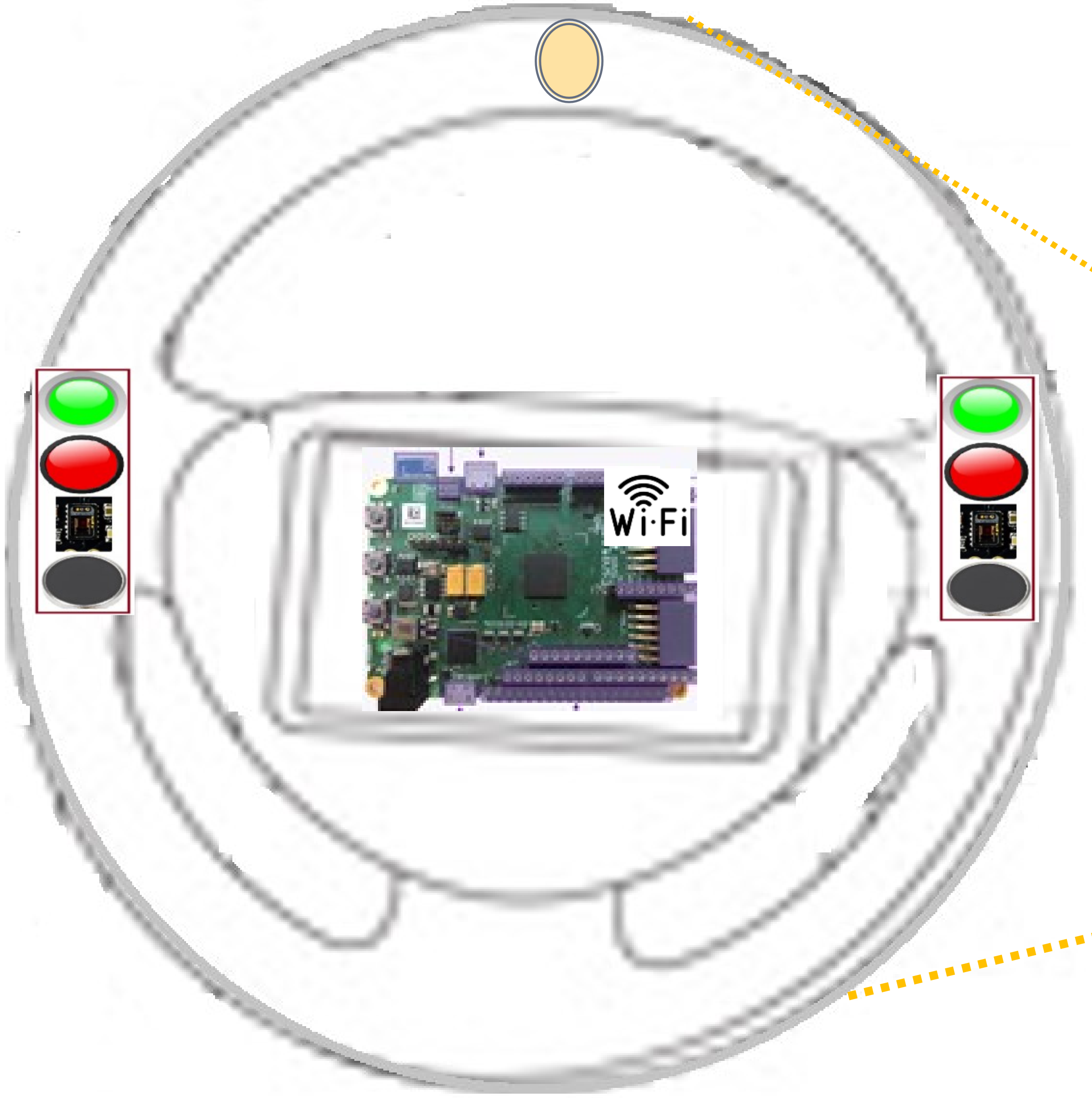
Abstracts ：心動安全方向盤作品概述



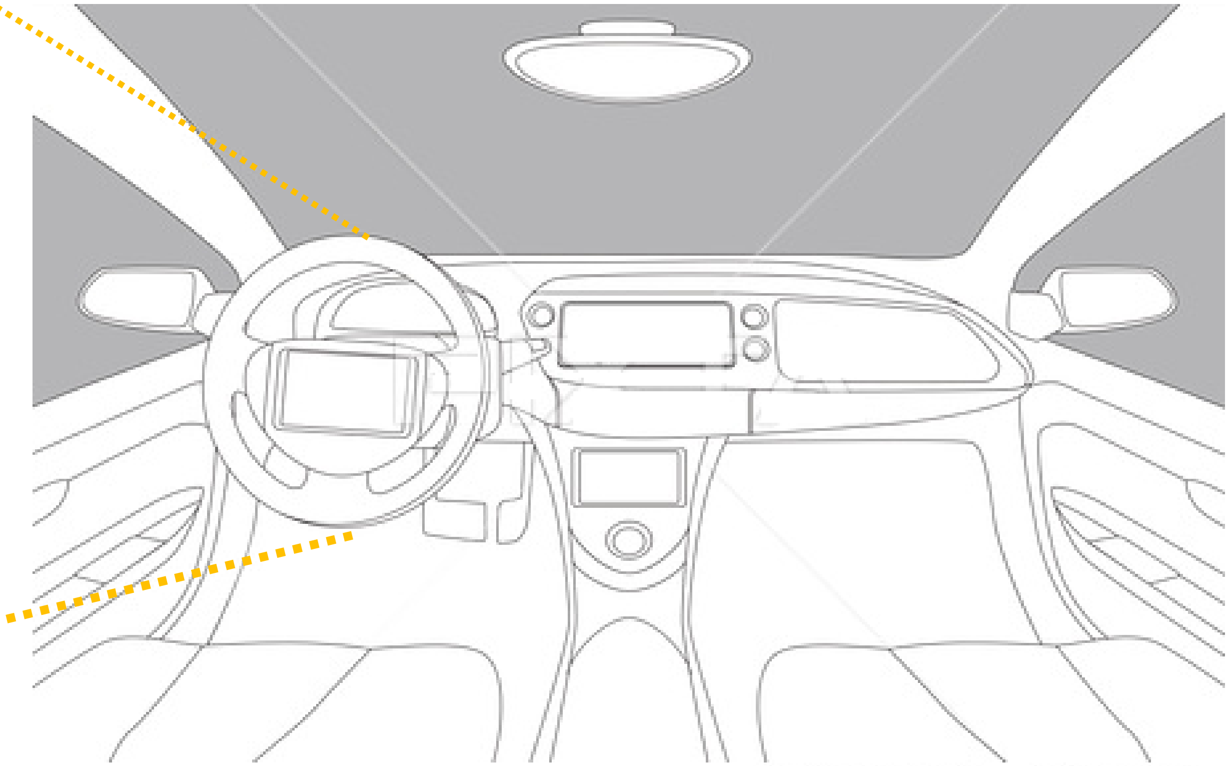
作者：經濟部 / 駐比利時台北代表處經濟組　　歐盟實施車輛通用安全法規　　2022/07/07

一、歐盟執委會成長總署(DG GROW)發布新聞資料表示，新的歐盟「車輛通用安全法規」(Vehicle General Safety Regulation)於2022年7月6日開始實施，導入一系列強制性先進駕駛輔助系統，以改善道路安全，並建立歐盟批准自動化及完全無人駕駛車輛之法律框架。相關重點如次：

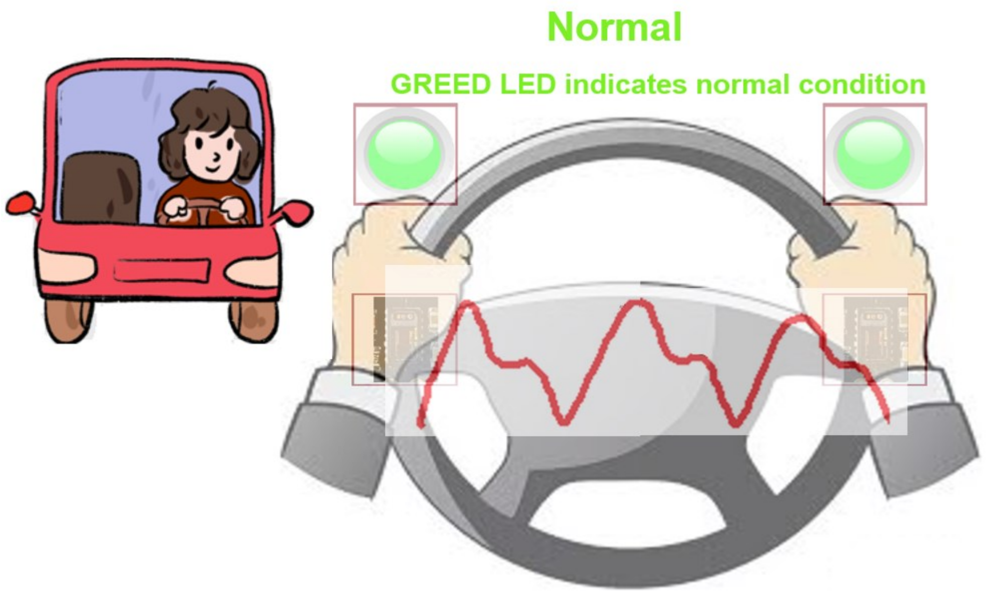
(一)歐盟新的車輛安全措施將有助保護乘客、行人及騎乘自行車人士，預計至2038年將挽救25,000多人生命，並使14萬人免受重傷。目前所導入新指施包括：

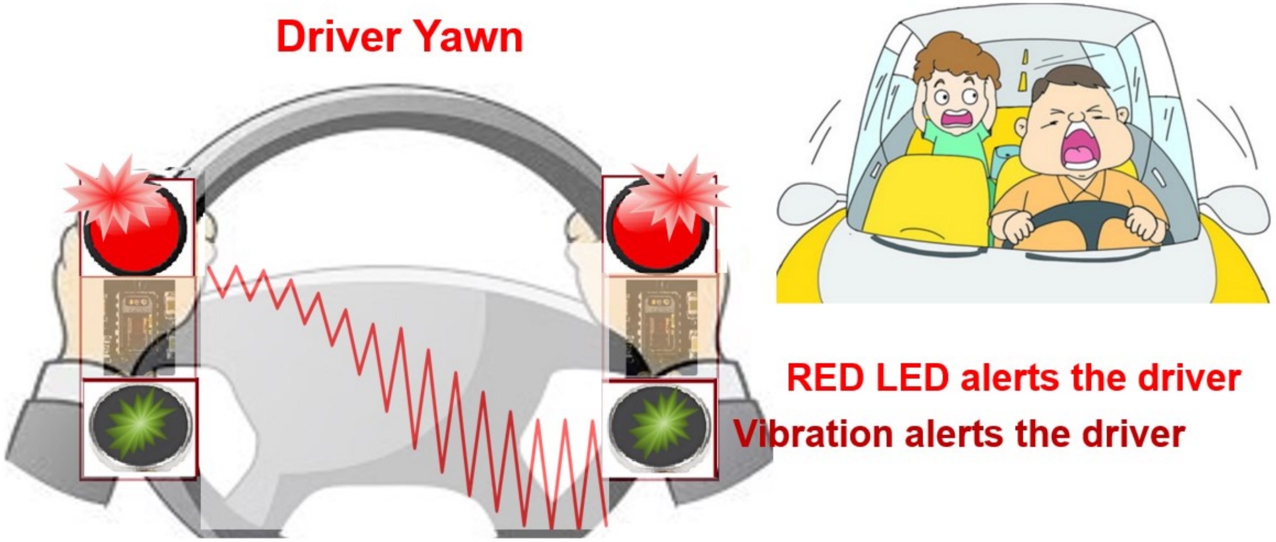
1、所有車輛(即轎車、貨車、卡車及公共汽車)：智慧速度輔助、倒車影像或感測器、駕駛困倦或分心警示、事件數據記錄器及緊急停止訊號；

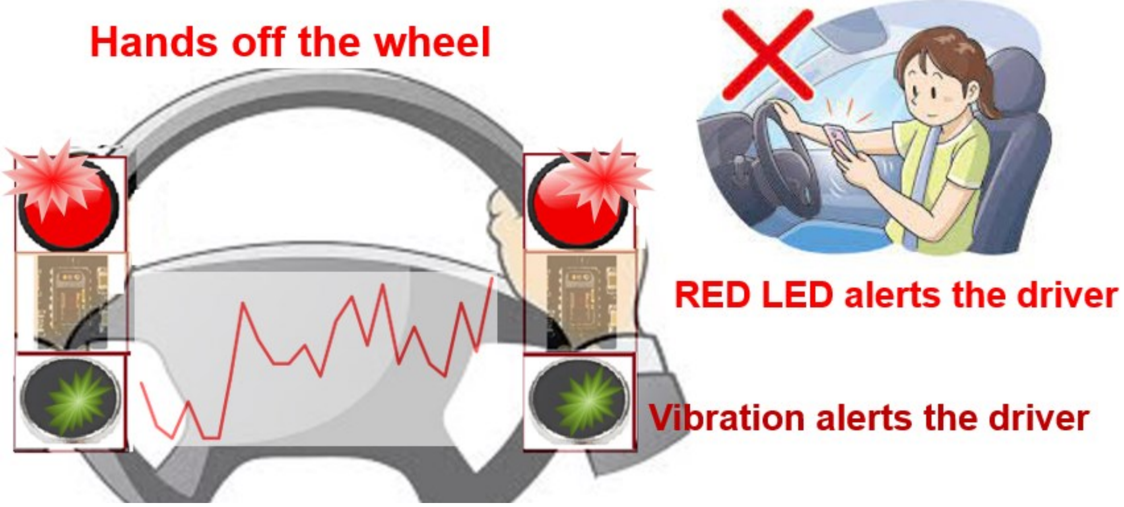
Driver Monitoring System (DMS)

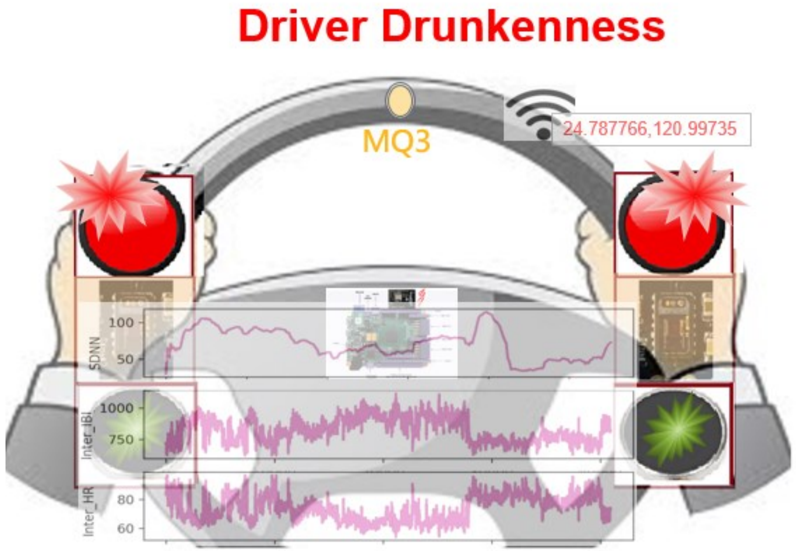


Abstracts ：心動安全方向盤作品概述









- RED LED alerts the driver
- Vibration alerts the driver
- Send out Car Location

XX.XXX,XX.XXX

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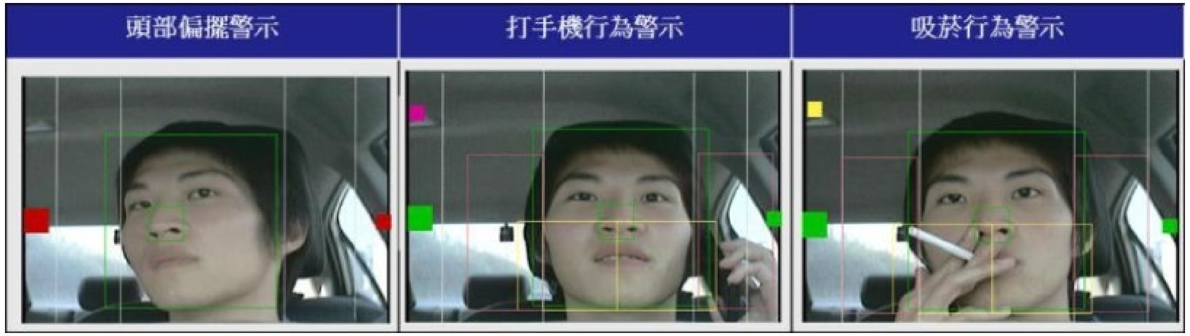
Challenge and Innovation: Driver Monitoring System(DMS)

- 駕駛者監控系統最早是於2006年由 Toyota所提出，並導入其Lexus 車款，用以監控駕駛者的狀態，並且可以與碰撞預防系統共同運作。
- 被動DMS根據方向盤的轉向和行駛軌跡來判斷駕駛員的狀態。
- 主動DMS通常由攝像機和近紅外技術啟用，可通過眼瞼閉合，眨眼，注視方向，打哈欠和頭部運動來檢測駕駛員的狀態。



駕駛異常行為作動警示。圖／ARTC 提供

基於視覺的DMS面臨哪些挑戰!!

- 系統穩健性較差，容易被遮擋或光照變化干擾
- 基於圖像運算較複雜，平台計算能力上的挑戰

- 如何量化界定疲勞狀態、瞌睡狀態是個難題，真值的確定也是個難題。最有效的方法是脈搏和心跳變異 HRV（Heart rate variability），但目前大多數視覺型DMS 系統缺乏測量脈搏和心率變異HRV，技術仍不足夠成熟與穩健。

Challenge and Innovation: Camera-DMS vs 心動安全方向盤

Innovation (Camera-DMS vs 心動安全方向盤)

功能	Camera-DMS	心動安全方向盤
打哈欠	O	O
手未正確握持方向盤	O	O
喝酒偵測	X	O
心率偵測	X	O
心率變異偵測	X	O

O: 功能正常 X:無此功能

Challenge and Innovation -心動安全方向盤技術困難度

Challenge (心動安全方向盤)

功能	技術困難度	說明
手未正確握持方向盤	☆☆	於動態環境中獲得高品質的PPG信號
打哈欠	☆☆☆	採集足夠多的使用者數據以維持高正確性
喝酒偵測	☆☆☆☆☆/☆☆☆	1.單純PPG信號難度較高&系統偵測時間需較長 2.結合氣體偵測器，正確性高以及偵測時間可大幅縮短
心率偵測	☆☆	需取得高品質PPG信號
心率變異偵測	☆☆	需取得高品質PPG信號
整合全部功能	☆☆☆	1.單一平台上同時兼具全部功能的正確性 2.邊緣計算平台上實現即時監控和警報功能

☆ 數越多難度相對較高

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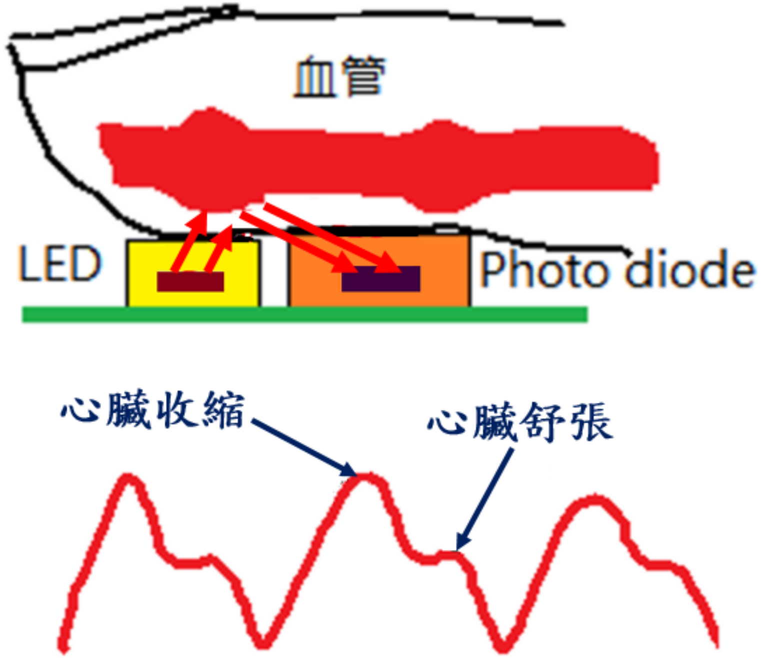
Design and Implementation: PPG (Photoplethysmography) Signal

PPG 原理

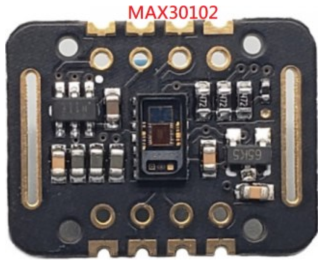
PPG (Photoplethysmography)信號，PPG信號是利用光感測元件吸收光線能量的原理，紀錄光線於血管中受血流脈動的變化而偵測出來的信號。

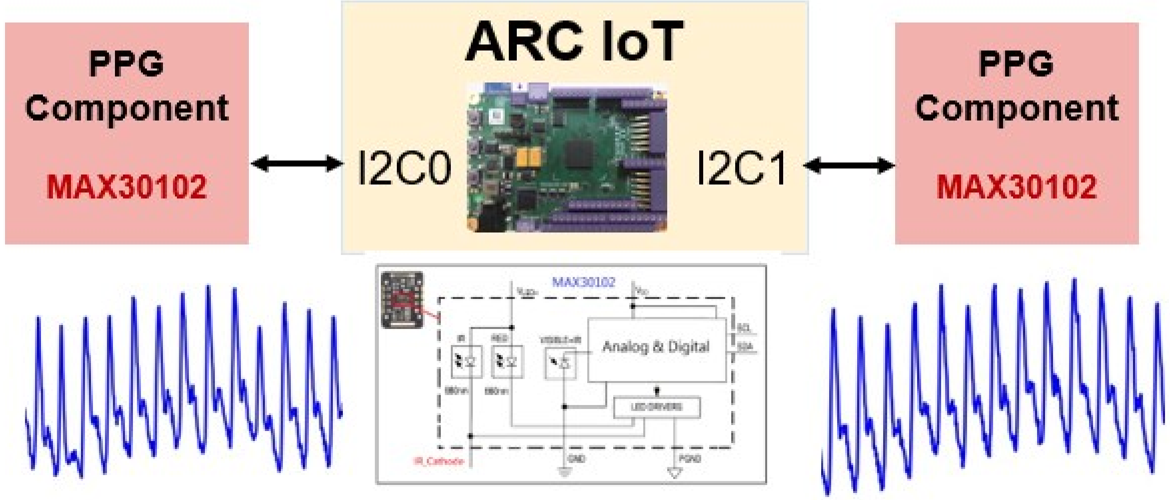


反射式PPG量測裝置

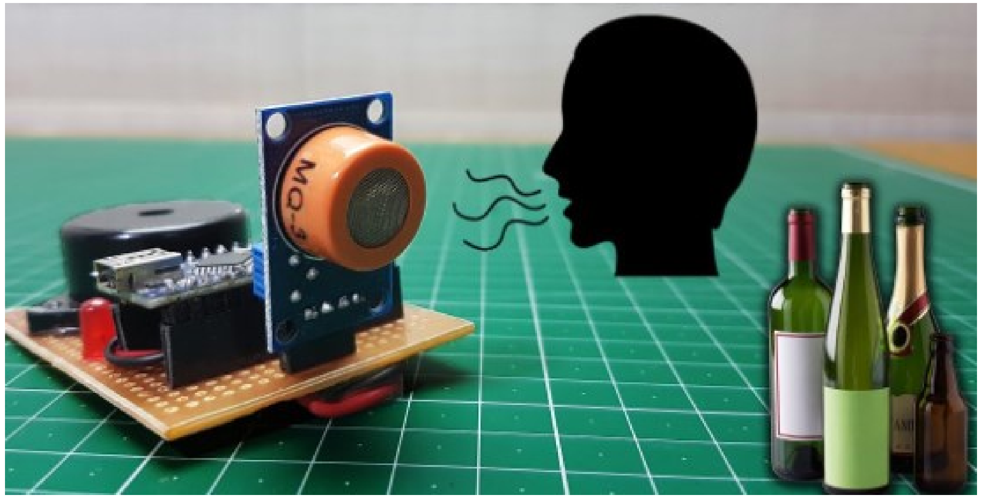
PPG 元件: MAX30102

- 兩個 LED分為紅外光(880nm)及紅光(660nm)
- 一個光感測器(photodetector,PD)
- 18位元的類比數位轉換器(ADC)
- 取樣率可達3200samples/sec
- 透過標準的I2C傳輸介面與控制器做連結
- 體積小成本低，適合在汽車方向盤上擷取駕駛者生理信息



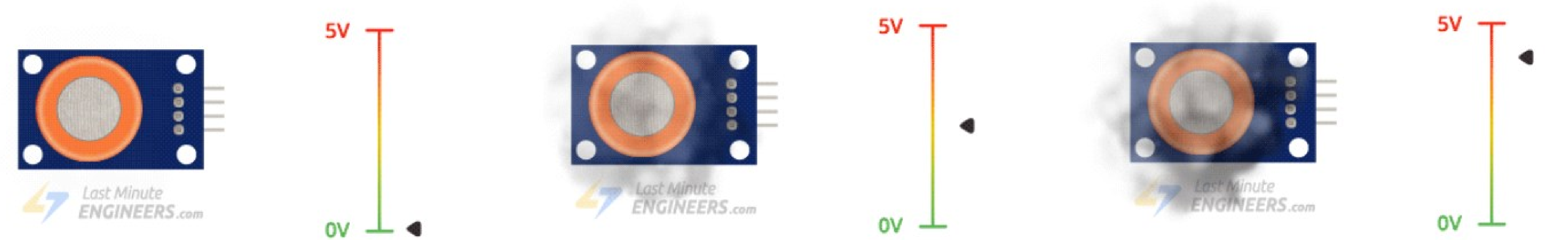


Design and Implementation: Alcohol Detection (Alcohol Sensor)



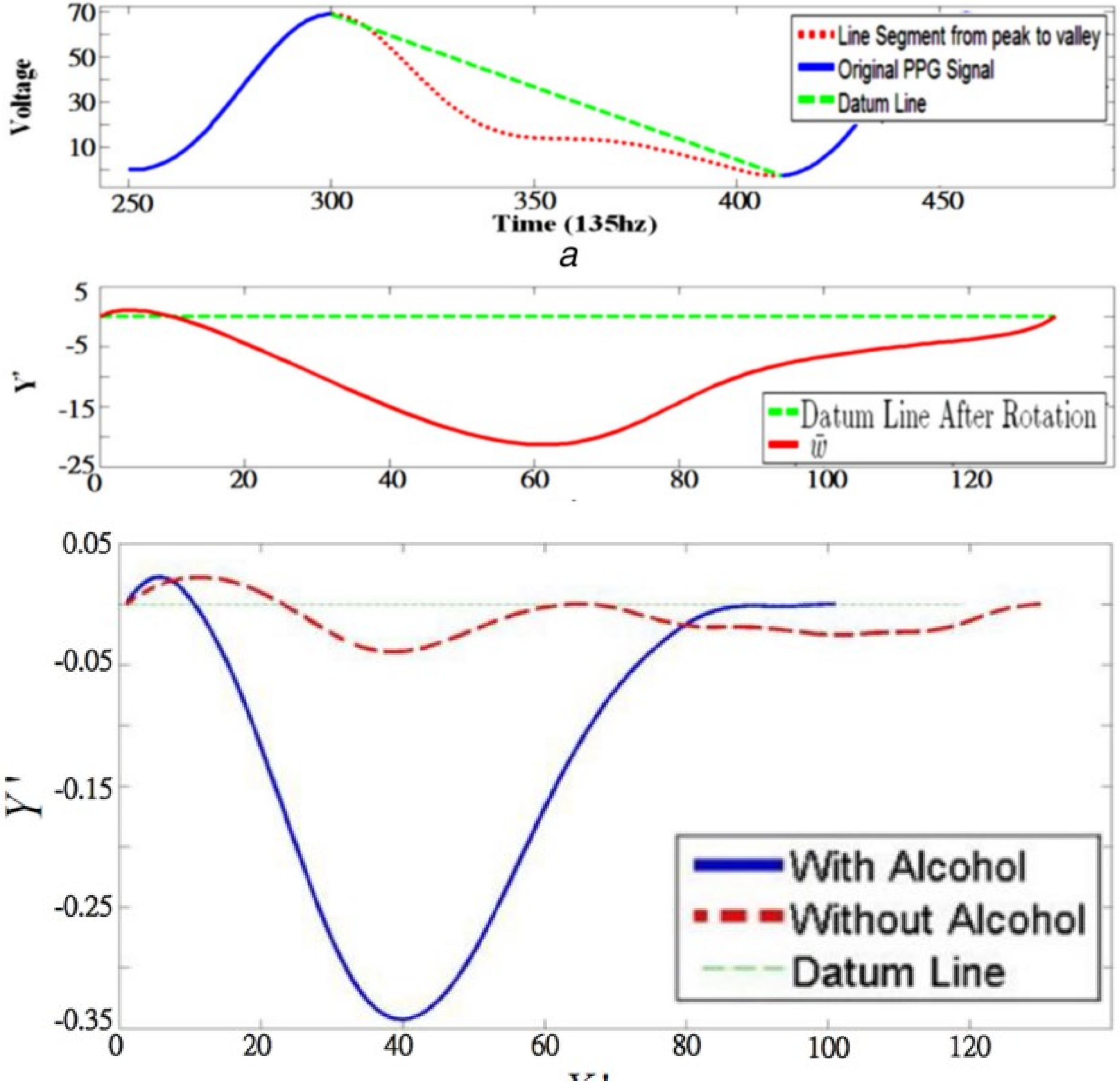
氣體感測器(MQ3)

- 工作電壓：直流5V
- 具有信號輸出指示
- 類比量輸出
- 類比量輸出0~5V電壓，濃度越高電壓越高
- 對乙醇蒸汽具有很高的靈敏度和良好的選擇性



Clean Air | Output Voltage | Low Alcohol | Output Voltage | High Alcohol | Output Voltage

Design and Implementation: Alcohol Detection (PPG Signal only)



參考文獻:

Non-invasive detection of alcohol concentration based on photoplethysmogram signals

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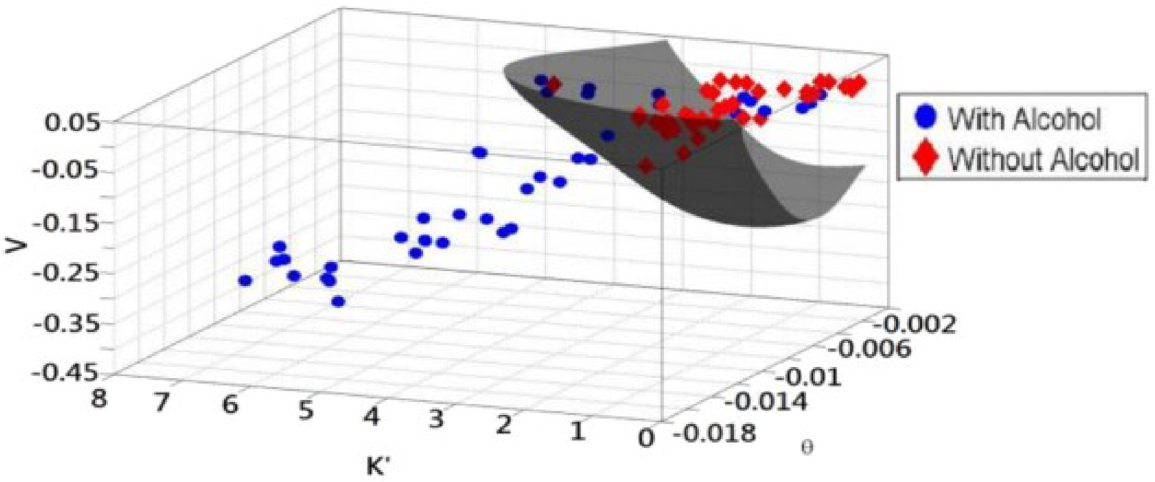
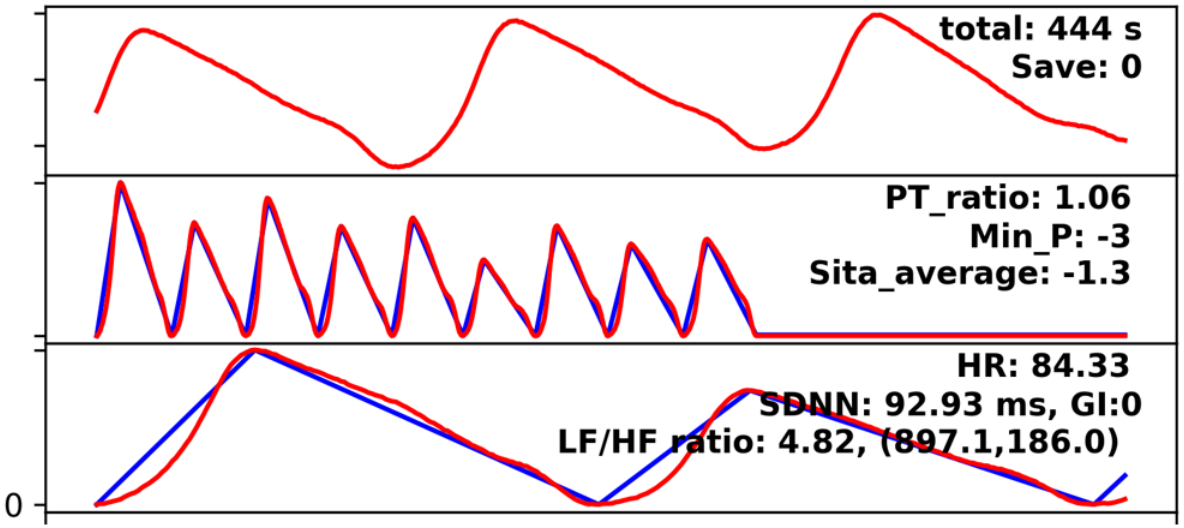
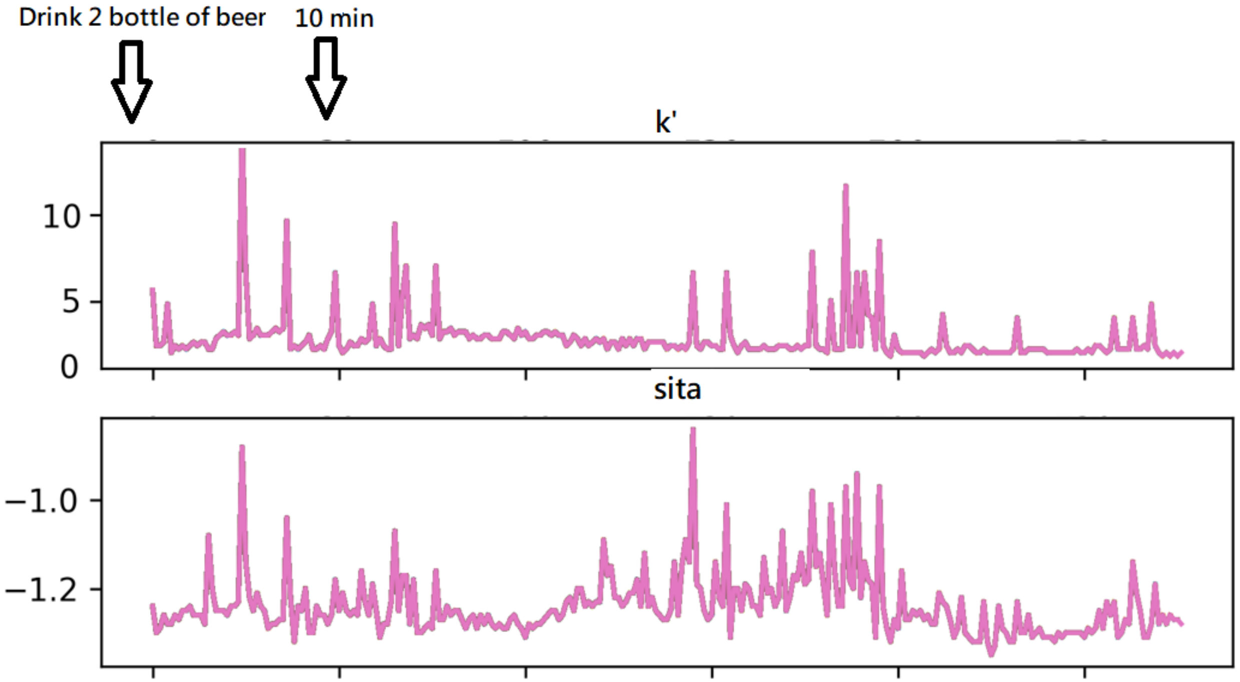
✉ *E-mail: chunlin@dragon.nchu.edu.tw*



Experimental results of the human alcohol intake classification using SVM

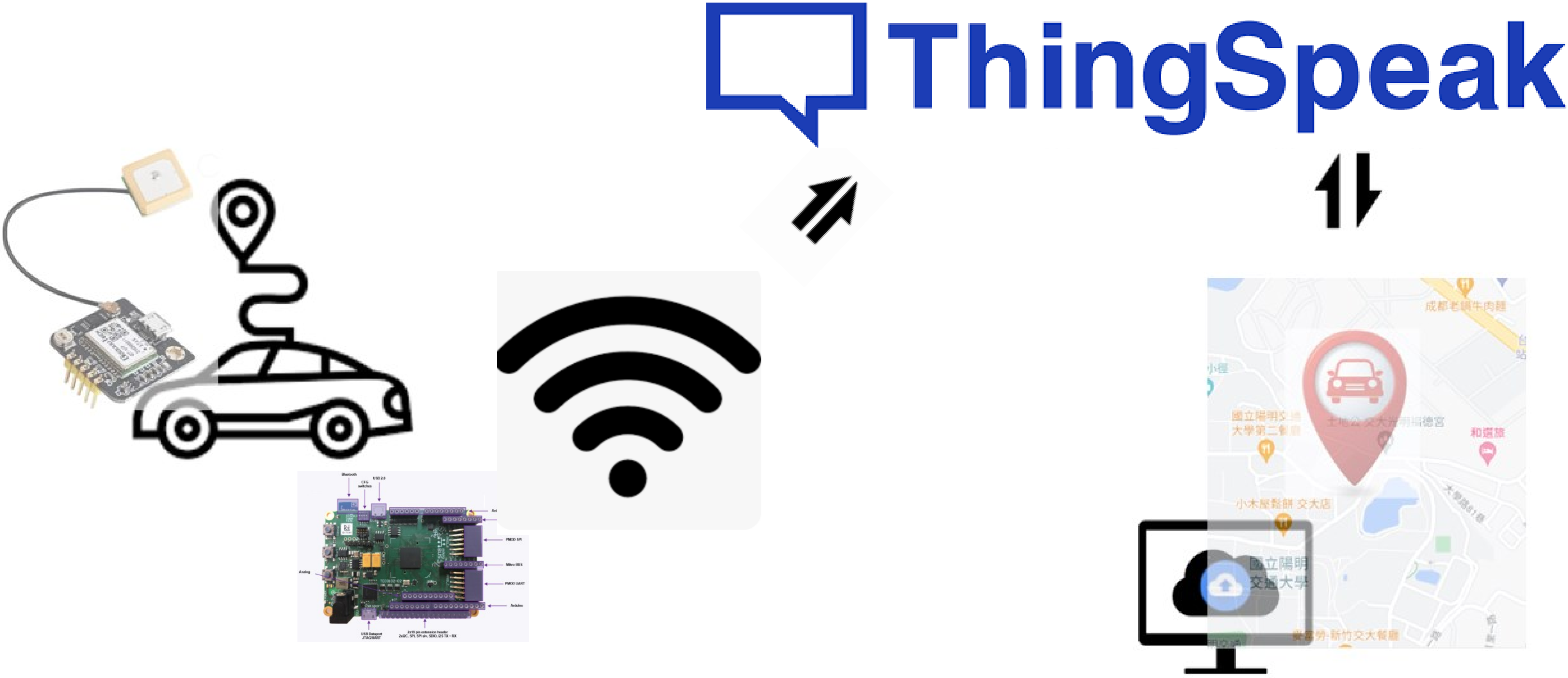
Design and Implementation: Alcohol Detection (PPG Signal only)



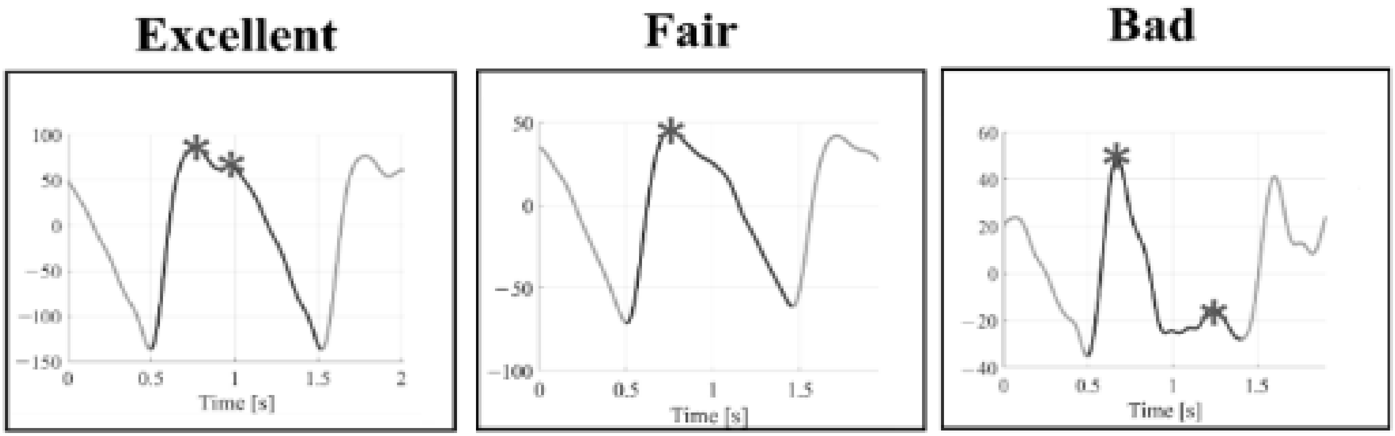


- 依照參考文獻，飲酒後k'會變。
- 依照實測結果觀察，k'變化於飲酒後10分鐘左右有往上的趨勢，但變化不明顯
- 考量偵測正確性以及偵測即時性，本作品暫時不以單一PPG信號做為酒駕偵測的唯一輸入源

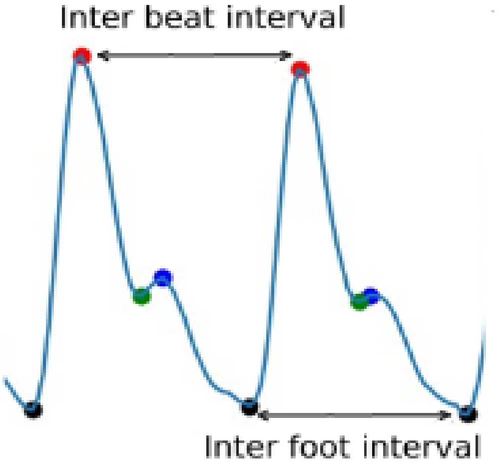
Design and Implementation: GPS and Wifi function



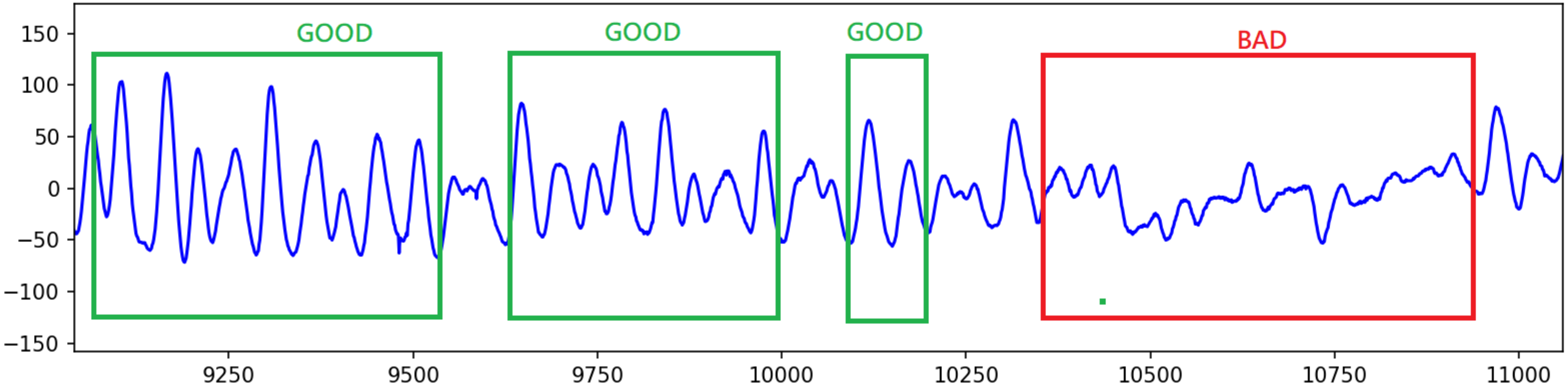
Design and Implementation: PPG Signal Quality Index (SQI) Detector using CNN



(a)Examples of Excellent, Fair, and Bad



(b)Inter Beat/Foot Interval



PPG SQI Detector using CNN

PPG Signal from MAX30102

PPG Signal Preprocessing

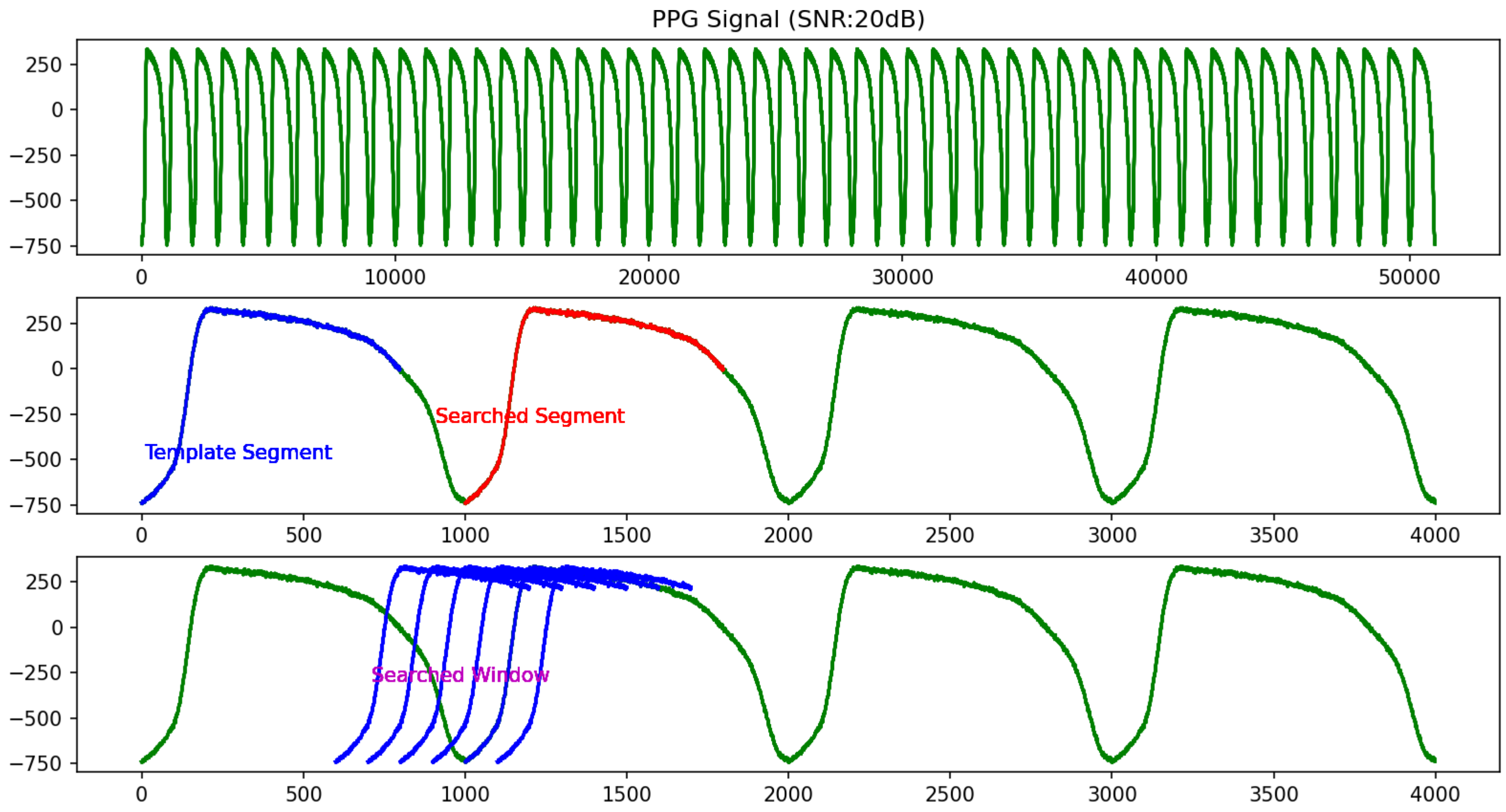
Digital Filter → segmentation → SQI Score (SSD) → PPG Image for CNN

CNN Model Training

Training and Test Dataset → CNN Model Training

SQI CNN Model for Our Project

Design and Implementation: segmentation



TS=PPG[t0:t0+W]

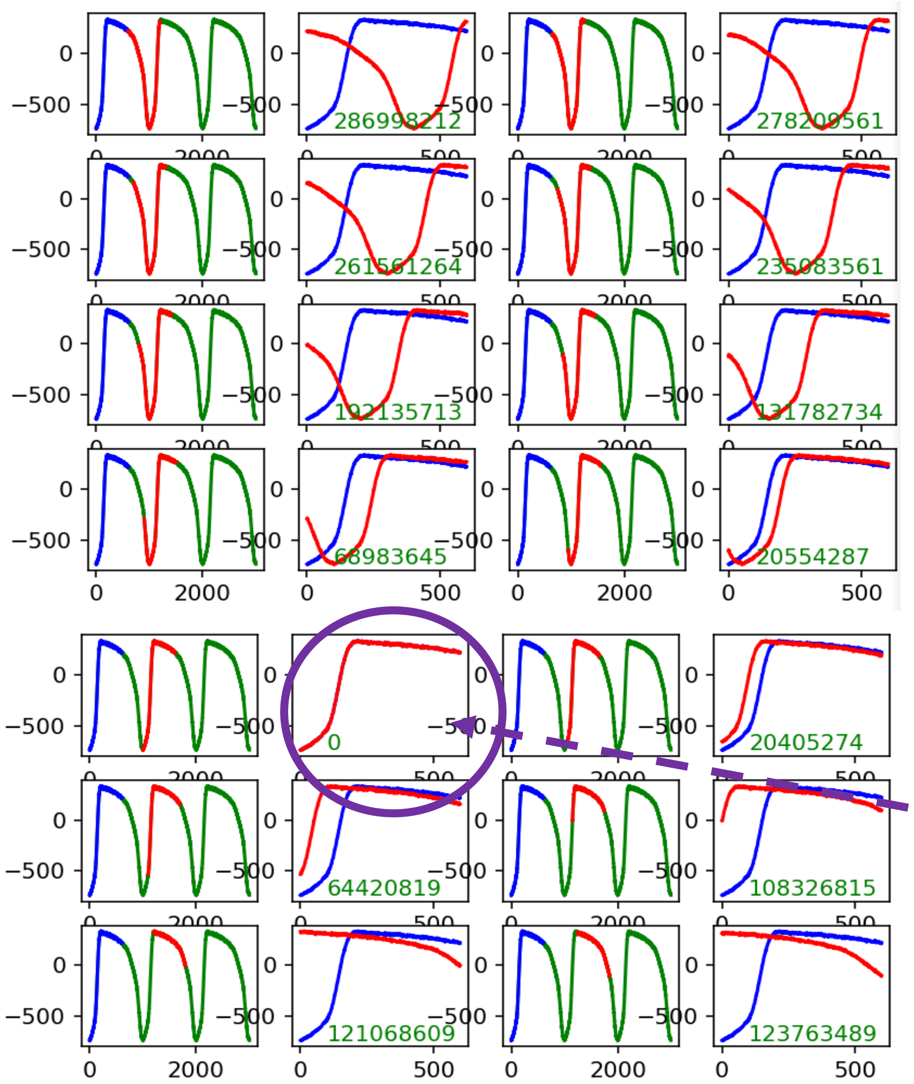
SS=PPG[s0:s0+W]

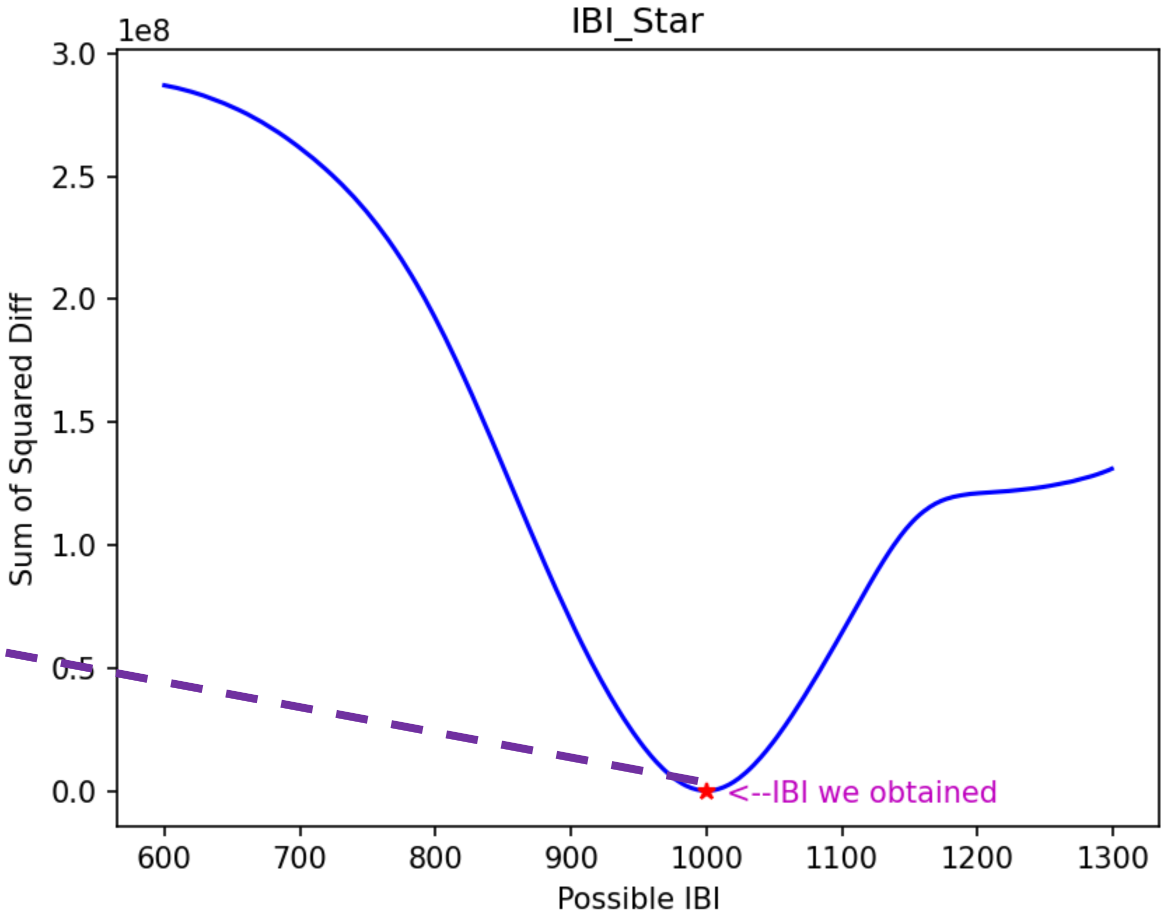
$$SSD = \sum_{w=1}^{W} (TS[w] - SS[w])^2$$

For all s in the searched window, we can have SSDi, s=0,1,….S. And the IBI*=argmin(SSDi,i=0,1,..,S)

Design and Implementation: SQI Score (SSD)

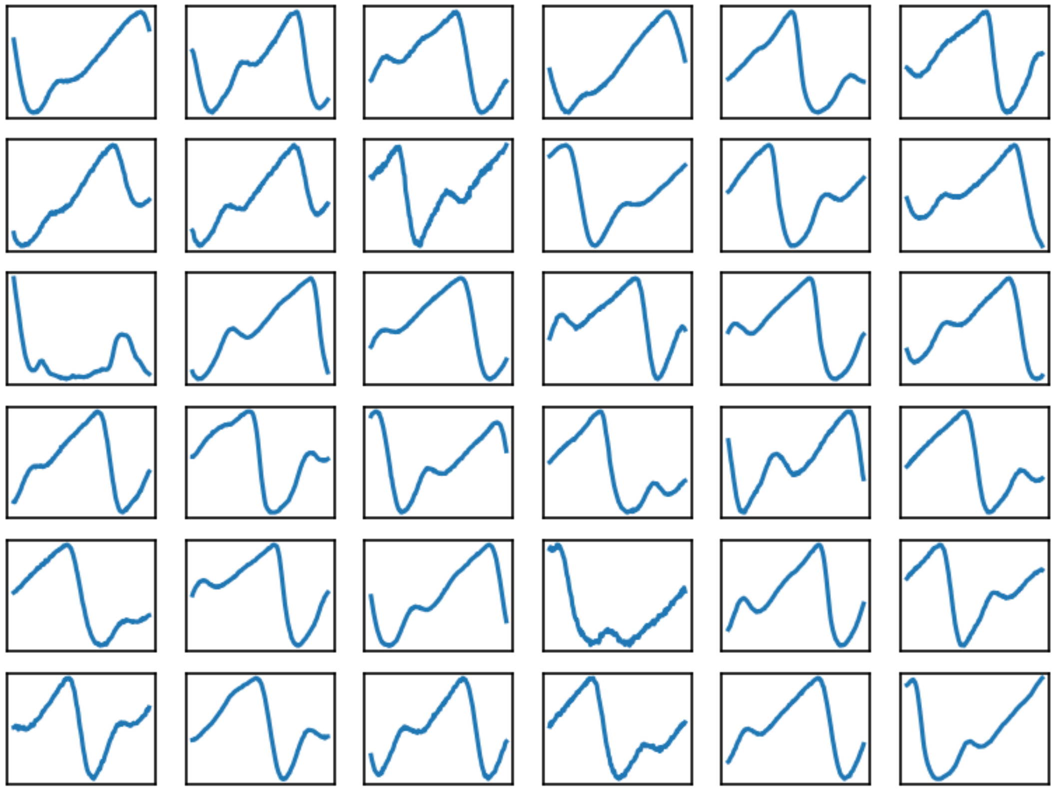
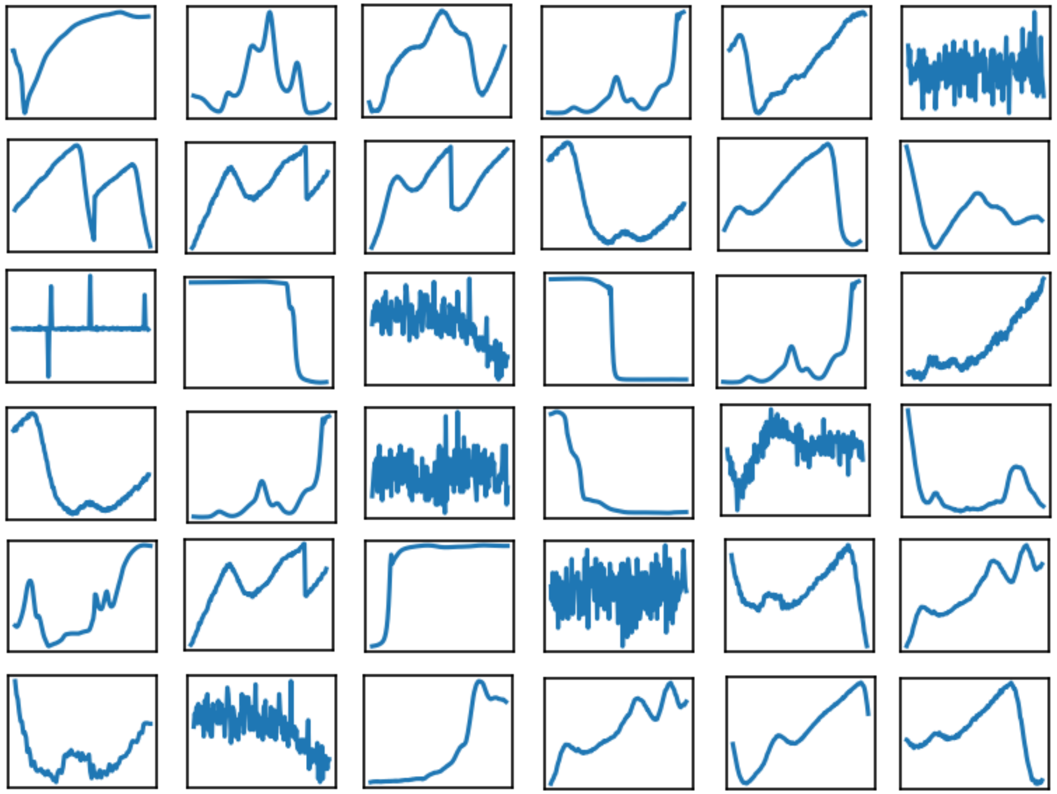
$$SSD = \sum^{W} (TS[w] - SS[w])^2$$



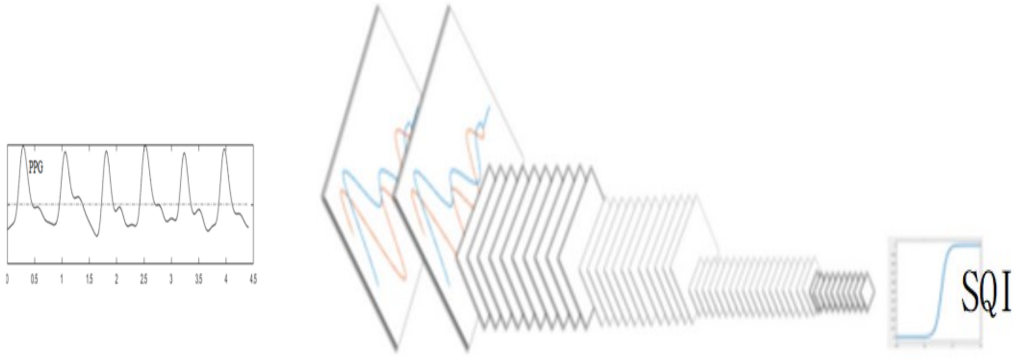


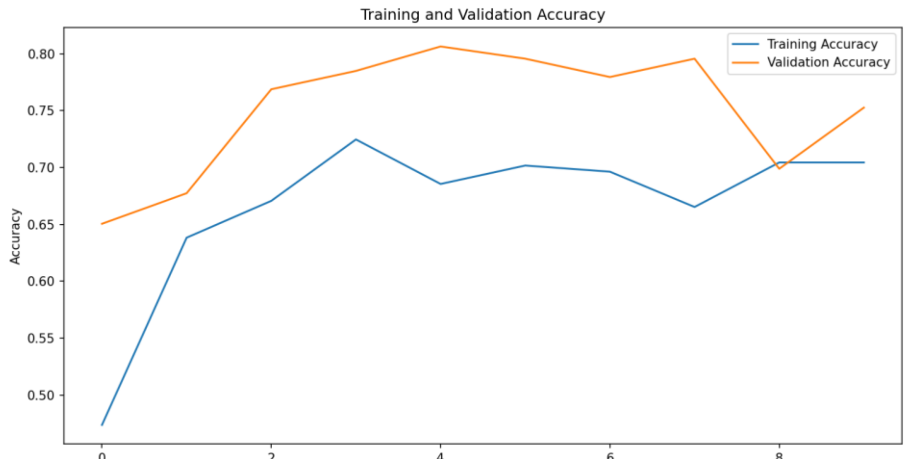
IBI with good quality

Design and Implementation– SQI CNN Training Pattern

Good SQI	Bad SQI
	
收集此類 Good Pattern 一共418個，資料被隨機切分成80% train，20% Test	收集此類 Bad Pattern 一共428個，資料被隨機切分成80% train，20% Test

Design and Implementation:
PPG SQI Detector using CNN

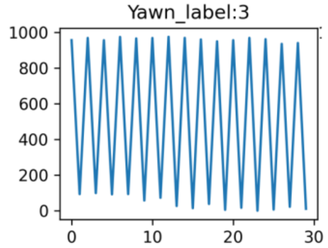




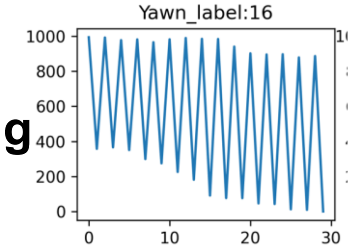

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                  Output Shape            Param #
=================================================================
 conv2d (Conv2D)               (None, 98, 1, 8)        32
 max_pooling2d (MaxPooling2D)  (None, 49, 1, 8)        0
 conv2d_1 (Conv2D)             (None, 47, 1, 16)       400
 max_pooling2d_1 (MaxPooling2D) (None, 23, 1, 16)      0
 flatten (Flatten)             (None, 368)             0
 dense (Dense)                 (None, 8)               2952
 dense_1 (Dense)               (None, 1)               9
=================================================================
Total params: 3,393
Trainable params: 3,393
Non-trainable params: 0
```

Design and Implementation– Yawn Detector using CNN

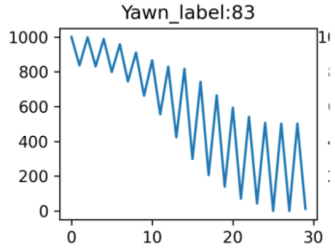
Not Yawn



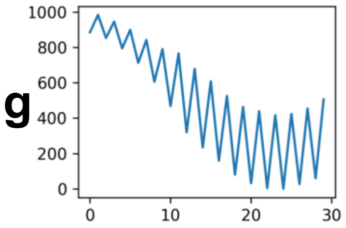
Little Yawning



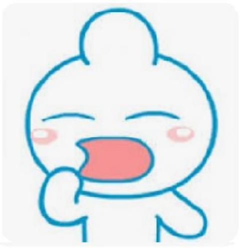
Yawn

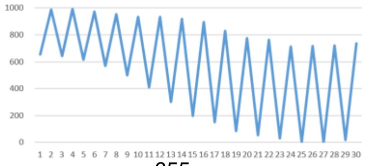


Very Yawning



15個peak y軸值
15個valley y軸值
1個peak/valley接續一個valley/peak
最大peak正規化到1000
最小valley正規化到0



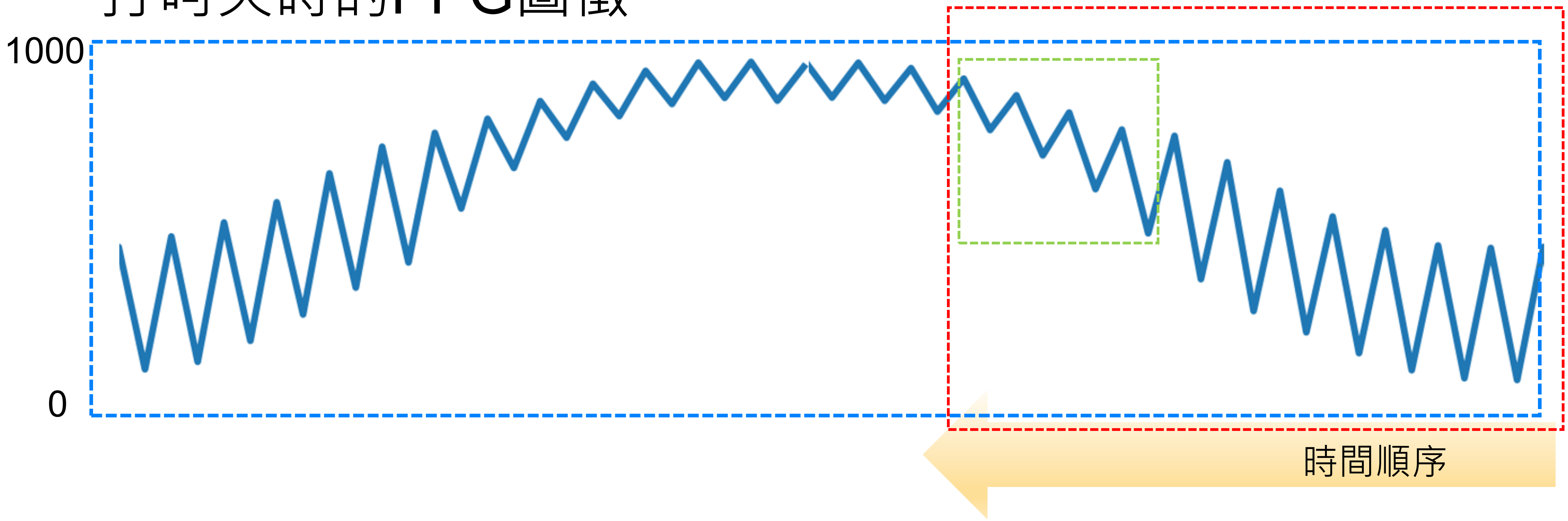


655
988
641
990
617
972
571
953
501
934
411
932
301
917
195
895
150
829
84
775
54
763
28
713
4
717
0
721
17
735

CNN
Yawn

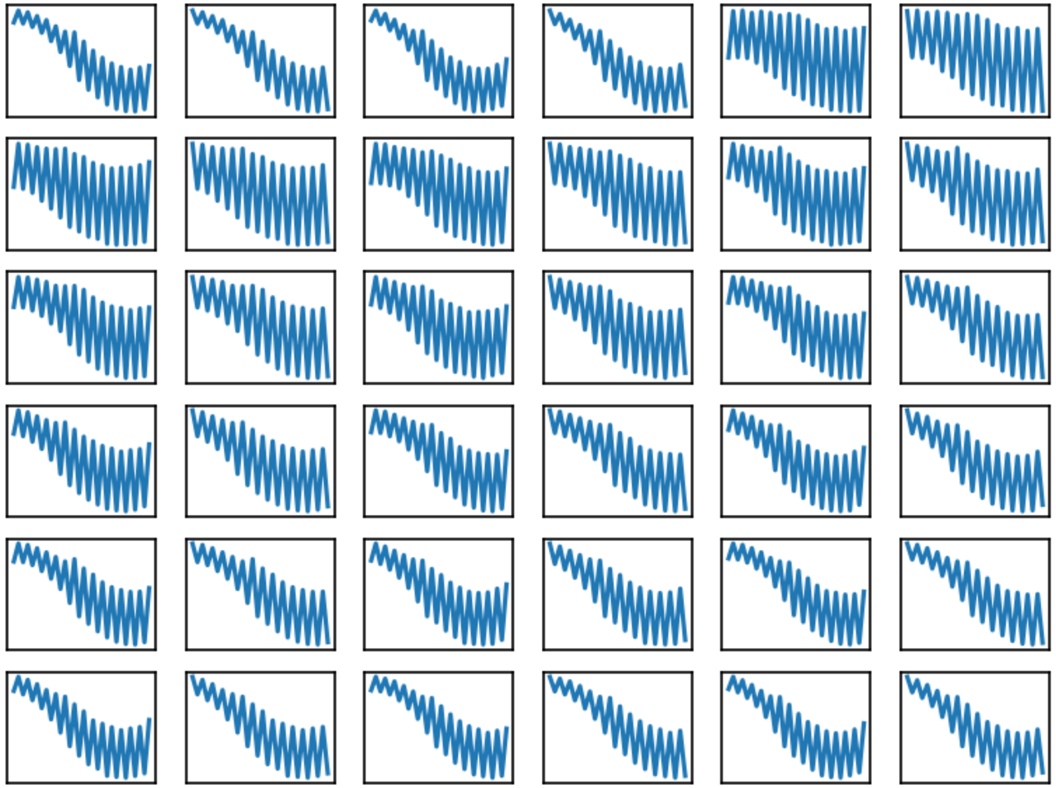
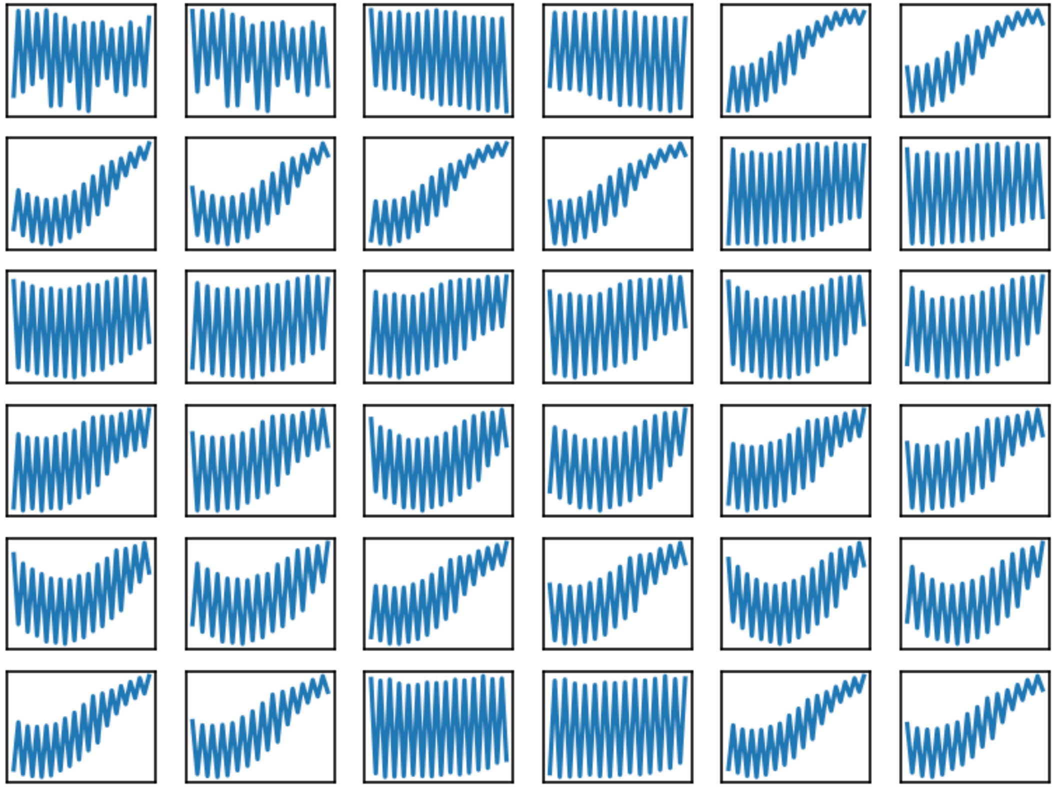
1: 打呵欠
0: 無打欠

打呵欠時的PPG圖徵



- 以準確度考量的話，以上圖藍色框框為輸入範圍會較佳，但偵測反應時間需較長
- 考量正確性以及偵測打呵欠的反應速度，我們採用紅色框框範圍為輸入區間
- 接近紅色框框的圖徵即就可能是Yawn，其他就不是Yawn
- 可能是Yawn圖徵時，每一個PPG的SQI都要是Pass 以及 Normaize 到0~1000之後，前1/3區間(上圖綠色框框區間)的最低點超過700為Very Yawn，介於500~699為Yawn，介於400~499為Little Yawn，

Design and Implementation– Yawn CNN Training Pattern

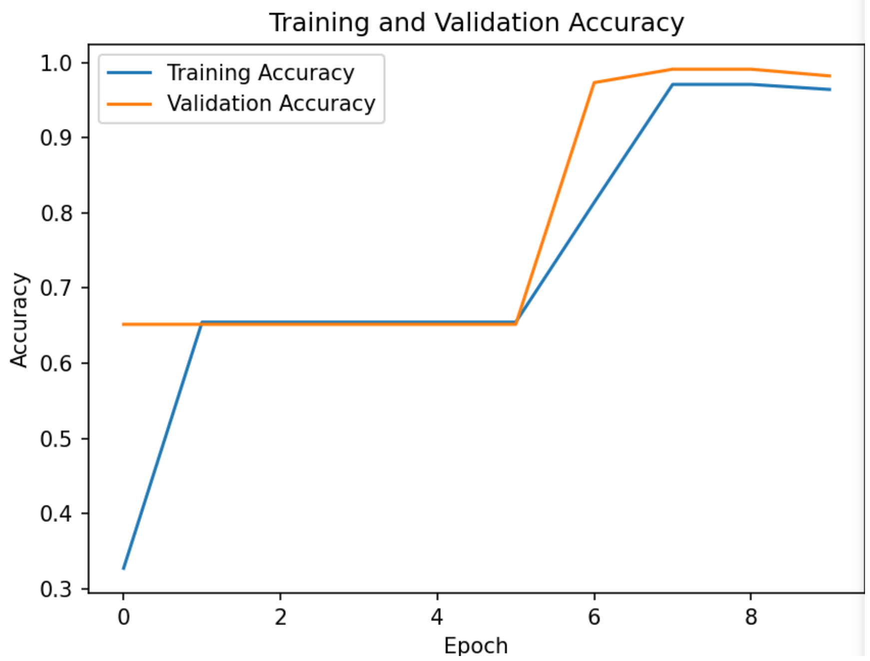
Yawn	Not Yawn
	
收集此類 Yawn Pattern 一共684個，資料被隨機切分成80% train，20% Test	收集此類 Not Yawn Pattern 一共1394個，資料被隨機切分成80% train，20% Test

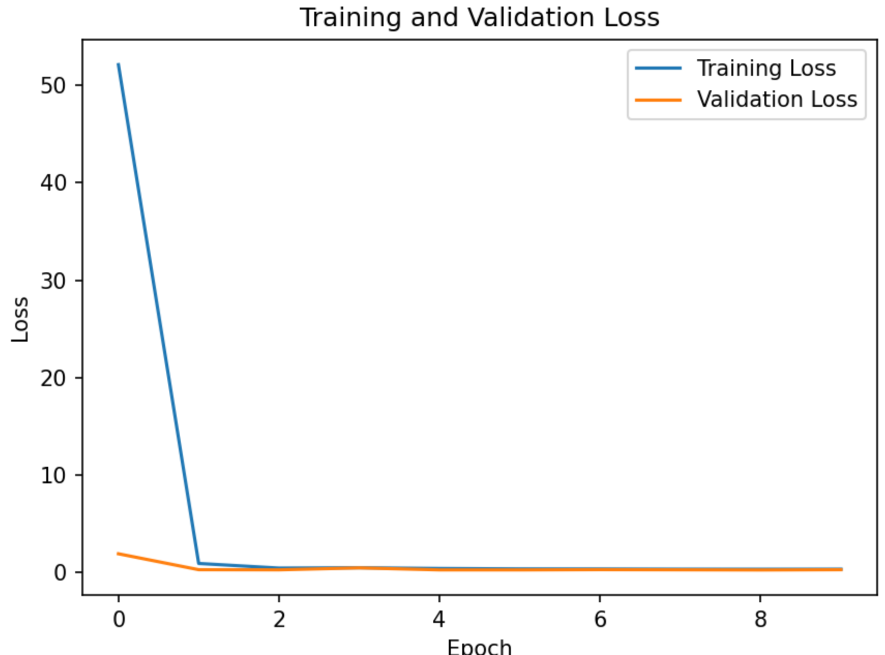
```python
def create_cnn_model(input_shape, num_classes):
    model = models.Sequential()

    model.add(layers.Conv2D(8, (3, 1), activation='relu', input_shape=input_shape))
    model.add(layers.MaxPooling2D((2, 1)))
    model.add(layers.Conv2D(16, (3, 1), activation='relu'))
    model.add(layers.MaxPooling2D((2, 1)))

    model.add(layers.Flatten())
    model.add(layers.Dense(8, activation='relu'))

    model.add(layers.Dense(num_classes, activation='sigmoid'))
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 28, 1, 8)	32
max_pooling2d (MaxPooling2D)	(None, 14, 1, 8)	0
conv2d_1 (Conv2D)	(None, 12, 1, 16)	400
max_pooling2d_1 (MaxPooling2D)	(None, 6, 1, 16)	0
flatten (Flatten)	(None, 96)	0
dense (Dense)	(None, 8)	776
dense_1 (Dense)	(None, 1)	9

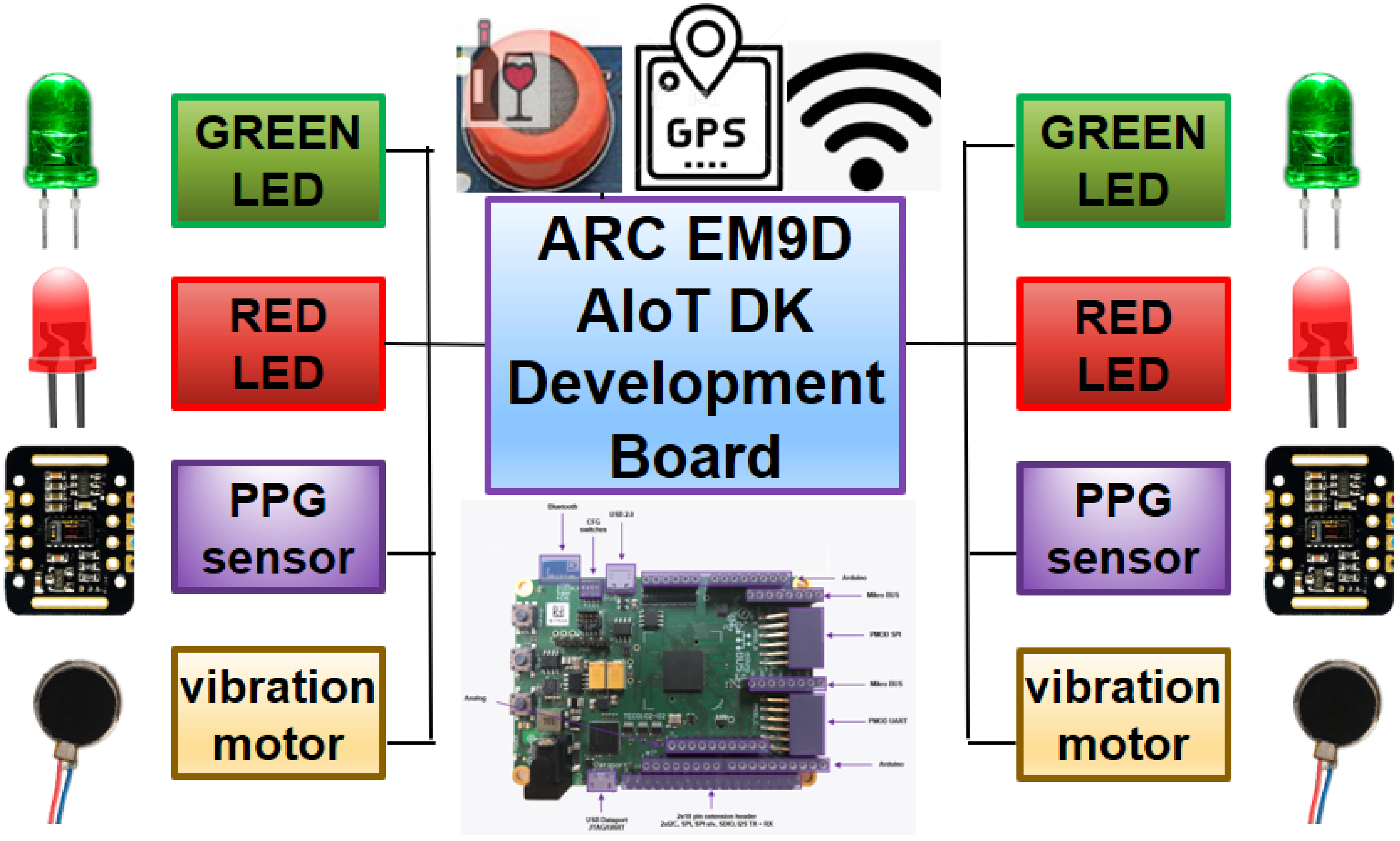
Total params: 1,217
Trainable params: 1,217
Non-trainable params: 0





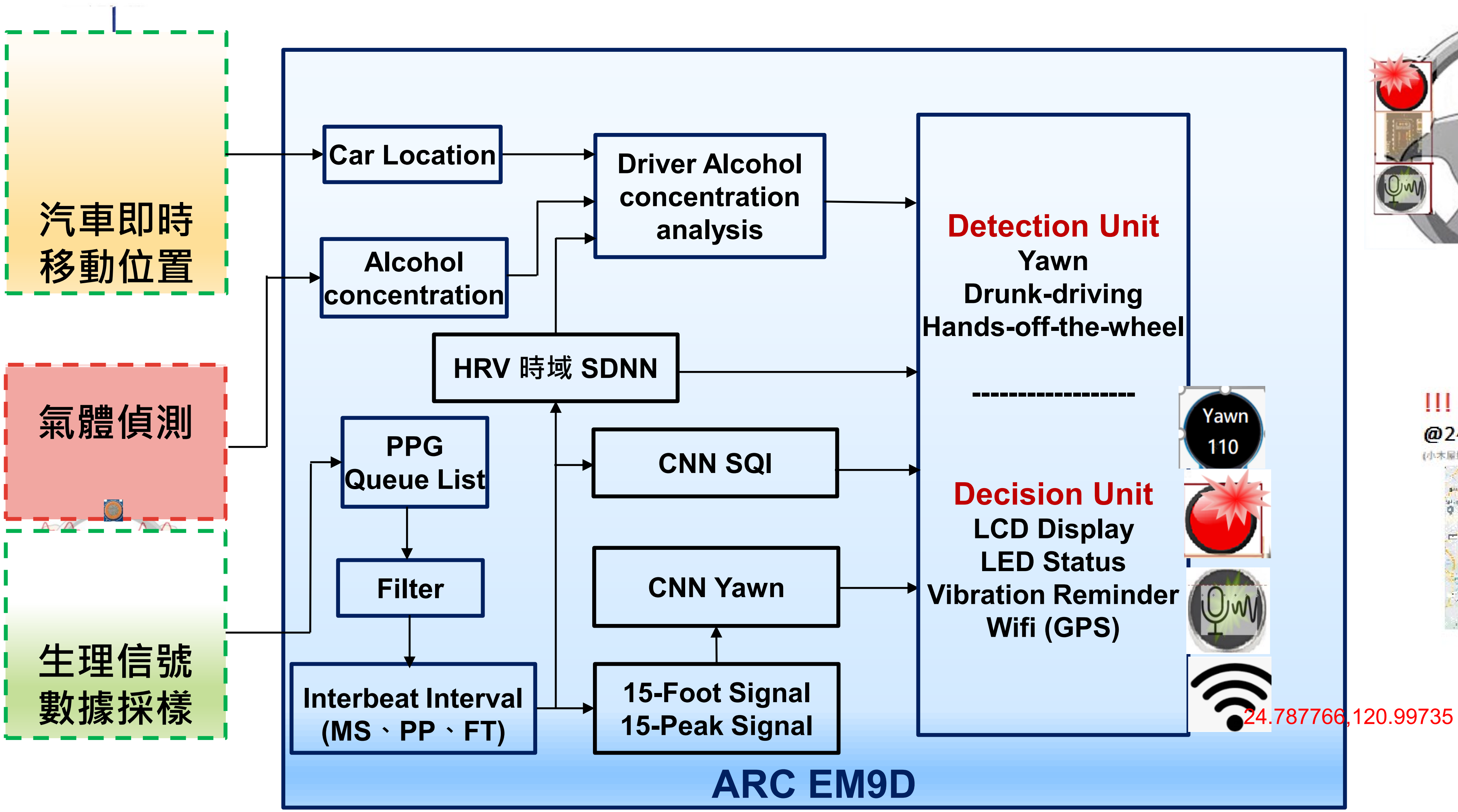
Design and Implementation-- Hardware Architecture

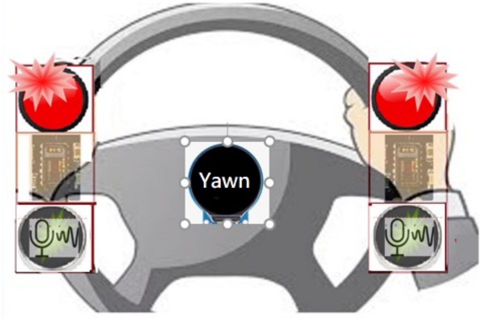
- **ARC IoT Development Kit (IoT Applications Platform)**
- **PPG Sensor (Max30102, Physiological Signal Detection)**
- **GREEN/RED LED (Status Indicator)**
- **Vibration Motor (Warning Vibration Reminder)**
- **Alcohol detector sensor(MQ3)**
- **GPS trackers for cars report a vehicle's location**
- **Wifi for vehicular communication function**

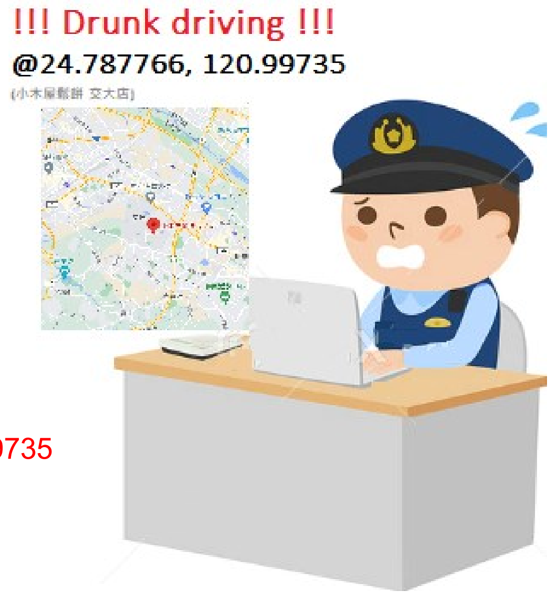


Hardware Architecture

Design and Implementation– Functional Block Diagram







Agenda

- Abstracts
- Challenge and Innovation
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- **Project Progress**
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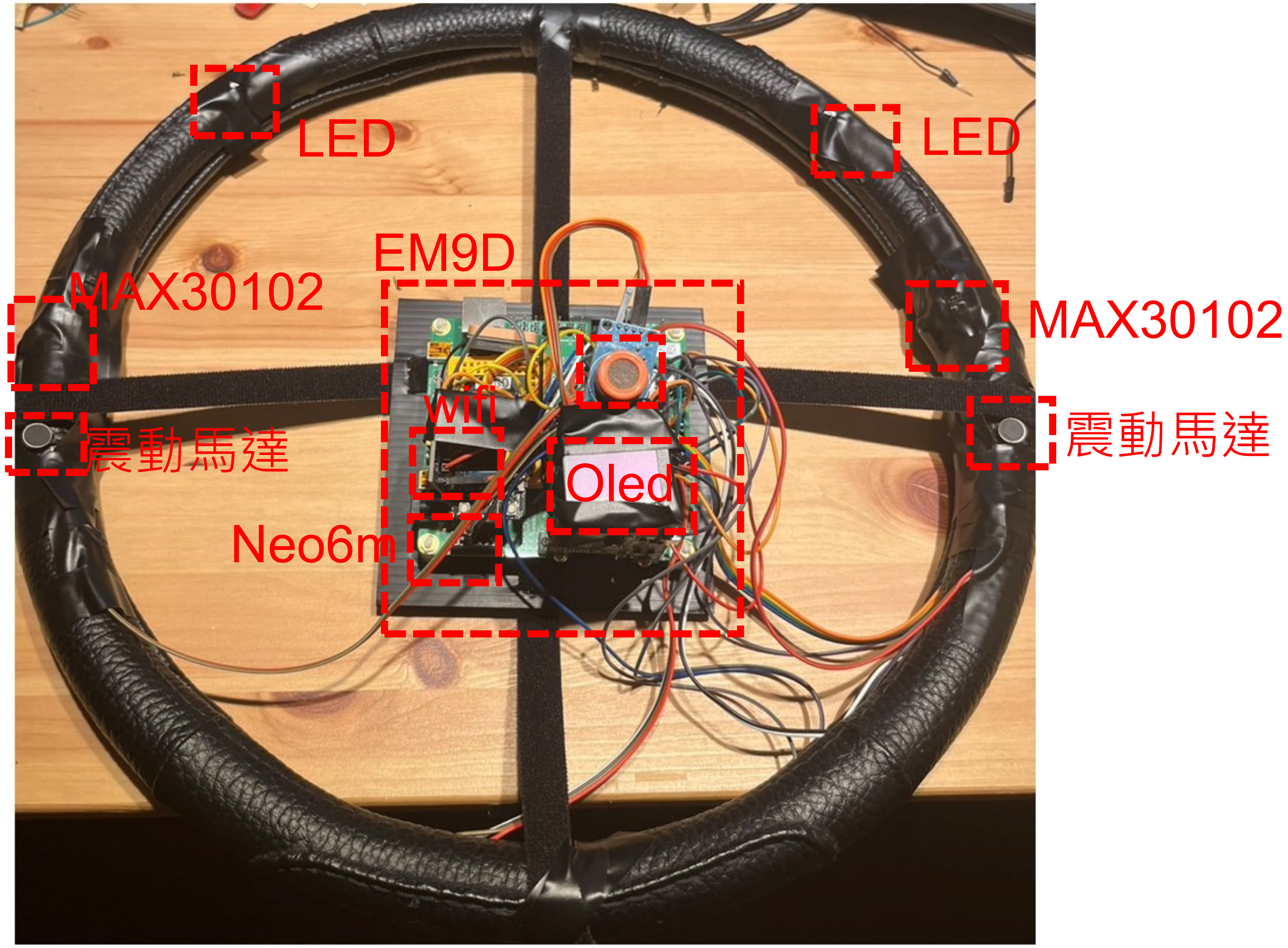
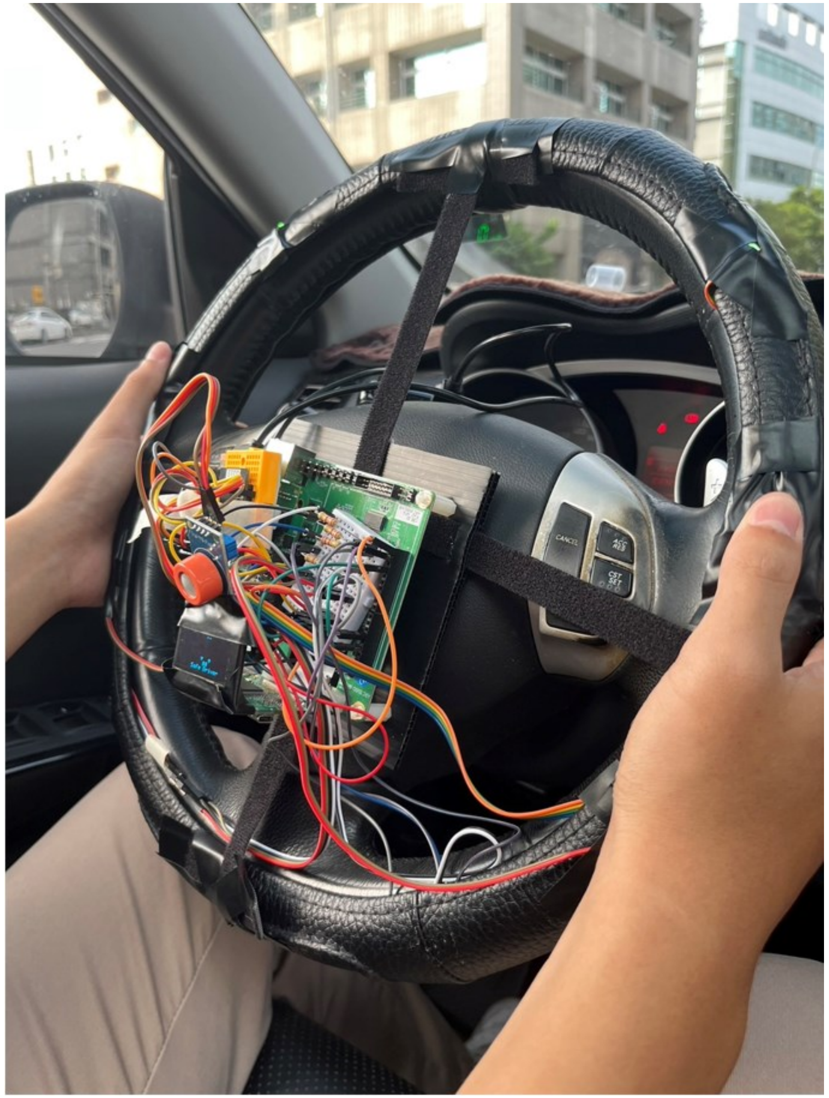
Project Progress- Hardware Components Installation

硬體

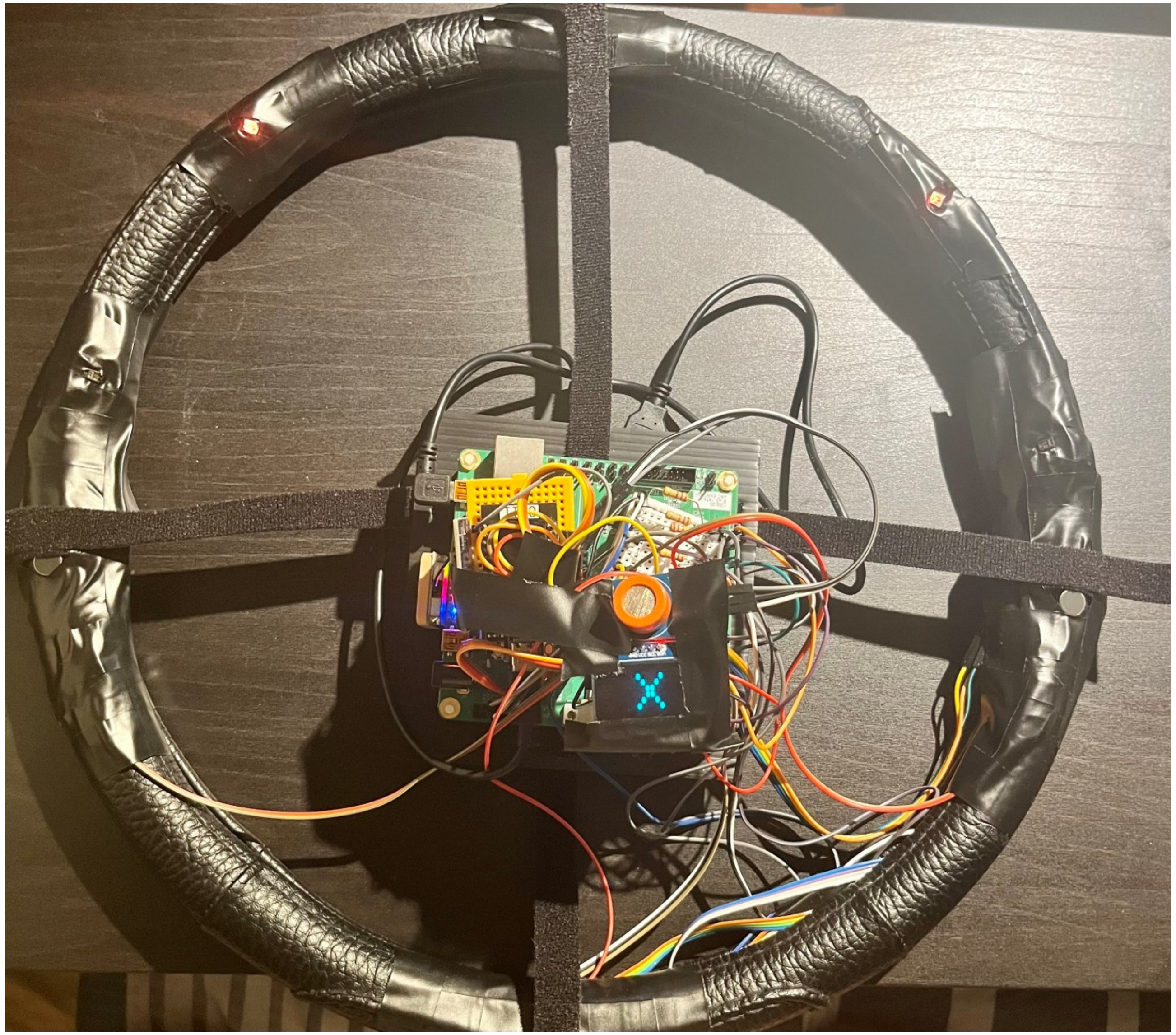
EM9D
MAX30102*2
LED*2
Mq3
Neo6m
Oled
震動馬達*2
TTGO(wifi module)

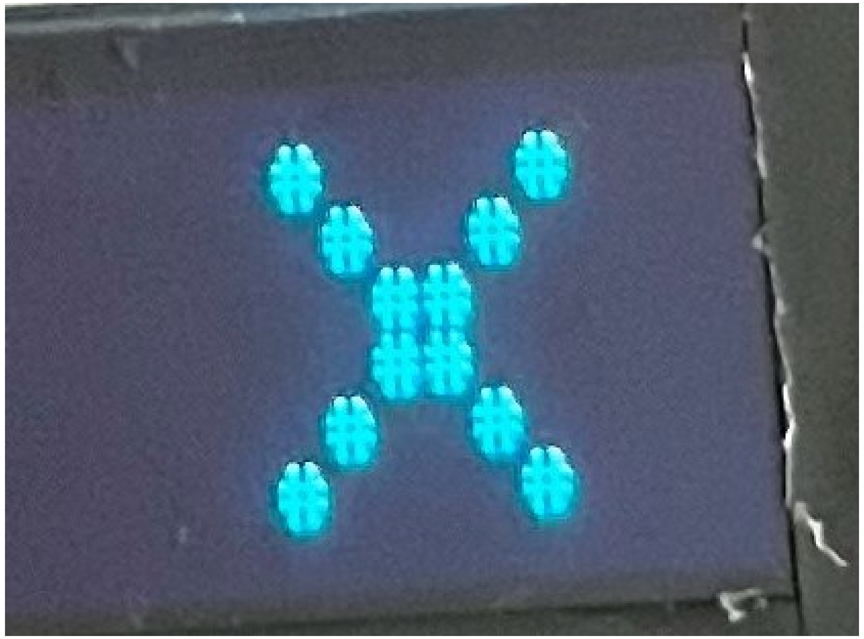


Project Progress– Setup on Car

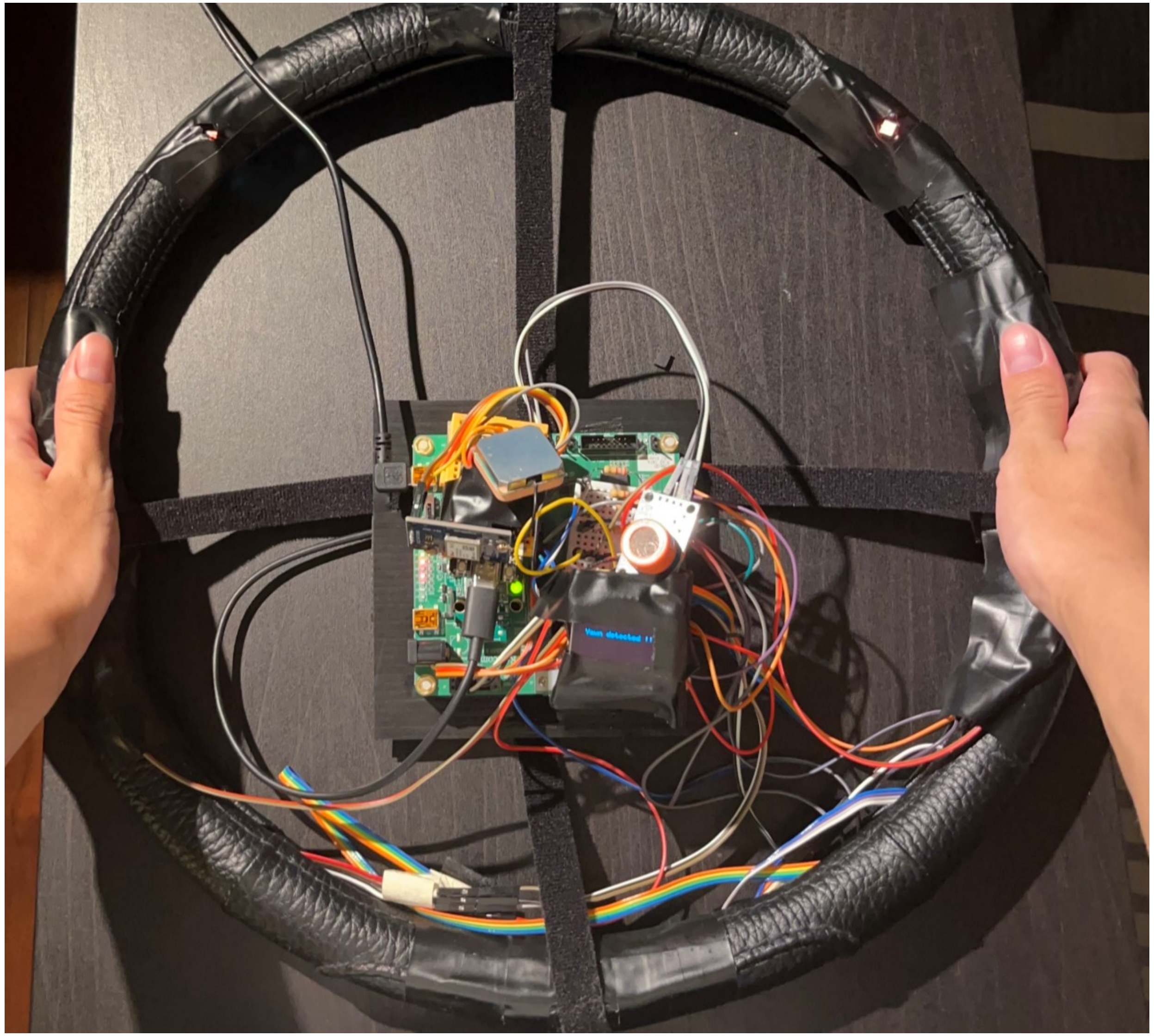


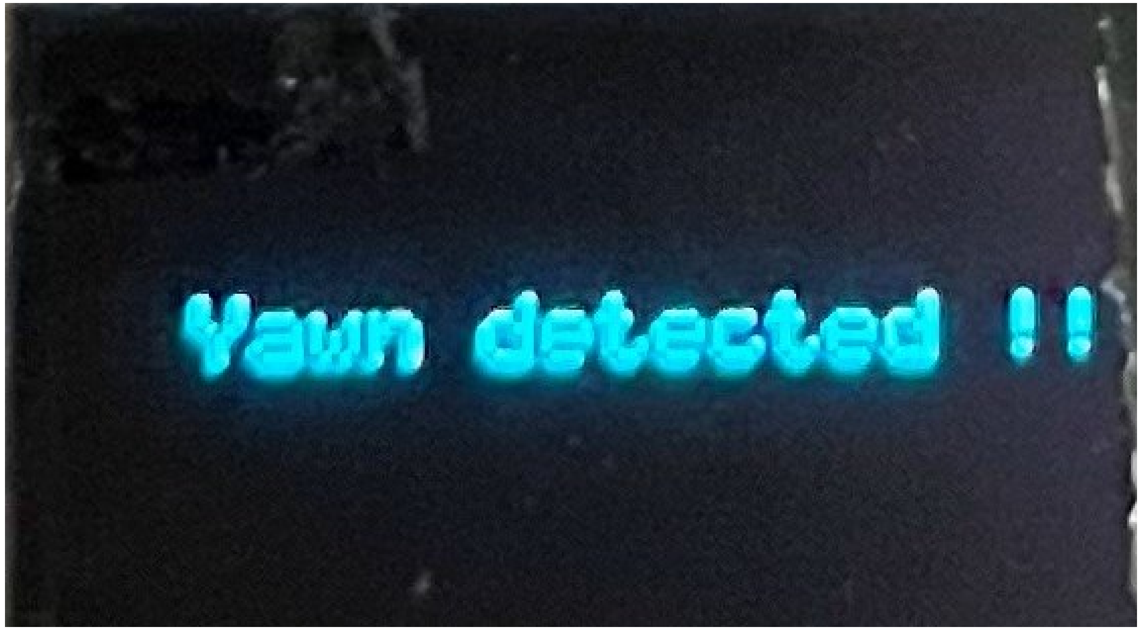
Project Progress– **Hands off the wheel**



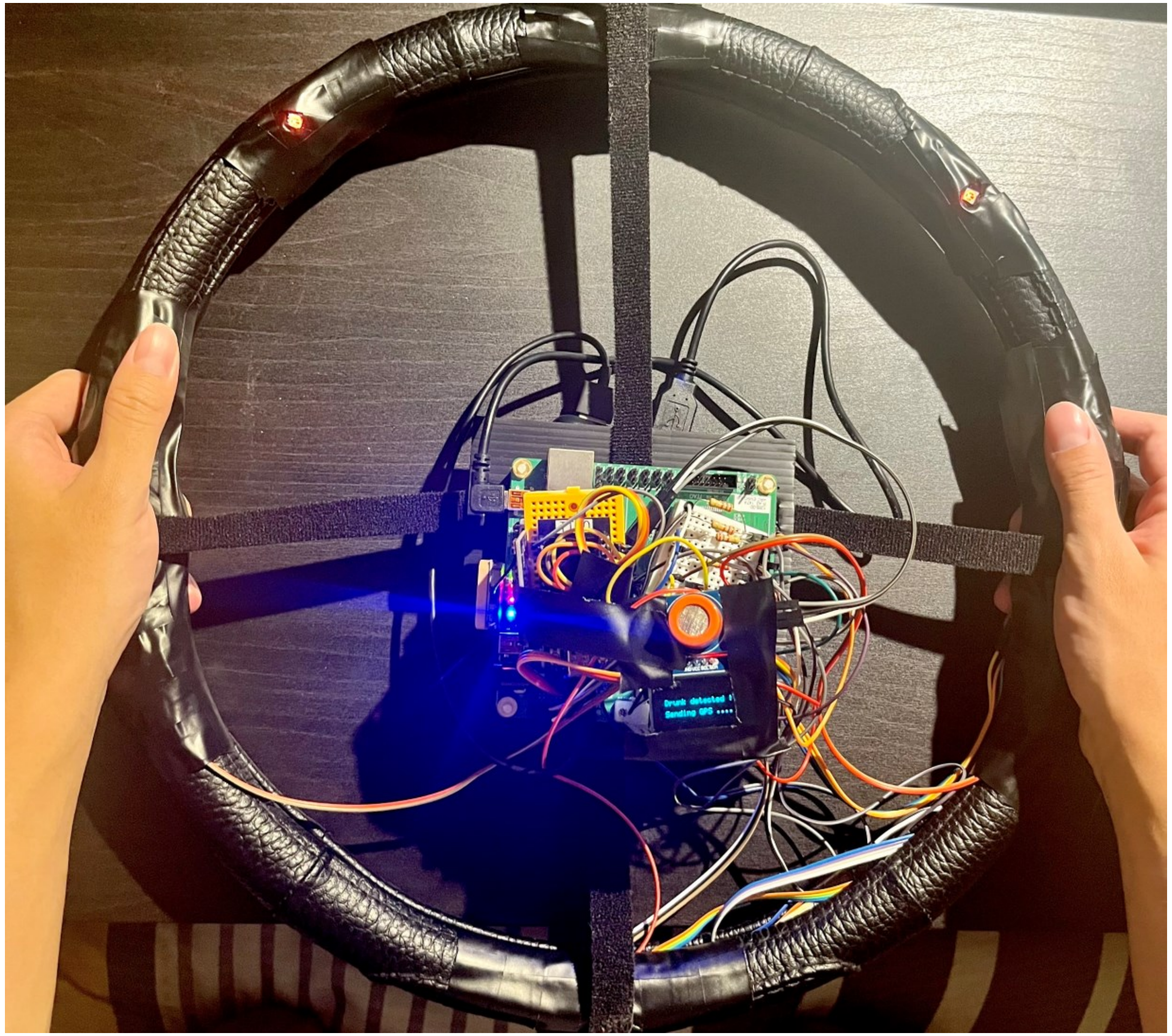


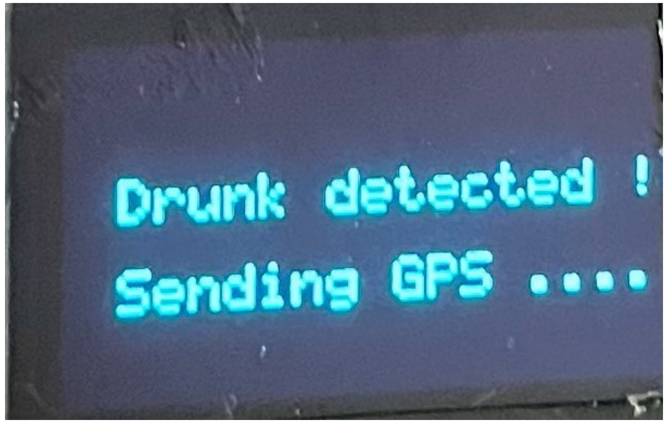
Project Progress– Driver Yawn

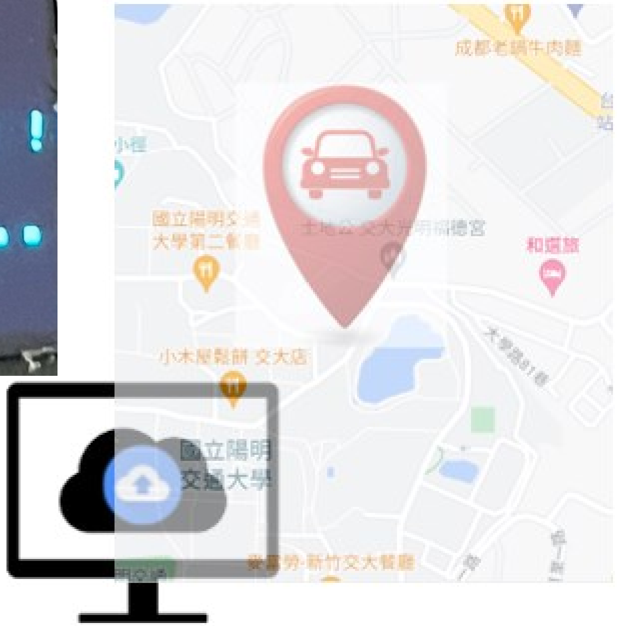




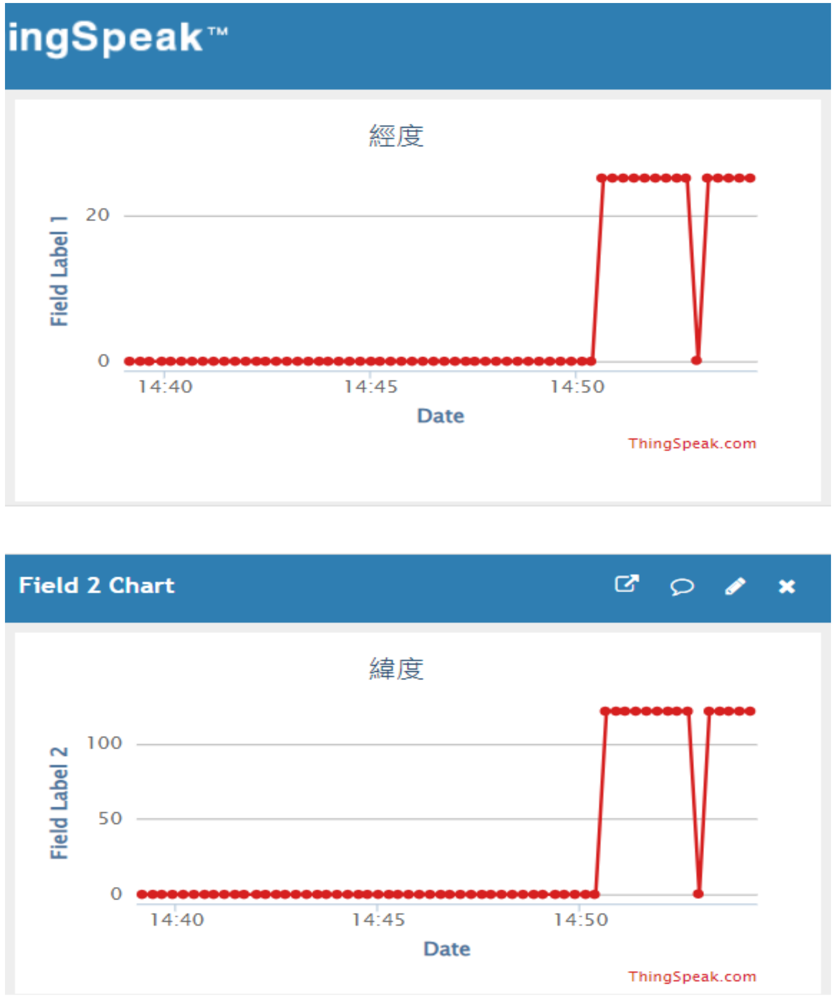
Project Progress– **Driver Drunkenness**



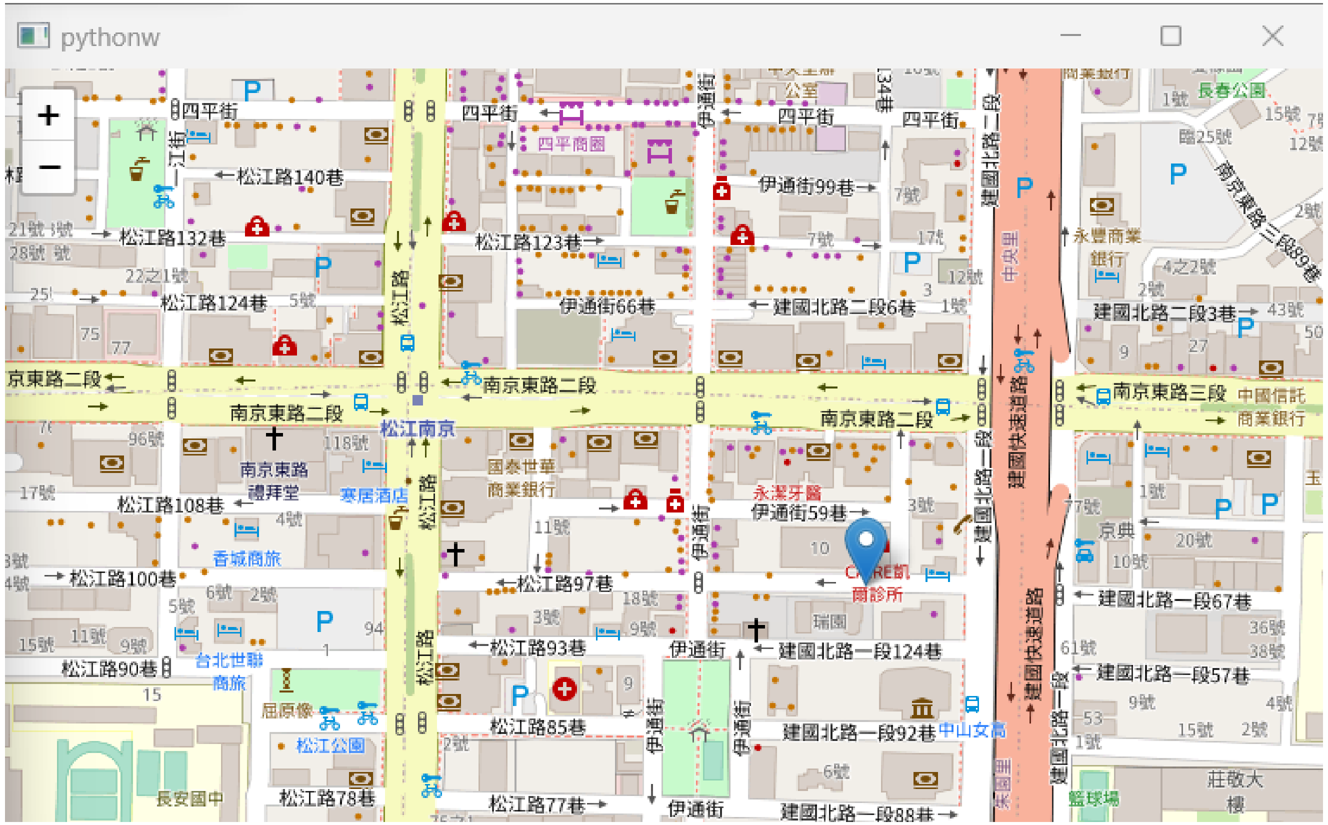




Project Progress– **GPS, Wifi, 雲端實測**



ThingSpeak(雲端)



使用Python從雲端將資料取出並標記酒駕者位置

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Test Result

心動安全方向盤功能	測試者1	測試者2	測試者3
手未正確握持方向盤	30/30	30/30	26/30
打哈欠	29/30	22/30	18/30
喝酒偵測(PPG only)	1/5	-	-
喝酒偵測(PPG+MQ3)	9/10	8/10	10/10
心率偵測誤差[1] (心動安全方向盤測量值- S9+測量值)	0.5 bpm	0.3 bpm	0.8 bpm

註1: 心動安全方向盤測量左手，同時用Samsung S9+測量右手

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Overall Summary: 心動安全方向盤

結論

- 我們完成了一個基於嵌入式系統之主動式輔助駕駛者的心動安全方向盤，成功使用 PPG訊號與氣體偵測器來完成汽車駕駛者之心率偵測、打哈欠、手未正確握持方向盤、喝酒駕駛偵測。同時依據該駕駛者當時的行為予以燈號警示、顯示器提醒、震動提醒、或於危險酒駕時傳送車子的位置上雲端做為報警之警告手段
- 經過實測的結果顯示，每一個功能的三個受測者的平均準確率皆達75%以上(PPG only的喝酒偵測準確率不如預期，未實現於最終版本中)

未來展望

- 未來我們希望能再縮小裝置的體積，讓整個裝置更便利地安裝，對駕駛者的干擾最小
- 繼續優化心動安全方向盤，全部功能正確性再往上提升。酒精偵測的部分持續改良做法，目標是朝單一PPG元件方向努力
- 希望此裝置未來有量產性，達到降低交通事故之成效

參考資料

[1] Y. Y. Chen, C. L. Lin, Y. C. Lin, and C. Zhao, 'Non-invasive detection of alcohol concentration based on photoplethysmogram signals,' IET Image Processing, vol. 12, no. 2, pp. 188-193, 2018.
[2] http://xm.fjsen.com/2016-03/31/content_17583138.htm
[3] https://blog.miyoko-jp.com/driveusephone/
[4] https://699pic.com/tupian-401536513.html
[5]https://medium.com/%E5%AD%B8%E4%BB%A5%E5%BB%A3%E6%89%8D/%E9%A7%95%E9%A7%9B%E8%80%85%E7%9B%A3%E6%8E%A7%E7%B3%BB%E7%B5%B1-driver-monitoring-system-dms-2830f3008c81


THANK YOU