# 科技部補助專題研究計畫成果報告
# 期末報告

## 睡眠呼吸障礙之監測與矯正輔助系統研發

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中 華 民 國 103 年 12 月 22 日

中文摘要： 一人的一生有三分之一的時間用在睡眠上，不良的睡眠品質對於生理及心理健康皆會造成不良的影響，高齡者更常為了不同程度的睡眠呼吸障礙感到困擾。根據調查統計，在台灣估計有約52%會打鼾，超過五十萬人患有阻塞性睡眠呼吸中止症候群(Obstructive Sleep Apnea Syndrome, OSAS)。OSAS治療方式包括：顎咽部手術、陽壓式呼吸器、口腔裝置器、止鼾枕等，價格不一且效果也不顯著。

本計畫首先利用整夜進行PSG診斷之長時間血氧飽和濃度序列資料集共544筆，透過實數型基因演算法(Read-Coded Genetic Algorithms, RCGA)進行睡眠呼吸障礙偵測演算法之改良開發；繼之以多通道生理訊號閘道器為核心，接收血氧脈搏探針之即時感測數據以偵測人體睡眠生理訊號傳送至系統晶片；當演算法分析判斷為產生睡眠呼吸障礙時，系統晶片可驅動警示感測單元；協助使用者改變睡姿，並偵測睡姿改變的有效性，對於睡眠呼吸障礙者將可產生矯正作用。

中文關鍵詞： 阻塞性睡眠呼吸中止症候群、血氧、實數型基因演算法、監測與矯正輔助系統

英文摘要： Sleep quality is essential to the physical and mental health. Older adults in particular have different levels of sleep disorders. According to the survey, estimated that about 52 percent of Taiwanese will snore and more than fifty million people suffer from obstructive sleep apnea syndrome (OSAS). OSAS treatment methods include: jaw throat surgery, continuous positive airway pressure (CPAP), dental fixtures, snoring pillow, etc. The price is varying and the effect is not significant.

Firstly, the research team applied the Read-Coded Genetic Algorithms (RCGA) with the clinical sleep time series – SpO2 signals for developing a better sleep disordered breathing detection algorithm. By using the physiological signal gateway as the core, this project will integrate this system chip with an oxygen pulse to receive human sleep physiological signals, to detect sleep disordered breathing, to drive alarm sensing unit to help users change their sleep position, and to identify the effectiveness of sleeping position changing.

英文關鍵詞： OSAS, SpO2, RCGA, monitoring and correction auxiliary system

# 中文摘要


一人的一生有三分之一的時間用在睡眠上，不良的睡眠品質對於生理及心理健康皆會造成不良的影響，高齡者更常為了不同程度的睡眠呼吸障礙感到困擾。根據調查統計，在台灣估計有約 52%會打鼾，超過五十萬人患有阻塞性睡眠呼吸中止症候群(Obstructive Sleep Apnea Syndrome, OSAS)。OSAS 治療方式包括：顎咽部手術、陽壓式呼吸器、口腔裝置器、止鼾枕等，價格不一且效果也不顯著。

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# Abstract

Sleep quality is essential to the physical and mental health. Older adults in particular have different levels of sleep disorders. According to the survey, estimated that about 52 percent of Taiwanese will snore and more than fifty million people suffer from obstructive sleep apnea syndrome (OSAS). OSAS treatment methods include: jaw throat surgery, continuous positive airway pressure (CPAP), dental fixtures, snoring pillow, etc. The price is varying and the effect is not significant.

Firstly, the research team applied the Read-Coded Genetic Algorithms (RCGA) with the clinical sleep time series – SpO2 signals for developing a better sleep disordered breathing detection algorithm. By using the physiological signal gateway as the core, this project will integrate this system chip with an oxygen pulse to receive human sleep physiological signals, to detect sleep disordered breathing, to drive alarm sensing unit to help users change their sleep position, and to identify the effectiveness of sleeping position changing.


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# 壹、緒論

## 一、 前言

根據最新社會趨勢與文獻得知[1]，隨著經濟的發展、醫療的進步與預防保健的推展，國民的平均餘命增長，社會人口結構逐漸呈現高齡化現象，我國 65 歲以上的老年人口於 1993 年 9 月底計 1,485,200 人，佔總人口數 7.09%，達聯合國世界衛生組織所訂的高齡化社會指標；內政部統計處 2005 年底戶籍登記資料顯示 65 歲以上者 221 萬 6,802 人佔總人口 9.74％，且扶老比（65 歲以上人口比 15-64 歲工作年齡人口）逐年緩慢上升至 13.6％；65 歲以上老年人口比 0-14 歲人口之老化指數為 52.05％，再創歷年新高，而 2031 年老年人口估計會佔總人口的 20.07％，即每五人中就有一位是老年長者。

睡眠障礙是銀髮族群中常見的問題。人的一生有三分之一的時間都在睡眠中度過，睡眠品質的好壞影響了身體健康及生活品質。國內目前睡眠障礙人口劇增，根據我國行政院主計處 2012 年 8 月中旬發佈，目前我國人口有睡眠障礙已超過三分之一[2]，亞洲睡眠協會（Asian Sleep Research Society, ASRS）針對菲律賓、泰國以及台灣所作之「2000 年睡眠調查」，亦發現睡眠問題在亞洲普遍嚴重。睡眠醫學研究指出[3-9]若長期有睡眠障礙，容易產生記憶力減退、情緒不穩，甚至會影響免疫系統因而生病。睡眠品質好壞影響個人健康甚鉅，研究顯示 SAS 和高血壓、糖尿病、代謝症候群、心血管疾病、夜尿症，甚至憂鬱症都有極密切的關係。嚴重者還可能發生睡眠呼吸中止症候群(Sleep Apnea Syndrome, SAS)。根據統計睡眠呼吸障礙（Sleep Disordered Breathing, SDB）的疾病盛行率佔總人口數的 5%以上，40 歲以上的中年男性，甚至高達 25%[10]。相較於其他年齡，銀髮族有比較高比例的睡眠呼吸障礙，根據台灣社區老年人的身心調查研究顯示[11]，但同時也發現，大多數的銀髮族並未積極求醫或未能接受有效的治療。

一般人面對睡眠障礙問題時，嚴重時通常需要至醫院進行睡眠障礙的診斷評估，由醫生透過專業醫療儀器及醫院專用睡眠障礙量測空間進行相關症狀評估及相關的參數收集後，方可進行適當的醫療診治。但是一般的睡眠障礙診療，需要至醫院進行一整晚的睡眠障礙的診斷方可得知相關數據的作法，不但造成病患不便，同時亦需要花費相當高昂的醫療成本。另一方面，目前睡眠呼吸障礙治療方式包括：顎咽部手術、陽壓式呼吸器、口腔裝置器、止鼾枕等，價格不一且效果也不顯著。所以，如何便利且平價化地對於初期睡眠障礙病患提供矯正輔助工具仍有相當改善空間。

## 二、 研究目的

本計畫首先利用睡眠臨床時序資料-血氧訊號與鼾聲訊號，透過實數型基因演算法(Read-Coded Genetic Algorithms, RCGA)進行參數優化，提出改良型睡眠呼吸障礙偵測演算法。繼之以多通道生理訊號閘道器為核心，接收即時血氧感測數據傳送至系統晶片，當演算法分析判斷為產生睡眠呼吸障礙時，系統晶片可驅動警示感測單元，協助使用者改變睡姿，並偵測睡姿改變的有效性，對於睡眠呼吸障礙者將可產生矯正作用。

# 貳、文獻探討

## 一、睡眠呼吸障礙（Sleep Disordered Breathing, SDB）

依據國際睡眠障礙分類( International Classification of Sleep Disorder, ICSD )，將睡眠障礙分成八類，包括失眠( Insomnia )、過眠( Hypersomnia )、過度嗜睡、睡眠呼吸障礙( Sleep Disordered Breathing, SDB )、睡眠週期障礙、異睡症(Parasomnia)和其他未分類疾病等。其中睡眠呼吸障礙(SDB)是一種很常見的睡眠疾病。顧名思義，它是睡眠的時候呼吸發生了問題，在臨床上包括：上呼吸道阻力症候群(Upper Airway Resistance Syndrome, UARS)，阻塞性呼吸不全(Obstructive Hypopnea)，阻塞性睡眠呼吸中止症候群(Obstructive Sleep Apnea Syndrome, OSAS)等。引起這一類疾病的主因，與睡眠時上呼吸道的狹窄或塌陷有直接的關係。解剖上最常見的位置，是鼻腔、口咽和下咽(如舌頭後方)的空間。再者，因為重力吸引的關係，喉頭和舌後空間躺著的時候比坐著或站著時狹窄。而睡著之後，尤其在快速動眼期，肌肉的張力會降低，甚至完全喪失，此時呼吸道的空間會比清醒時更加狹窄，更容易造成睡眠時呼吸的問題。

「阻塞型睡眠呼吸中止症」(OSAS)是指：在睡眠過程中，上呼吸道重複地發生阻塞，使口鼻的呼吸氣流減少或停止 10 秒鐘以上，有時會合併有缺氧或醒覺(Arousal)。以睡眠呼吸中止指數(Apnea Hypopnea Index, AHI)判別其嚴重程度：AHI＝呼吸中止(Apnea)加上呼吸不足(Hypopnea)的次數/每小時。目前根據美國睡眠醫學會的定義，呼吸中止指數(AHI)在 5 到 15 之間是輕度，15 到 30 之間是中度，30 以上是重度[10]。有許多研究顯示 OSAS 有以下危險因子：打鼾、年齡、性別、身體質量指數(肥胖)、頸圍、膽固醇、血壓、扁桃腺肥大、顱顏頸部結構異常(包括上顎與下顎發育不好、咽頭軟組織或淋巴組織增生、鼻中隔彎曲)、某些內分泌疾病(如甲狀腺機能低下、肢端肥大症)、酒精或鎮定劑或安眠藥、家族病史等，與 OSAS 呈現顯著相關[10, 12-14]。根據統計，阻塞性睡眠呼吸中止症候群(OSAS)的盛行率佔總人口數的 3%以上，在 30 至 60 歲的中年人中，男性的發生率約 4%，而女性的發生率約 2%；40 歲以上的中年男性，甚至可以高達 25%[10]。許多研究顯示 OSAS 和高血壓、糖尿病、代謝症候群、心血管疾病、夜尿症，甚至憂鬱症或癌症都有密切的關係。

## 二、睡眠呼吸障礙之診斷-多導睡眠監測儀(PSG)

多導睡眠監測儀(Polysomnography, PSG) 是國際公認的診斷 SDB 的黃金準則(Gold Standard)，也是診斷打鼾或 OSAS 最重要的主要檢查方法[15]，如圖 1 所示。多導睡眠監測是在特定的睡眠中心進行的一種夜間試驗，多種監控器被用來測量睡眠時各種不同的生理訊號，圖 2 為試驗者使用 PSG 量測情形，常見的測量參數包括：

(1) 呼吸相關監測，如鼾聲、鼻部氣流、呼吸動作、血氧濃度。
(2) 睡眠階段判別，如腦波圖(Electroencephalography, EEG)與眼動圖(Electrooculogram, EOG)。
(3) 身體活動監測，如肌電圖(Electromyography, EMG)與體位感測(Body Position)。
(4) 其他感測訊號，如心電圖(Electrocardiograph, ECG)。

根據 PSG 監測結果，不僅能對 OSAS 作出診斷，而且能對其嚴重程度作出判斷，其中有兩種評估方法經常被引用來概括睡眠監測結果[3]：

(1) 通過計算夜間睡眠呼吸中止及呼吸不足的數量的總和的平均值，來計算每小時呼吸紊亂的平均值，也就是呼吸障礙指數(RDI)或稱睡眠呼吸中止指數(AHI)，成人 AHI 大於等於 5 即可定義為睡眠呼吸中止症候群(OSAS)。
(2) 睡眠呼吸中止綜合徵時最低血氧飽合度，雖然沒有具體提示睡眠呼吸中止綜合徵的數值，但低於 85%可以斷定為睡眠呼吸中止症候群(OSAS)。

根據文獻指出，國人至少有 45 萬人患有 OSAS 的睡眠呼吸障礙，但是施行相關的檢測與治療必須耗費大量時間與金錢才能完成，這並不是一般民眾可以負擔的。一般而言，使用 PSG 進行睡眠監測必須在專業的睡眠中心進行，並由專業護理人員進行操作，過程中必需黏貼大量的感測器，包括腦波電極、心電圖電極、肌電圖電極、鼻部氣流感測器、胸腔活動感測帶以及血氧計等，在不熟悉的環境以及配戴大量感測裝置的狀況下，往往反而對受測者的睡眠造成影響。在專業的睡眠中心以 PSG 做整晚的睡眠監測，成本相當昂貴，近年來由於可攜式多項生理監測儀的出現，患者可於家中進行睡眠監測，但醫護人員仍需至受測者家中進行感測器的黏貼與儀器的設置。隨著感測器技術的進步以及睡眠研究的發展，許多學者致力研究如何以更輕巧、更簡便、非接觸式的感測技術做睡眠監測，因之，使得 OSAS 監測上的研究方向多為以較低成本、較少的特徵變數估測 AHI 但依然可以有不錯的正確率來作為 OSAS 診斷輔助為目標，來簡化傳統睡眠呼吸中止症診斷的流程與負擔，例如單以心電圖(ECG)、鼾聲(Snore)、血氧(SpO2)、呼吸器流訊號波峰值(Peaks of Flow Rate Signals)等變數來估測[10, 12, 13, 15, 16] 。

圖 1 多導睡眠監測儀（PSG）[17]

圖 2 使用 PSG 量測圖

**三、睡眠呼吸障礙之治療或矯正**

睡眠呼吸障礙的治療概念即是改善上呼吸道的狹窄或塌陷所造成的呼吸量不足或暫停，其治療方式分成醫學治療和外在行為矯正[10]：口服藥物治療、連續氣道正壓呼吸器(CPAP)、口內裝置、手術治療與保守療法(側姿睡眠)等方式，不過並不是所有人能夠或都會願意接受這些治療。睡眠時使用鼻部正壓呼吸器(Continuous Positive Airway Pressure, CPAP)是一種有效的治療方式，為目前睡眠呼吸障礙的第一線治療。但由於 CPAP 會有漏氣、呼氣阻力、面罩壓迫、氣流乾燥與攜帶不便等問題，造成病患接受此種治療的意願不高和治療過程的持續配合度低。

外在行為矯正治療雖然無法根治 SDB 的症狀，但是可以有效改善鼾聲與缺氧的程度。例如配戴於手腕處之手錶型振動器或電脈衝器刺激睡眠者[18, 19]、或輔助改變睡姿來減輕鼾聲與 OSAS 的發生[19-21]。因此，如何以較低成本設計一套易於攜帶的睡眠呼吸障礙(SDB)即時監測警示系統，可提供患有鼾聲與 OSAS 的病患使用，適時地提醒患者藉由改變睡姿來改善其睡眠品質，是本計畫的研究動機。

**四、睡眠呼吸障礙與血氧飽和濃度偵測**

血氧飽和濃度（SpO2）檢查主要是測量呼吸相關之動脈血氧含量的變化，它也是代表血液中全部血紅素之氧化血色素的百分比，正常人清醒期的血氧飽和濃度約為 97%。血氧飽和濃度可代表心肺能力是否正常，因在大氣中的氧氣從呼吸道進入肺泡，經由擴散作用至肺微血管，與血紅素結合後藉著以心臟為動力的動脈血流至微血管供組織細胞使用，產生的二氧化碳及剩下的氧氣經由靜脈血回流到肺微血管而完成呼吸循環[22]，達到身體正常平衡運作。而血液中運送氧氣的能力來自於心臟功能強弱

與否，所以，若心臟或胸腔功能有狀況，其身體血液含氧量自然降低。典型阻塞型睡眠呼吸中止是指在睡眠過程中引發的間歇性呼吸暫時中止得情況，其患者睡眠週期簡易示意圖如圖 3 所示，患者在入睡之後（Fall Asleep)，咽喉部的肌力（Throat Muscles）漸漸下降，之後上呼吸道塌陷（Upper Airway Collapse)，此時呼吸氣流下降所以造成血氧飽和濃度(SpO2%)下降，而心臟為了減少氧耗故心率(Heart Rate）也會降低，過一段時間之後若呼吸氣流依舊無法恢復，腦波會出現暫時覺醒（Arousal)，刺激心率(Heart Rate)加速並提升咽喉部肌力(Throat Muscles)，使得上呼吸道再度打開(Upper Airway Open)，然後血氧飽和濃度（SpO2%）恢復，之後再進入睡眠狀態。[23]

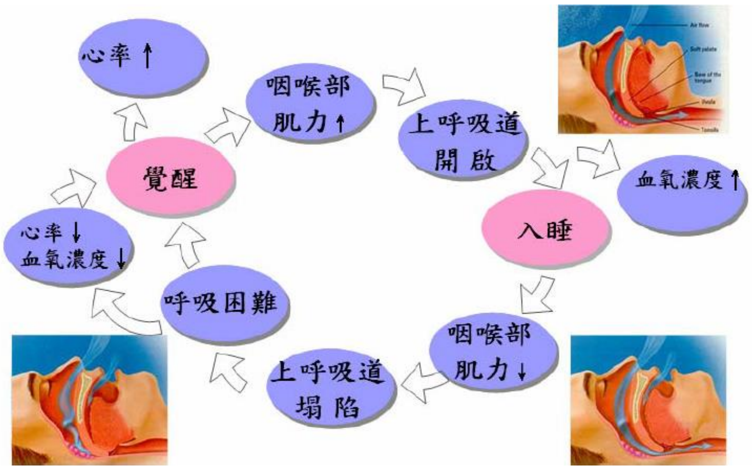



圖 3 睡眠呼吸中止流程示意圖 [23]

前人有關利用血氧訊號進行 OSAS 偵測演算法[24, 25]可以蓋分為兩大類：時間域特徵指標法與頻率域特徵指標法，如表 1 所示。其中時間域特徵指標法方面最簡單的如：SpO2_Min(整夜血氧濃度訊號最小值)、SpO2_Mean(整夜血氧濃度訊號平均值)、SpO2_Median(整夜血氧濃度訊號中值)、TI(整夜血氧訊號低於α%的比例)、DI(整夜血氧訊號低於α %的次數)、Delta Index(整夜非重疊 12 秒視窗中血氧濃度差值的均值)、ODI(整夜血氧濃度下降β%並持續 t 秒的次數)以及 Complexity(血氧濃度變化的複雜程度)，目前文獻上以 ODI 居多；另外還有四種頻域上的特徵：STotal(所有頻帶面積和)、S30-70(頻帶 0.01~0.033Hz 的面積和)、SRatio(S30-70/STotal)、PA(0.01~0.033Hz 的最大值)。由於時間域特徵指標法不論是準確率或計算效能都比頻率域特徵指標法來的好[24, 25]，所以本計畫採用時間域特徵指標法進行血氧偵測 OSAS 演算法的開發、測試與驗證。

表 1 各種時域與頻域的血氧濃度特徵指標整理[25]

| 特徵型態 | 說明 | 相關文獻 |
|---|---|---|
| 時域特徵 | | |
| $SpO_2$_Min | 整夜血氧濃度訊號最小值 | Heter et al., 1999; |
| $SpO_2$_Mean | 整夜血氧濃度訊號平均值 | Heter et al., 1999; Choi et al., 2000 |
| $SpO_2$_Median | 整夜血氧濃度訊號中值 | Choi et al., 2000 |
| TI | 整夜血氧濃度訊號低於 $\alpha$%的比例 | Heter et al., 1999; Choi et al., 2000; Urschitz et al., 2003; Magalang et al., 2003 |
| DI | 整夜血氧濃度訊號低於 $\alpha$%的次數 | Urschitz et al., 2003 |
| Delta_Index | 整夜非重疊 12 秒視窗中血氧濃度差值的均值 | Levy et al., 1996; Choi et al., 2000; Magalang et al., 2003 |
| ODI | 整夜血氧濃度下降 $\beta$%並持續 t 秒的次數 | Zamarron et al., 1999; Chiner et al., 1999; Vazquez et al., 2000; Choi et al., 2000; Urschitz et al., 2003; Magalang et al., 2003; Ayappa et al., 2005 |
| Complexity | 血氧濃度變化的複雜程度 | 本文 |
| 頻域特徵 | | |
| $S_{Total}$ | 所有頻帶的面積和 | Zamarron et al., 1999; Zamarron et al., 2003 |
| $S_{30\text{-}70}$ | 頻帶 0.01~0.033Hz 的面積和 | Zamarron et al., 1999; Zamarron et al., 2003 |
| $S_{Ratio}$ | $S_{30\text{-}70}/S_{Total}$ | Zamarron et al., 1999; Zamarron et al., 2003 |
| PA | 0.01~0.033Hz 的 Maximum amplitude | Zamarron et al., 1999; Zamarron et al., 2003 |

本研究從相關文獻共整理出4個前人所提出之指標法（DI_β、TI_α、Delta Index、ODI-B-D-L）進行說明如下:

DI_β：整夜血氧飽和濃度下降至低於 β%的次數除以總測量時間。由文獻可知，設定下降參數為3%，基準線為整夜血氧飽和濃度下降至低於92%，持續時間須超過1秒，測試的結果會有較佳結果[26, 27]。

TI_α：整夜血氧訊號下降至低於 α%的次數占總測量時間的比例。基準線為整夜血氧飽和濃度下降至低於90%[28, 29]。

Delta Index：整夜記錄中以非重疊的方式計算每12秒視窗中血氧濃度差值得絕對值和 ψ，並最後取整夜所有視窗值的平均[28, 29]。

ODI-B-D-L：ODI(Oxyhemoglobin desaturation index)系列特徵較其他特徵指標有較佳的預測效果[28, 29]。ODI-B-D-L 特徵指標以下降門檻比例、基線(Baseline)計算方式、下降持續時間等三個參數作為描述血氧飽和濃度下降情形，如圖 4 所示。D 為下降幅度參數，因正常人呼吸事件也有可能出現微幅下降的情形，故不能設定太小，通常為3%或4%，而基線 B 是做為血氧飽和濃度下降的基準線，可分為固定基線法、非固定基線法。前人文獻使用非固定基線有較佳的預測效果，採用待測訊號前60秒最大前 20%的平均值。下降持續時間 L 則為血氧濃度較基線下降 D%的持續時間，常見有 1 秒、2 秒及 5 秒。

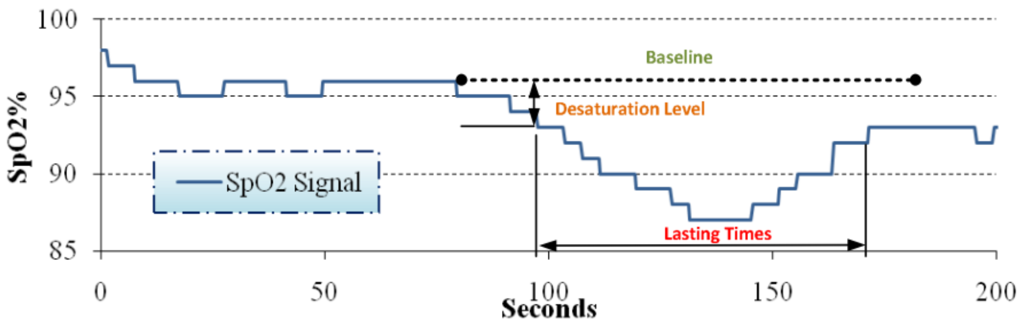



圖 4 ODI-B-D-L 指標之參數定義

**五、睡眠呼吸障礙之監測或警示系統**

在睡眠呼吸障礙之監測系統方面，隨著微處理器技術的發展，從1990年代開始，可攜式的監測設備得以實現，如[30, 31]Penzel et al.建構了一套適合居家環境中使用的睡眠呼吸監測系統，命名為MESAM IV，以數位方式記錄血氧濃度、心跳、鼾聲、身體姿勢，並利用血氧濃度、心率變化、間斷鼾聲等指標進行鼾聲與 OSA 的判斷評估。[32] [28]開發了一套適合居家環境下使用的非侵入性遠距健康監測系統，利用心電圖、體重、身體活動、鼾聲等訊號的監測，評估受測者的健康與睡眠狀態。[32, 33]利用心電圖、床上身體活動感測器、鼾聲感測器，針對臥室環境打造了非察覺性的睡眠監測系統。[18, 34]基於分散式遠距照護系統架構下，設計可攜式鼾聲與呼吸中止症監測系統，簡稱為 SOD (Snoring and OSAS symptom Detector)。[14, 16]利用 OSAS 造成的鼾聲與一般的鼾聲在時域上的變異量不同，還有發生鼾聲時間間隔上的特性，可用來偵測目前是否發生睡眠呼吸中止，評估自身是否患有睡眠呼吸中止症。由於睡眠中發生呼吸暫止或淺呼吸時通常會伴隨血氧飽和濃度的下降(Oxygen Desaturation, OD)，因此也有學者利用血氧脈搏感測器量測病患睡眠之血氧飽和濃度訊號，開發相關血氧偵測演算法[12, 15, 27, 35-39]進行 OSAS 的監測。部分學者[20, 37, 40, 41]則以心電圖基礎，利用心電圖上的心律週期性變動特徵開發演算法來進行 OSAS 之判斷。

在睡眠呼吸障礙之警示系統方面，聲響警示與電刺激常被應用來降低鼾聲或呼吸中止症發生的頻率。如[30, 36, 40, 42]所設計的呼吸中止症監測器中利用聲響的方式警示睡夢中的患者，患者受到聲響刺激而恢復呼吸，降低呼吸中止症的發生頻率。而[18, 31, 41, 43]則是用低週波電脈衝刺激的方式降低患者 OSAS 的發生頻率，當系統偵測到長度超過 5 秒的呼吸中止徵狀，系統會以頻率 50 Hz 的低週波脈衝刺激使用者皮膚，當呼吸恢復 10 秒後隨即停止。[18, 34]設計的 SOD 系統亦藉由低週波訊號刺激使用者皮膚，期能藉此降低 OSAS 發生的可能性。[19]設計頭部抬升機構將床頭最大可抬高 30 度完成具止鼾功能之智慧型床墊開發。[44]在睡眠醫學年會發表以專利「智慧型止鼾枕」介入 OSAS 合併打鼾患者之臨床成效評估，證實藉由改變睡姿進行矯正輔助治療，確實有調節改善 AHI 及鼾聲之效果。

本研究團隊[20]過去應用藍芽無線血氧感測器、Zigbee 無線感知網路、震動刺激模組、與即時判斷 OSAS 主機系統的整合，經由血氧訊號收集、主機端訊號分析、刺激訊號派送，建置完成 OSAS 之監測與警示雛形系統。但其睡眠呼吸障礙之偵測演算法的準確性約僅 7 成、感測設備與刺激模組須分別佩戴，活用性不足，加上藍芽無線血氧感測器的單價成本過高(約 5 萬元)、通訊模組同時採用 Bluetooth 與 Zigbee 稍嫌複雜。為了改善上述問題，進行本計畫相關軟硬體開發。

**六、基因演算法**

在競爭日益激烈的今日，最佳化處理 (Optimization)已成為工程設計與商業模式是否成功的重要因素。近年來各領域基於需要，已逐漸接受所謂演化式計算或基因演算法或作為有效的大型複雜系統最佳化處理方式。演化式計算為人工智慧研究領域之一，其中的方法統稱為演化式演算法 (Evolutionary Algorithms, EA)：包含 Genetic Algorithm (GA, 基因演算法)、Evolutionary Strategy (ES, 演化式策略)、Genetic Programming (GP, 基因規劃)、Particle Swarm Optimization (PSO, 粒子群算法)、Immune Algorithm (IA, 免疫演算法)等等。這類演算法以模仿自然界的演化機制來解決一些複雜的問題，例如搜尋與最佳化問題。演化式演算法的「隨機性質」以及「仿效自然」的作法有別於傳統的演算法，並為其帶來強大的解題能力以及許多演算法上設計上的可能性。目前演化式演算法已廣泛用於機器學習、數值與組合最佳化、多目標最佳化、生物資訊、以及工程設計等問題上。GA 是所有 EA 理論模型中最廣為人知、也是應用最多的演化式演算法。

GA 以達爾文進化論「自然選擇」及「適者生存」的概念設計，由美國密西根大學學者 John Holland 於 1975 年所提出，同年他的學生 De Jong 發表一結合 Holland 的概型(Schema)理論與本身的研究，證實了複製、交配與突變等機制在 GA 上的功能，並由 Goldberg 於 1987 在電腦系統上實現。基因演算法的運作可包含五個核心模組：選擇/複製(Selection/Reproduction)、交配(Crossover)、突變(Mutation)、評估適應(Evaluation Fitness)、菁英(Elite)；將最佳化問題之設計為二位編碼(Binary Code)字串，由這些字串所組成的設計形成群族，模擬生物演化的原理求得最佳解。經過將近三十年的不斷發展，GA 已被廣泛應用到求解最佳化問題、最佳化控制、機器學習、圖形辨識、生產排程、資料搜尋的領域上[23]。GA 強調基因型的轉變，將問題的可能解答經過編碼成為基因形式，利用遺傳運算子演化來找到最佳解。這些遺傳運算子是模擬生物界的演化程序，主要機制有選擇、交配與突變，其中交配是 GA 的主要運算子，而突變是次要的。許多前人文獻大都採用位元編碼基因演算法 (Binary Coded Genetic Algorithm；BCGA)進行問題編碼，並使用傳統 BCGA 之選擇、交配、突變機制進行演化，故計算效率通常會較差。而近來文獻中 BCGA 與 RCGA（Real Coded Genetic Algorithm；實數編碼基因演算法）在醫學資料探勘的比較，發現 RCGA 的探勘效率與整體準確性都比 BCGA 來的更好[45]。本研究團隊以往利用多菁英保留、實驗設計、適應性突變等機制改善原有 RCGA 的選擇、交配、突變運算，並進行高維度函數最佳化的測試，改善效能比前人文獻都來的顯著有效[46]。

# 參、研究方法

本計畫之研究方法將由下列四方面進行說明：(一)系統架構；(二)偵測演算法研發；(三)相關硬體整合；(四)系統效益評估。

## 一、系統架構

本研究開發完成的系統結構如圖 5 所示，系統流程如圖 6 所示。

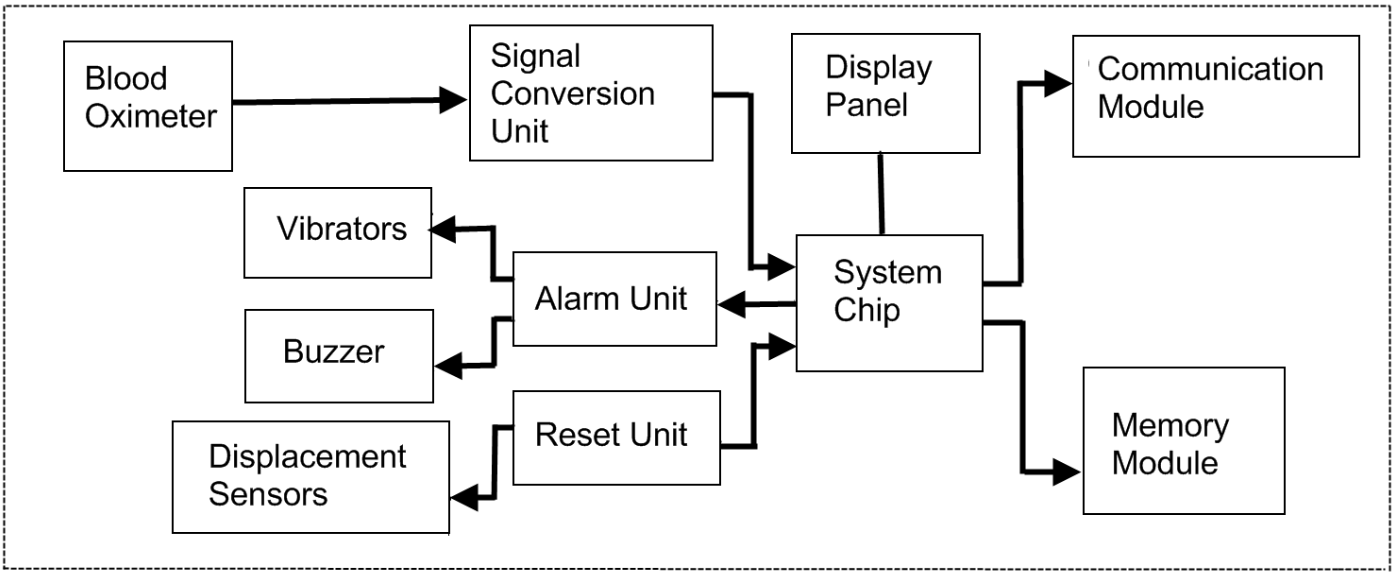



圖 5 系統結構圖

本研發系統整體運作流程：當人體進入睡眠狀態時，該生理訊號機(本計畫以血氧探針為實施例)會感測人體睡眠生理訊號，並透過該訊號轉換單元將相關的訊號傳遞至系統晶片，當系統晶片分析判斷人體在睡眠障礙狀態時，此時，該系統晶片會產生一訊號驅動該回饋警示單元(本計畫以震動器、蜂鳴器為實施例)產生作動以輔助使用者改變睡眠姿勢，進而降低睡眠障礙情況，使用者若於此階段被改變睡眠姿態時，其身體會產生一動作變化，令該重置單元之位移感測器產生一位置之變化，而產生一訊號至該系統晶片，使該系統晶片可知該使用者已經變換睡眠姿勢而使該回饋警示單元停止動作，若在警示單元震動數次仍無法讓使用者改變睡眠姿態時，此時警示單元之蜂鳴器會再進行一聲音訊號之警示，除可喚醒使用者外亦可告知他人，使用者發生睡眠障礙之情況而可協助喚醒使用者，而該警示單元於本實施例中其係與系統晶片連結設於腕帶上，亦可依不同的需求而可放置在不同的地方，例如與主機分離置於枕頭內，或置於穿戴物上。另外，可將該系統晶片所接收之相關資料直接儲存於記憶模組內，待需與醫療人員討論相關之進度時，即可將該記憶模組取下，取下後可由醫療人員讀取相關之內容，以進行適當之診療者，使用時，亦可直接透過顯示器面板得知相關之訊息者，其整體系統流程圖可如圖 6 所示。

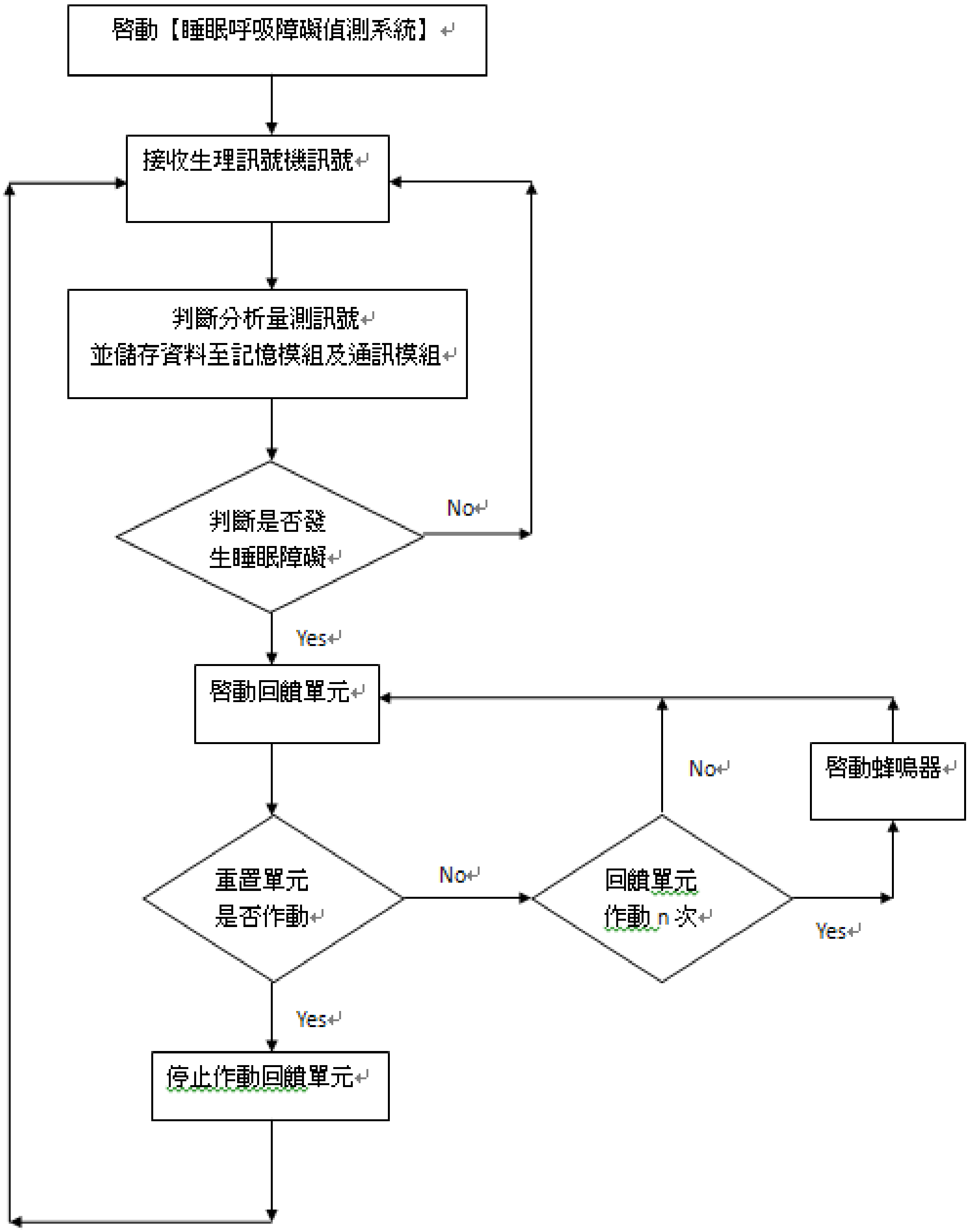



圖 6 系統流程圖

## 二、偵測演算法研發

本計畫開發之阻塞型呼吸中止症合併打鼾之偵測演算法係應用本土 OSAS 臨床資料集進行率定與驗證，臨床資料集之來源係由本計畫共同主持人丁化醫師過去幾年在中山附醫睡眠門診之研究成果提供，採回溯性且去關聯性之無隱私權疑慮的個案控制進行研究目前共募集 544 位睡眠障礙受試者，收集變項含括整晚的血氧訊號與鼾聲訊號之時間序列與 AHI 診斷值。

本研究提出之改良血氧飽和濃度偵測方法，其處理流程如圖 7 所示：

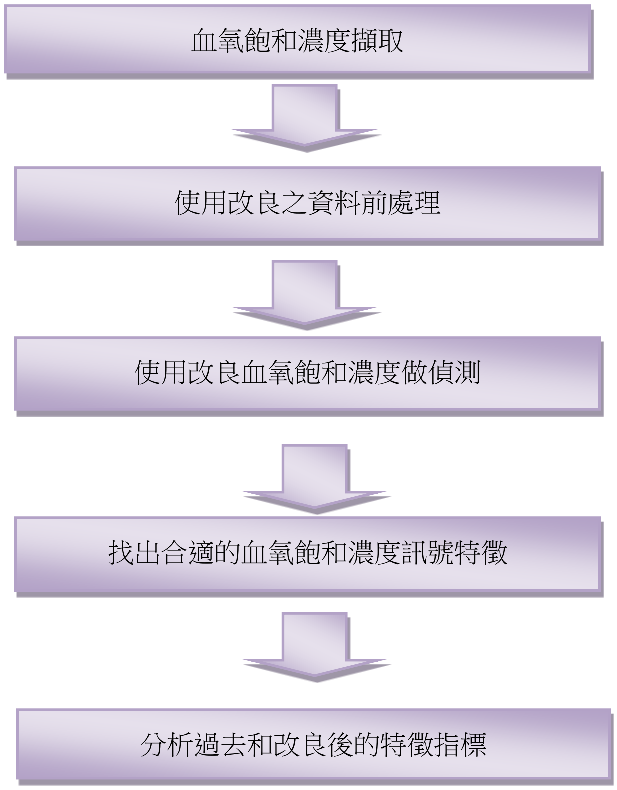



圖 7 改良型血氧飽合濃度偵測法之流程圖

本計畫的主要工作是設計合適的血氧濃度訊號特徵來改善對睡眠呼吸中止症的預測。但在進行特徵計算之前要先介紹血氧飽和濃度訊號用於排除雜訊影響的訊號前處理方法[5]。雜訊通常來自各項無法控制的干擾，本研究改良的前處理方式包含以下三個步驟，如圖 8 所示：

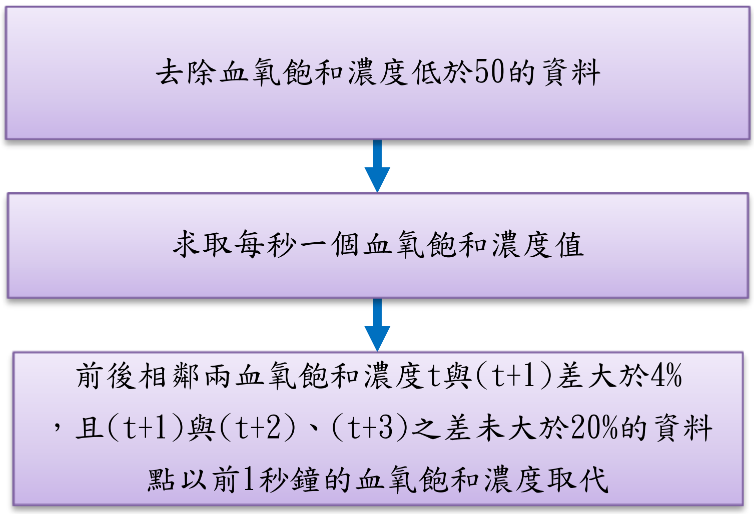



圖 8 改良血氧飽和濃度資料前處理

繼之，本研究再透過 RCGA 改良血氧飽和濃度偵測方法，整體演算流程如圖 9 所示。

1. 搜尋4個參數(待判7斷訊號時間前x秒血氧飽和濃度值最大前y%之平均值、平均每小時有多少次血氧飽和濃度值會持續L秒以上低於其基線至少D%)來求得血氧飽和濃度指標。
2. 在以求得的ODI與真實AHI的算出相關係數值。

3. 假如迭代完成選擇相關係數值最好者。

4. 輸出最佳相關係數的血氧飽和濃度指標。

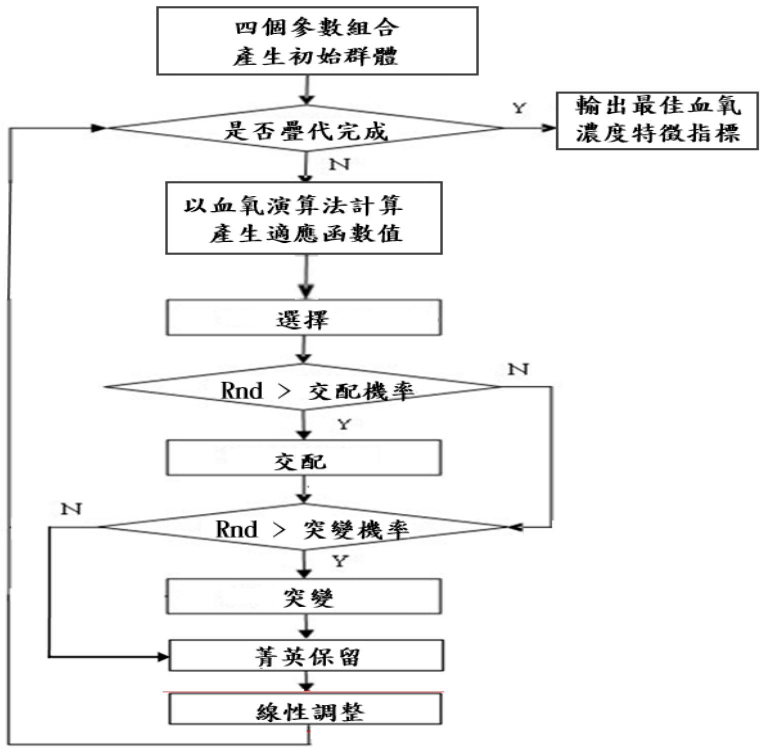



圖 9 改良型血氧飽和濃度偵測演算法

**三、相關硬體整合**

單元模組包含：系統晶片單元、生理訊號測量單元、回饋單元與重置單元、記憶模組等進行硬體整合加值運用，茲分別說明如下：

(1) 系統晶片單元

本研究將上述開發之改良型血氧偵測演算法寫入 PSoC 晶片，利用此 PSoC 晶片同步接收使用者之血氧濃度、脈搏心率等瞬時量測值，並可將量測資料儲存在 SD 卡上方便後續資料應用。

(2) 生理訊號測量單元-血氧脈搏探針

血氧濃度(Bloood Oxygenation)是指血液中血紅素(Hemoglobin, Hb)攜帶氧的程度，人體內的組織與器官都藉由呼吸與循環系統提供所需的氧氣來維持運作，因此可藉由血氧濃度評估人體的呼吸與循環系統功能，也是生命跡象的重要指標。現今常見的光學式脈搏血氧濃度計，即是利用此光學特性做血氧濃度量測。手指與耳垂部位組織層較薄，且充滿微血管與血液貫流，相當適合作為量測血氧濃度的量測點，而考量到使用上的便利性，目前大多數產品採用手指作為量測點。血氧濃度計上裝設兩個可發出不同波長的發光二極體(Light Emitting Diode, LED)光源，以 805nm（或 940nm）近紅外光作為 Hb 與 HbO2 對光的吸收率的比較基準，另一 660nm 紅光則用來偵測 Hb 與 HbO2 的光吸收率差異，量測時兩光源交替照射，穿透手指組織與血液的光源由一個光感測器(Photo Detector)接收，利用光學感測與光調變技術比較兩穿透光源的不同強度，經過訊號處理後，即可換算出血氧濃度數值。

此外，由於心臟收縮與舒張時，動脈血液與皮膚組織對光吸率會呈週期性變化，靜脈血液中光吸收率則變化較小；由動脈血液之光吸收率變化，可得知脈搏的跳動，因此光學式血氧濃度計除了血氧濃度的量測外，也可提供脈搏偵測。在心臟搏動期間，光被身體組織所吸收的量會有強弱變化，將訊

號轉為電壓顯示，可呈現出脈搏波。由相關研究[47, 48]得知，利用 SpO2 量測之峰值點的確可代替 ECG 之 R 點計算心跳。且 SpO2 比 ECG 之量測方法較簡便，不需進行傳統電極貼片式量測，更適用於遠距醫療及老人照護。現有的醫學報導[49]將心率帶測出的 R-R interval 和 ECG 測出的 R-R interval 去做分析比對，其相關性約在 0.927 到 0.998，證明兩者間有很高的相關性。因此，由血氧脈搏探針所量測出的瞬時脈搏值可用來偵測計算心律不整。

雖然利用血氧脈搏計進行睡眠狀態的判定，並不如使用 PSG 來得準確，但在 OSAS 的判別上已具有相當的準確率。本計畫利用系統晶片 PSoC 整合血氧脈搏探針，朝著降低開發成本和提供可攜式去落實量測血氧濃度與脈搏的方便性。

(3) 回饋單元與重置單元

本計畫利用系統晶片 PSoC 整合震動器、蜂鳴器與位移完成回饋單元與重置單元建置。

(4) 記憶模組

本計畫利用系統晶片 PSoC 整合 micro-SD 卡模組，提供 8GB 以上記憶容量可供量測資料儲存。

**四、系統效益評估**

科技接受模型 (Technology Acceptance Model, TAM)是 Davis (1989)[24]修正 Ajzen and Fishbein's 理性行為理論這個模式所提出的，主要用來解釋電腦和使用者行為間的關係，目前調查使用者接受度和滿意度，最常使用的就是科技接受模型，其目的是在說明及預測使用者對系統的接受度。科技接收模型已被廣泛的應用及測試且多數的資訊科技研究者接受這個理論。「科技接受模型」以「自覺易用性(Perceived Ease of Use)」和「自覺有用性(Perceived Usefulness)」作為獨立變數,「使用者態度 (Attitude)」、「行為意圖(Behavioral Intention) 」、和「實際使用 (Usage Behavior)」為相依變數，研究彼此間關係。

本研究使用修正型科技接受模型[50]對系統使用者進行系統效益評估，主要分為相容符合性、自覺有用性、自覺易用性、信賴性、自覺成本、使用意願等六大構面來建構問卷題項。問卷設計與題數上採精簡為主，對每一假說設計將以兩～三題為主，在文句敘述將採淺顯易懂，力使受試者不會有壓力及不悅感，設計出共 13 道問卷題目，如表 2 所示。評估方式為受試者使用系統一段時間後，請受試者填寫問卷，問卷題目設計將採用李克特量表五點尺度（Likert），請施測人員以口述方式協助受試者無法填寫者進行回覆，受試對象為實際使用過本系統的患者，從問卷中量化分析本計畫所研發的系統是否會影響使用者的意願與滿意度。

表 2 受試者問卷

**第一部分 基本資料**

請勾選：

性別：□ 男 □ 女

年齡：□ 30↓ □ 31 ~50 □ 51～65 □ 65↑

是否知道自己有睡眠呼吸障礙: □ 是 □ 否

是否知道自己為呼吸中止症患者: □ 是 □ 否 (如勾選是請填寫下題)

是否知道自己的 AHI 指數: □ 是 □ 否 (如勾選是，請填寫 AHI 指數:_____)

**第二部分：睡眠呼吸障礙之監測與矯正輔助系統之使用接受度調查**

以下為針對此系統使用接受度調查(1 為非常不滿意，2 為不滿意，3 為普通，4 為滿意，5 為非常滿意)

| | 非常不滿意 | 不滿意 | 普通 | 滿意 | 非常滿意 |
|---|---|---|---|---|---|
| 1. 使用此系統(含軟硬體)符合我的生活型態 | 1 | 2 | 3 | 4 | 5 |
| 2. 使用此系統(含軟硬體)符合我的使用習慣 | 1 | 2 | 3 | 4 | 5 |
| 3. 此系統(含軟硬體)能夠測出我的睡眠呼吸障礙情形 | 1 | 2 | 3 | 4 | 5 |
| 4. 此系統(含軟硬體)能改善我的睡眠呼吸障礙問題 | 1 | 2 | 3 | 4 | 5 |
| 5. 此系統的使用流程易於操作與使用 | 1 | 2 | 3 | 4 | 5 |
| 6. 此系統的介面設計與顏色配置具舒適度 | 1 | 2 | 3 | 4 | 5 |
| 7. 我確信此系統(含軟硬體)提供非常好的功能 | 1 | 2 | 3 | 4 | 5 |
| 8. 我確信此系統(含軟硬體)能幫助了解我的睡眠呼吸障礙問題 | 1 | 2 | 3 | 4 | 5 |
| 9. 我認為要使用此系統(含軟硬體)的購置成本是昂貴的 | 1 | 2 | 3 | 4 | 5 |
| 10. 我認為要學習使用此此系統(含軟硬體)需花費許多時間成本 | 1 | 2 | 3 | 4 | 5 |
| 11. 我想要繼續使用此系統(含軟硬體)來了解自己的睡眠呼吸障礙狀況 | 1 | 2 | 3 | 4 | 5 |
| 12. 我將推薦此系統(含軟硬體)給親友們使用 | 1 | 2 | 3 | 4 | 5 |
| 13. 此系統(含軟硬體)若上市收費，我願意花錢購買 | 1 | 2 | 3 | 4 | 5 |

您對此系統的建議事項或待改進的地方:____________________________________________

# 肆、結果與討論

## 一、血氧偵測 OSAS 演算法

（1） 前人之血氧訊號指標法

本研究實作前人常用的四種血氧飽和濃度特徵之指標（DI_β、TI_α、Delta Index、ODI-B-D-L）。依照前人所提供之四個參數值:待判斷訊號時間前 60 秒血氧飽和濃度值最大前 50%之平均值、平均每小時有多少次血氧飽和濃度值會持續 5 秒以上低於其基線至少 5%，利用 554 筆整夜血氧量測資料進行其偵測效能測試。

1. DI_β 指標

真實 AHI 與本研究算出 DI_β 指標的相關係數值為 0.32，DI_β 與 AHI 關係分佈如圖 10 所示。

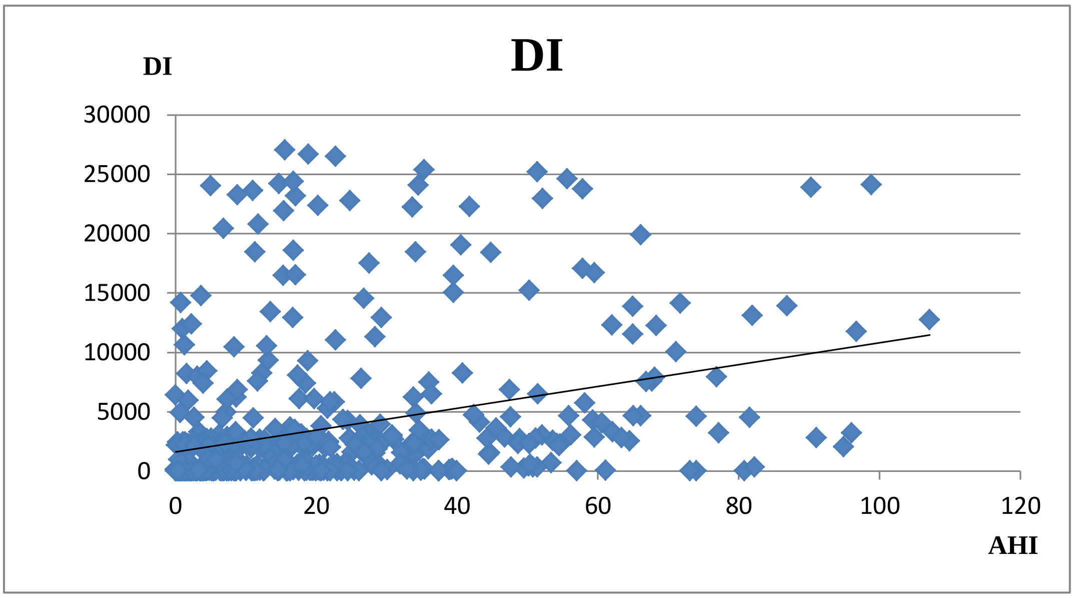



圖 10 DI_β 與 AHI 關係分佈圖

2. TI_α 指標

真實 AHI 與本研究算出 TI_α 指標的相關係數值為 0.28，TI_α 與 AHI 關係分佈如圖 11 所示。

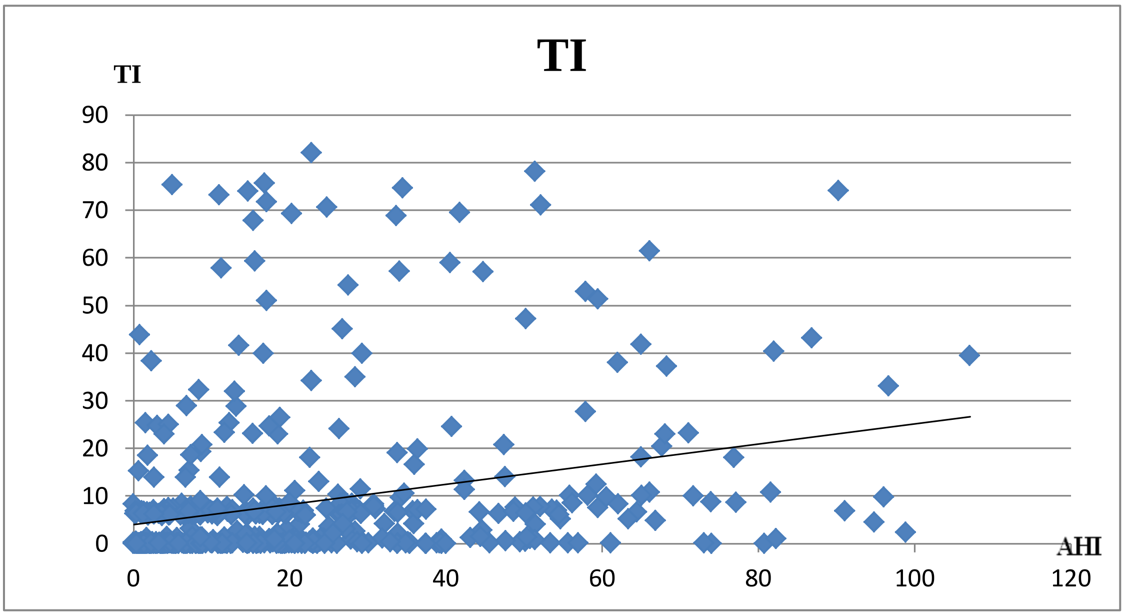



圖 11 TI_α 與 AHI 關係分佈圖

3. Delta Index 指標

真實 AHI 與本研究算出 Delta Index 指標的相關係數值為 0.35，Delta Index 與 AHI 關係分佈如 12 所示。

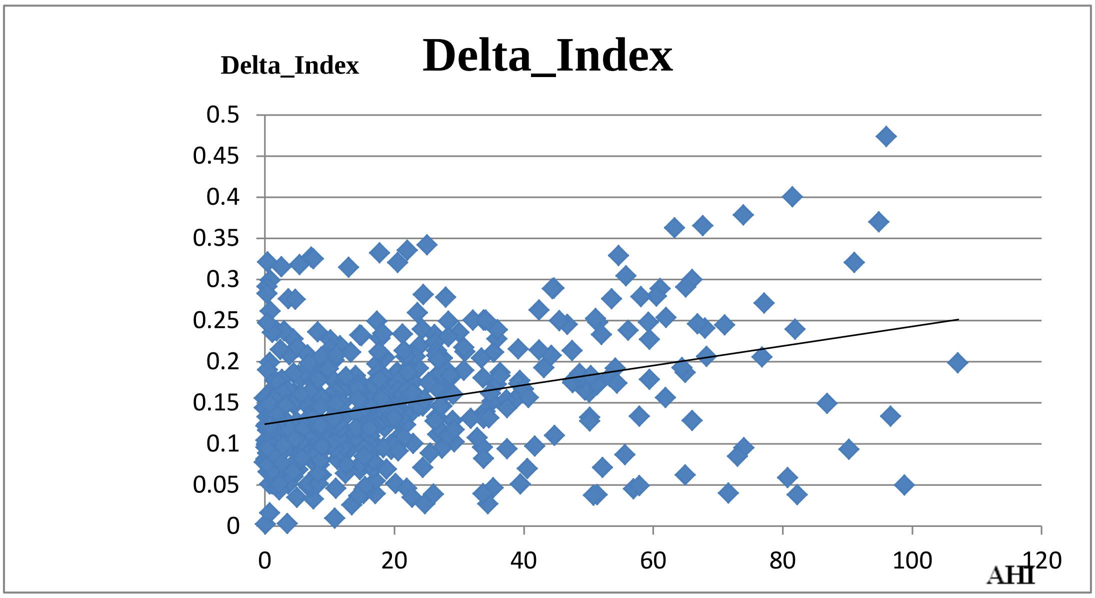



圖 12 Delta Index 與 AHI 關係分佈圖

4. ODI-B-D-L 指標

真實 AHI 與本研究算出 ODI-B-D-L 指標的相關係數值為 0.65，ODI-B-D-L 與 AHI 關係分佈如圖 13 所示。

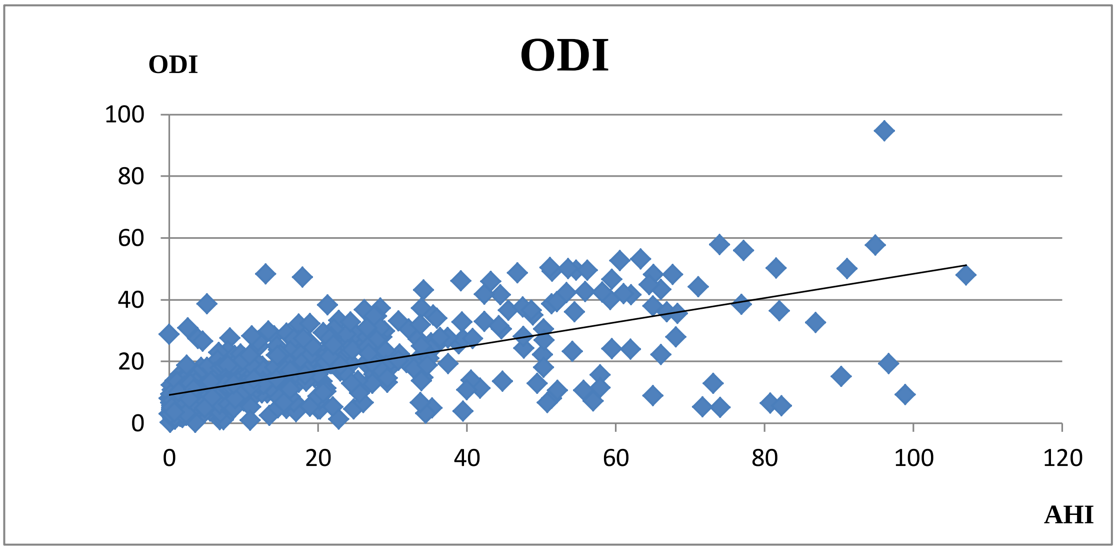



圖 13 ODI-B-D-L 與 AHI 關係分佈圖

（2） 改良型血氧偵測演算法

1. RCGA 演算法改良血氧飽和濃度指標參數

首先，本研究以 RCGA 演算法優化出血氧飽和濃度指標的 4 個參數值:判斷訊號時間前 30 秒血氧飽和濃度值最大前 50%之平均值、平均每小時有多少次血氧飽和濃度值會持續 3 秒以上低於其基線至少 4%，利用此法算出其與 AHI 相關係數值為 0.73，並畫出其與 AHI 關係分佈如圖 14 所示。

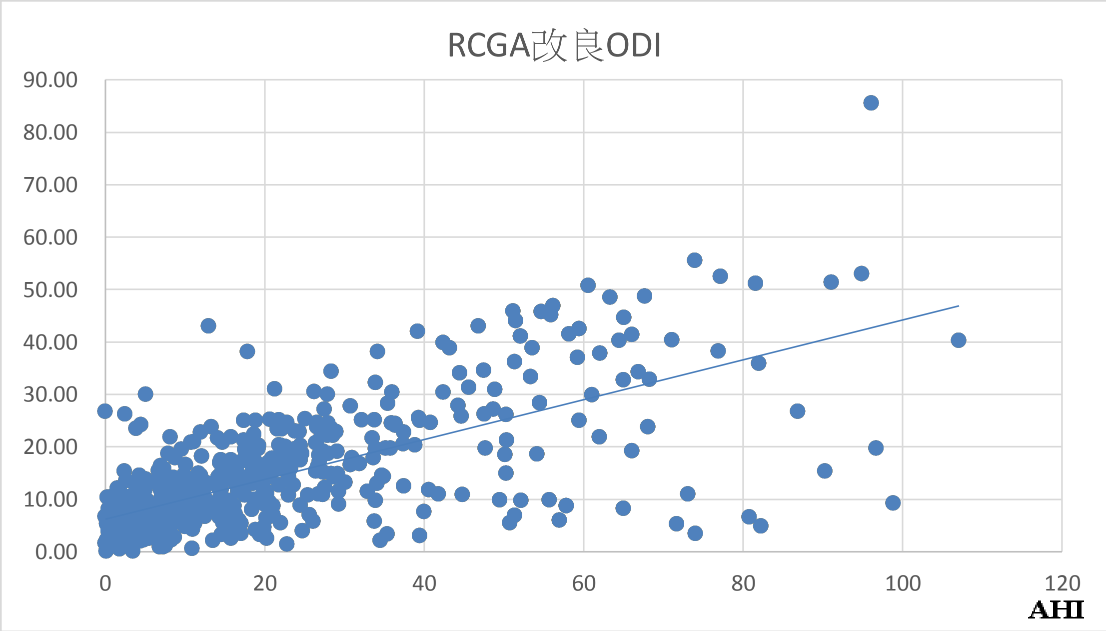



圖 14 RCGA 改良法之 AHI 關係分佈圖

2. 改良血氧飽和濃度演算法之資料前處理

繼之，本研究改良訊號前處理方法，前後相鄰兩血氧飽和濃度 t 與(t+1)差大於 4%，且(t+1)與(t+2)、(t+3)之差未大於 20%的資料點使用前 1 秒鐘的血氧飽和濃度取代之，利用此法求算出其與 AHI 相關係數值為 0.86，並畫出其與 AHI 關係分佈如圖 15 所示。

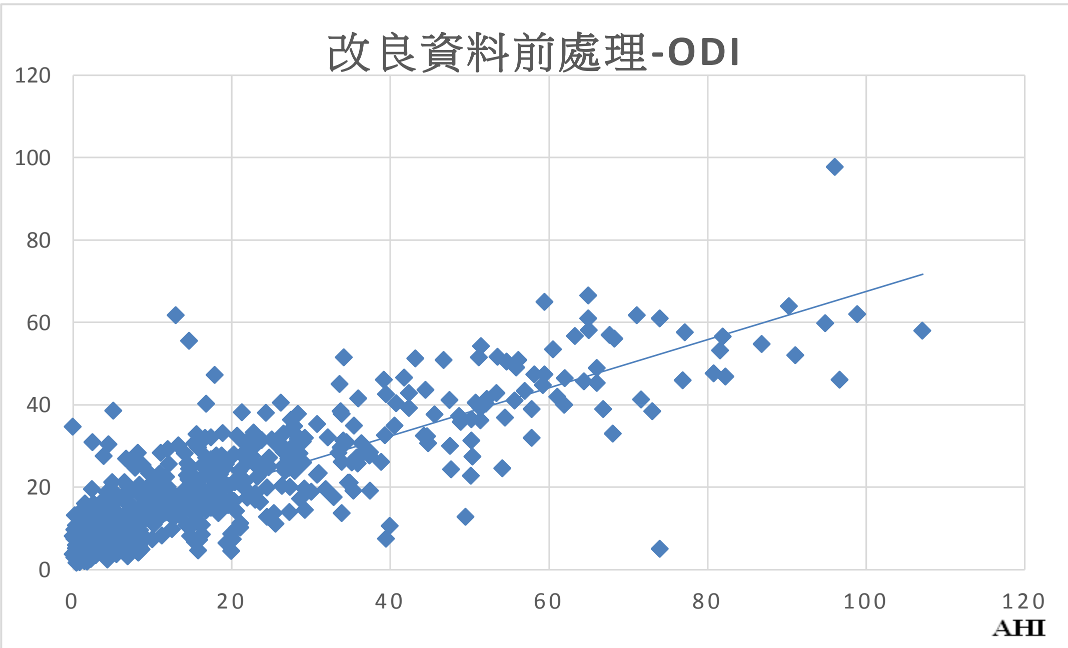



圖 15 改良資料前處理法之 AHI 關係分佈圖

3. 改良血氧飽和濃度演算法之資料前處理+RCGA 演算法改良血氧飽和濃度指標參數

最後，本研究將改良訊號前處理，前後相鄰兩血氧飽和濃度 t 與(t+1)差大於 4%，且(t+1)與(t+2)、(t+3)之差未大於 20%的資料點使用前 1 秒鐘的血氧飽和濃度取代，並以 RCGA 演算法優化出 4 個參數:判斷訊號時間前 30 秒血氧飽和濃度值最大前 50%之平均值、平均每小時有多少次血氧飽和濃度值會持續 3 秒以上低於其基線至少 4%，利用此法算出其與 AHI 相關係數值為 0.88，並畫出其與 AHI 關係分佈如圖 16 所示。

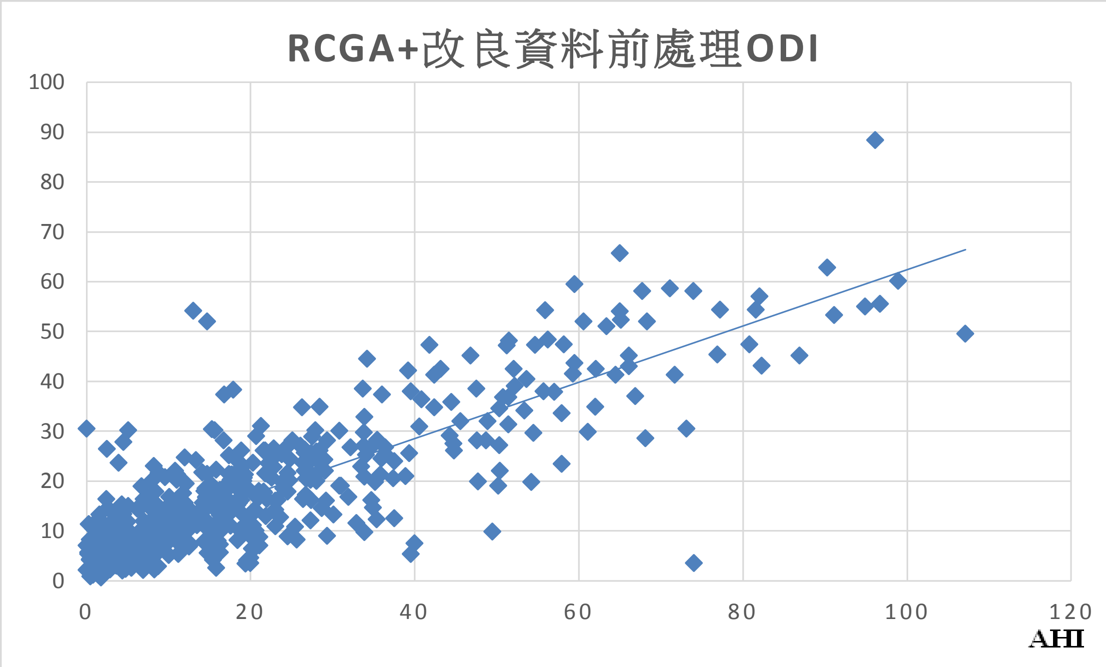



圖 16 RCGA+改良資料前處理之 AHI 關係分佈圖

本研究改良之結果如表 3 所示，改良之血氧偵測 OSAS 演算法(達 0.88 準確率)相對於前人方法(0.32~0.65)具有更佳的預測效能。

表 3 各種血氧偵測演算法之預測效能比較

| 血氧偵測演算法 | 相關係數 |
|---|---|
| DI_$\beta$ | 0.32 |
| TI_$\alpha$ | 0.28 |
| Delta Index | 0.35 |
| ODI-B-D-L | 0.65 |
| **實數型基因演算法改良 ODI** | **0.73** |
| **改良資料前處理 ODI** | **0.86** |
| **實數型基因演算法+改良資料前處理 ODI** | **0.88** |

## 二、系統展示

本計畫整合相關軟硬體，完成雛形系統開發，相關硬體單元或模包含：系統晶片單元、生理訊號測量單元、回饋單元與重置單元、記憶模組等，展示如圖 17~圖 26 所示。

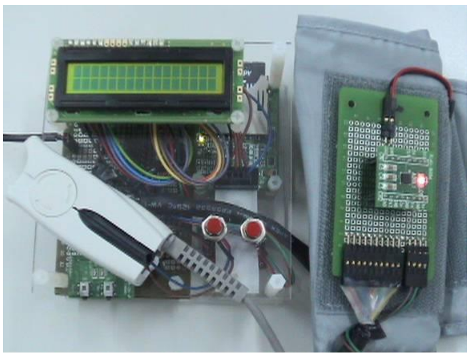
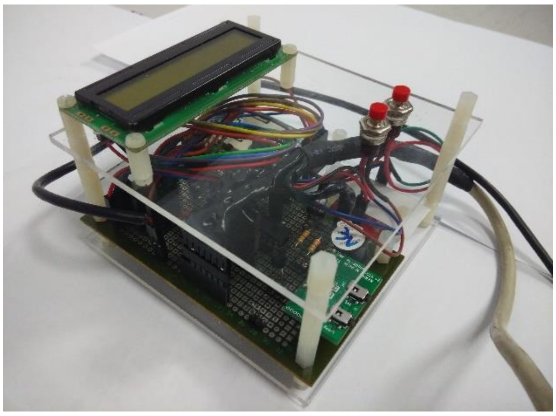


圖 17 雛型系統畫面

圖 18 雛型系統使用畫面



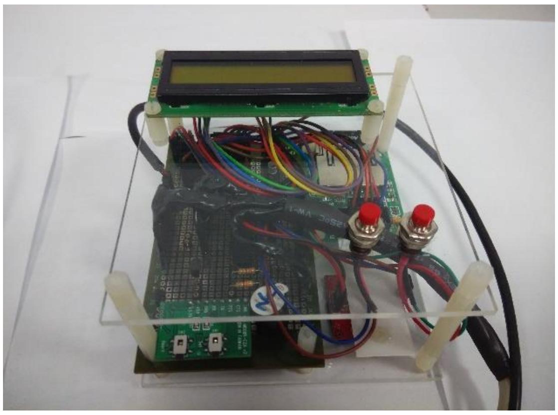


圖 19 系統晶片單元

圖 20 系統單元+血氧偵測 OSAS 演算法

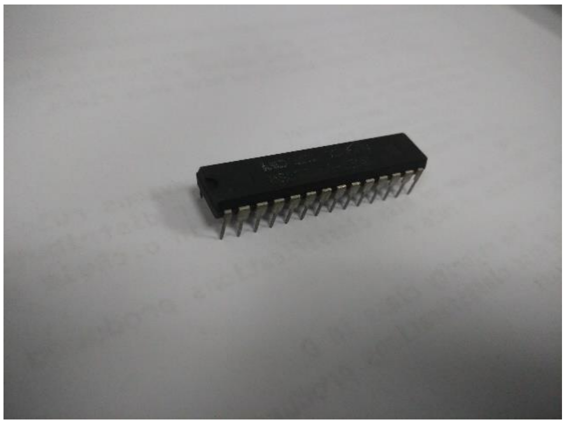
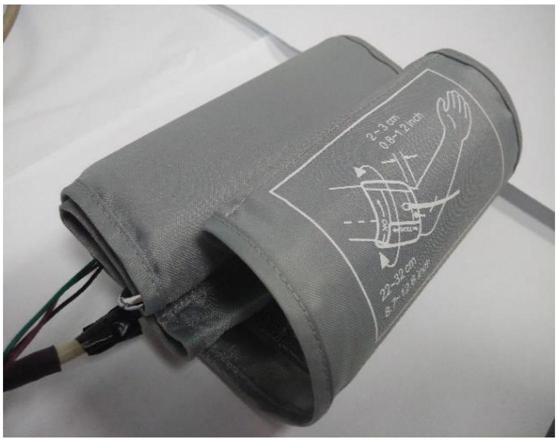


圖 21 生理訊號測量單元
(血氧脈搏探針)

圖 22 系統單元之 PSoC 晶片



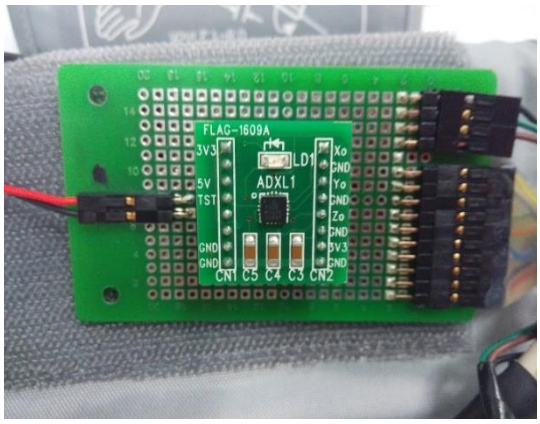



圖 23 回饋單元(震動器)

圖 24 重置單元(位移感測器)

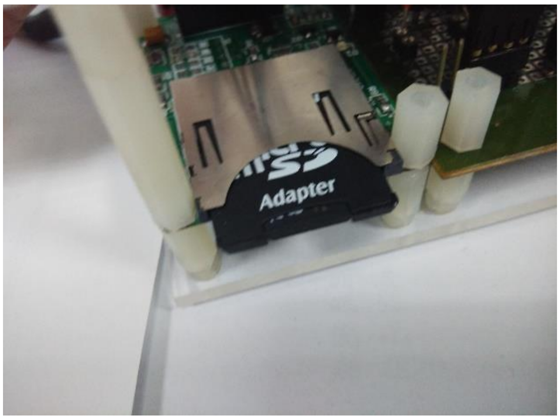




圖 25 記憶模組(micro-SD)

圖 26 系統單元+記憶模組

**三、系統效益評估**

本計畫完成系統接受度調查的受試者共 30 位，其中男女生各 15 人。年齡分佈 30 歲以下有 11 人、30～50 歲有 11 人、50 歲以上有 8 人。所有受試者對 13 題問題的接受度介於 3.20~3.86，顯示受試者對整體系統的接受程度覺得普通偏滿意。表 4 顯示各構面滿意度達到三以上的比率。

表 4 問卷統計結果列表

| 各構面 | 滿意度達到三以上的比率 |
|---|---|
| 相容符合性 | 79% |
| 自覺有用性 | 95% |
| 自覺易用性 | 95% |
| 信賴性 | 98% |
| 自覺成本 | 85% |
| 使用意願 | 94% |

# 伍、結論與建議

在軟體研發方面，本研究利用中山醫學大學附設醫院睡眠中心所提供之 554 筆整夜 PSG 量測的血氧飽和濃度（SpO2）記錄，來評估利用血氧飽和濃度演變歷程開發 OSAS 偵測演算法的效能。由研究結果可知，改良血氧飽和濃度偵測 OSAS 演算法的相關係數值為 0.88，相對於過去前人常用的血氧濃度特徵之指標 （DI_β 之相關係數值為 0.32、TI_α 之相關係數值為 0.28、Delta Index 之相關係數值為 0.35、ODI-B-D-L 之相關係數值為 0.64）有更優良的預測效能。

在硬體研發方面，本研究整合 PSoC 系統晶片、生理訊號測量單元(血氧脈搏探針)、回饋單元(震動器)、重置單元(位移感測器)、記憶模組(micro-SD)等完成雛型系統整合開發，整體雛型系統經 30 位受試者實際操作使用後，各構面接受程度達到三以上滿意的比率介於 85%~98%，顯見受試者對本研發雛形產品接近滿意程度。

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# 科技部補助專題研究計畫出席國際學術會議心得報告

日期：103 年 10 月 31 日

| | | | |
|---|---|---|---|
| 計畫編號 | MOST 102-2218-E-040-003 | | |
| 計畫名稱 | 睡眠呼吸障礙之監測與矯正輔助系統研發 | | |
| 出國人員姓名 | 曾明性 | 服務機構及職稱 | 中山醫學大學醫資系教授 |
| 會議時間 | 103 年 5 月 1 日至 103 年 5 月 2 日 | 會議地點 | Hong Kong |
| 會議名稱 | 2014 International Conference on Industrial Electronics and Engineering | | |
| 發表題目 | Mobile Healthcare Monitoring System for Sudden Cardiac Death | | |

一、參加會議經過

本計畫原先規畫參與 The 9th World Conference of Gerontechnology（ISG 2014），並已將研究成果投稿至 ISG 2014 並獲接受發表，發表題目為: Design and implementation of an automatic monitoring and correction auxiliary system for patients with obstructive sleep apnea syndrome。因本屆國際學術研討會在台灣舉辦，被視為國內學術研討會。因投稿時間剛好合適，故將本人主持 101 年度尚未發表的科技部計畫研究成果，撰寫此篇論文: Mobile Healthcare Monitoring System for Sudden Cardiac Death，投稿於香港舉辦的 2014 International Conference on Industrial Electronics and Engineering。 本會議徵文範圍包含工業電子和工程領域最新進展的相關研究議題，本論文投稿到 Computers and Information Technology 領域。

二、與會心得

本研討會係由美國 Information Engineering Research Institute、Taylor & Francis Group、WIT 出版社共同舉辦。本次會議研討內容涵蓋主題包括：Computers and Information Technology、Communication System、Signal Processing、Controls、Circuits and Systems。本次會議的 Plenary Speech 講題為 Overview of Swarm Intelligence，介紹相關群體智慧演算法的過去、現在與未來，包含 Particle and Cat Swarm Optimization, Ant Colony System, Bat Algorithm and Artificial Bee Colony…，本人的研究領域包含 Soft Computing，讓本人獲益良多。本人論文:『Mobile Healthcare Monitoring System for Sudden Cardiac Death』則被安排在 5 月 1 日下午發表。參與本次研討會後並參觀香港大學，時值台灣的太陽花學運，看到香港大學的民主牆讓學生可自由發表對民主的看法，也看到香港大學生對國際大事的關心，反觀台灣大學生常對國際情勢較無知悉，值得吾人深思。


三、建議

本人近年參加國際學術會議觀察到不少論文發表均為教授帶領學生出席發表，本次會議也看到中國大陸的學生群。由於本人只有大學生與碩士生參與計畫，建議科技部能提供更多大學生及碩士生參與國際學術會議的經費補助，對我國未來年輕一代的學術能力養成，必有重大貢獻。

四、攜回資料名稱及內容

1. Conference Program Guide 紙本一份。2.論文摘要(Abstract) 紙本一份。

五、發表論文全文

*2014 International Conference on Industrial Electronics and Engineering (ICIEE 2014), May 1-2, 2014, Hong Kong*

# Mobile Healthcare Monitoring System for Sudden Cardiac Death

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**Abstract**—Sudden death accounts for more than a quarter of the global human natural deaths. Due to the pressure of living with an aging population, the global number of sudden deaths is increasing year by year and patient age is becoming younger. According to statistics, the incidence of sudden cardiac death is about 1-2/1000 in the U.S., 30-50 thousand people/year in Taiwan, and more than 1000 people/day in mainland China. In general, patients with sudden death can be successfully recovered about 90% of the time if the rescue occurs within a minute. But it could result in death if patients are comatose more than six minutes. It would be very useful to life saving to use the wireless body area network (WBAN) technology to assist the early detection and real-time message notification for patients suffering from sudden cardiac death.In this paper, we propose a prototype of a pervasive mobile health system for monitoring elderly patients suffering from sudden cardiac death from indoor and outdoor environments. This prototype system uses a wireless chest-belt Electrocardiogram (ECG) sensor worn by the patient, performs local vital signs data analysis using a smartphone and transmits data to the cloud server over wireless networks. When suspected patterns of signals are detected, the patient's smartphone performs immediately transmits information to the caregiver's smartphone or tablet computer, and provides monitor alerts, message notification, patient's location, CPR teaching and the nearest AED locations.

*Index Terms—sudden cardiac death, wireless body area network, ECG sensor, monitors alerts, message notification.*

## I. Introduction

### A. AgingPopulation

The world is ageing so fast that most countries are not prepared to support their swelling numbers of elderly people, according to a global study by the United Nations (UN) and an elder rights group. They reported that Nations are simply not working quickly enough to cope with a population graying faster than ever before. The findings come at a time when the 21st century is seeing a growing ageing global demographic transition. The study showed that by the year 2050, for the first time in history, seniors over the age of 60 will outnumber children under the age of 15, and older people (defined as aged 60 and above) will make up more than one-fifth of the global population.

According to the Taiwan National Office of Statistics [1], the percentage of the total population of persons over the age of 65 has increased and is expected to increase further. The number reached 2.7 million out of a population of 35.5 million Taiwanese and it will reach 20 percent in 2030. In general, the greater part of the elderly population suffer from various chronic diseases, based on statistics, chronic diseases and serious illness that cause the death of 75.9 percent of elderly people in Taiwan.

According to the World Health Organization, aging populations are becoming a significant problem at the same time that a sedentary lifestyle is causing millions of people to suffer from obesity or chronic diseases everyday. It is thus reasonable to expect that this circumstance will only contribute to an ongoing decline in the quality of services provided by an already overloaded healthcare system [2].

### B. Wireless Body Area Network and Mobile Computing

The aging population in many developed countries and the rising costs of health care have triggered the introduction of novel technology-driven enhancements to current health care practices [3]. For example, recent advances in electronics have enabled the development of small and intelligent bio-medical sensors which can be worn on or implanted in the human body. These sensors need to send their data to an external medical server where it can be analyzed and stored. Using a wired connection for this purpose turns out to be too cumbersome and involves a high cost for deployment and maintenance. However, the use of a wireless interface enables an easier application and is more cost efficient [4].

The patient experiences a greater physical mobility and is no longer compelled to stay in a hospital. This process can be considered as the next step in enhancing the personal health care and in coping with the costs of the health care system. Where eHealth is defined as the healthcare practice supported by electronic processes and communication, the health care is now going a step further by becoming mobile. This is referred to as mHealth [5]. In order to fully exploit the benefits of wireless technologies in telemedicine and mHealth, a new type of wireless network emerges: a wireless on-body network or a Wireless Body Area Network (WBAN). This term was first coined by Van Dam et al. in 2001 [6] and received the interest of several researchers [7-11]. When referring to a WBAN where each node comprises a biosensor or a medical device with sensing unit, some researchers use the name Body Area Sensor Network (BASN) or in short Body Sensor Network (BSN) instead of WBAN [12]. These networks are very similar to each other and share the same challenges and properties [3]. In this study, we use the term WBAN which is also the one used by the IEEE.

Many protocols and algorithms have been proposed for traditional wireless sensor networks (WSNs) [13], and WBANs may interface with other wireless technologies, such as WSNs, radio frequency identification (RFID) technology [14], ZigBee [15], Bluetooth, Bluetooth Low Energy[15], video surveillance systems, wireless personal area network (WPAN), wireless local area networks (WLAN), internet, and cellular networks [15]. The increasing use of wireless networks and the constant miniaturization of electrical devices have empowered the development of WBANs. In these networks various sensors are attached to clothing or on the body or even implanted under the skin which are capable of establishing a wireless communication link. These devices provide continuous health monitoring and real-time feedback to the user or medical personnel. Furthermore, the measurements can be recorded over a longer period of time, improving the quality of the measured data, offering numerous new, practical and innovative applications to improve health care and the quality of life [3, 16].

Many smartphones now possess high-speed data transmission capabilities and have embedded microprocessors with the capability to wirelessly connect to external devices. It offers great potential in the development of wearable systems for mobility monitoring by integrating recent technological advances in wireless communications, sensor miniaturization and smartphone processing power [17]. Smartphones can be widely used in tele-monitoring serving as a conduit for receiving bio-health information from portable medical devices and mobile sensors. An important area of the mobile healthcare service is the mobile monitoring of the patient’s vital signs outside the clinical environment. Mobile healthcare can monitor common vital signs such as blood pressure, electrocardiogram, pulse rate, blood oxygenation, breathing rate, body temperature, body activity and weight, and other measures; this could also be useful in management of chronic disorders and to provide feedback about someone’s health in the form of behavioral feedback in order to prevent diseases[18, 19]. Once smartphones have received the pertinent information, it is micro-processed, encrypted, and the data packets are transferred to some form of localized or web-based server for secondary processing. At the server end, the data packets are organized into a functional database for analyses, integration, and user feedback. The process enables users the ability to easily self-monitor various health parameters and provides important information to healthcare providers facilitating timely healthcare decisions [20-25].

In this paper, we describe a prototype of the mobile healthcare system for monitoring elderly patients suffering from sudden cardiac death, it uses a wireless body area network (WBAN) to collect and send data to the cloud servers through 3G and Wi-Fi networks.

The rest of the paper is organized as follows: Section 2 provides the short descriptions of the related works; in Section 3 we describe the overall architecture of the system and the SCD detention algorithms. In section 4, the verification and demonstration of the prototype are presented. Section 5 concludes the paper.

## II. Related Works

### A. Epidemiology of Sudden Cardiac Death

Sudden cardiac death (SCD) is a common and devastating event, often occurring in the prime of life and having profound consequences for surviving members of the individual’s family. Out-of-hospital SCD is the cause of more than 60% of all deaths from cardiovascular disease, which is the leading cause of death worldwide [26-29].

Sudden cardiac death (SCD) accounts for 50% of all cardiovascular mortality with an estimated annual toll of between 100,000 and 120,000 deaths in the United Kingdom (UK) [30, 31]. The majority of SCDs are secondary to atherosclerotic coronary artery disease and heart failure and affect the older (>35 years) population [32]. The epidemiology of SCD in the young (<=35 years) is less well established. Estimates range from 0.5 per 100,000 in young American athletes 4 to 13 per 100,000 recruit-years in US military recruits [33]. A recent study in the UK apprising the Office of National Statistics data on deaths in individuals aged 1-34 years reported an incidence of 1.8 per 100,000 per year [34]. In contrast with older individuals, hereditary and congenital cardiac pathologies, including the cardiomyopathies and coronary artery anomalies, predominate in the young [33, 35-37]. There is a male predominance with a male to female ratio of 3:1 in the general population and 9:1 in young athletes [38].

The International Classification of Diseases, Tenth Revision, defines sudden cardiac death (SCD) as death dueto any cardiac disease that occurs out of hospital, in anemergency department, or in an individual reported dead on arrival at a hospital. In addition, death must have occurred within 1 hour after the onset of symptoms [39]. The underlying cause may be a ventricular tachycardia (VT), ventricular fibrillation (VF), asystole, or non-arrhythmic causes [40]. VF is the first recorded rhythm in ~ 75% cases and is the underlying mechanism for most SCD episodes [40]. Survival declines by ~10% per minute for patients in ventricular fibrillation [2]. SCD represents a major challenge for the clinician because most episodes occur in individuals without previously known cardiac disease [41-44]. Even with the best first responder systems the average survival is approximately 5% [45]. On average, only 8% of those receiving community-based resuscitation are discharged from the hospital alive [42]. In the past few decades, substantial progress has been made in our understanding of SCD and in its prevention and management. Multiple clinical, structural, autonomic, and genetic risk factors have been identified and the use of automated external defibrillators (AEDs) and implantable cardioverter defibrillators (ICDs) has increased. However, SCD continues to be an important public health problem, largely because the majority of SCDs occur in individuals without previously diagnosed heart diseases who do not meet the high-risk criteria defined by clinical trials and cohort studies [44, 46, 47]. The discovery of effective prediction and prevention modalities, therefore, is of great importance [48].

### B. CPR & AED for Sudden Cardiac Death

Prompt defibrillation of an individual who has suffered a sudden cardiac arrest is the most important determinant of survival. For every minute that passes between cardiac arrest and defibrillation, survival decreases by 7–10% without CPR, and by 3–4% with immediate CPR [49]. After 10 min or longer without defibrillation, 95% of patients dies. The response times for emergency medical services in most areas of the US are typically 8–15 min; therefore, overall survival after sudden cardiac arrest in most communities is only 5–10% [49, 50]. However, patients who are defibrillated within 10 min of cardiac arrest have a 40% chance of surviving to hospital discharge neurologically intact [51]. The long-term survival and quality-of-life scores of these patients are equal to age-matched and sex-matched individuals in the general population [51].

AEDs are portable, computerized devices that can analyze cardiac rhythm accurately and deliver a bi phasic electrical shock in cases of ventricular tachycardia or fibrillation. Studies have shown that AEDs can be easily operated by untrained laypersons [52, 53]. Indeed, AED programs at airports and casinos have been associated with 50–75% survival among individuals who suffer an out-of-hospital cardiac arrest when immediate CPR is provided and defibrillation occurs within 3–5 min of cardiac arrest [49, 53-55]. In the Public Access Defibrillation Trial [56], volunteer responders from ~1,000 community locations, such as shopping malls or apartment complexes, were randomly assigned to undergo training in CPR alone or to training in CPR plus AED use. Individuals who suffered a cardiac arrest in these communities were twice more likely to survive to hospital discharge when the responder was trained in CPR plus AED use than if the responder was trained in CPR alone [56].

Because implementation AEDs is effective in minimizing sudden cardiac deaths, in current, there are 5,413 AEDs, which have an average of 23.5 per 100,000 people in Taiwan. All public places including railway stations, airports, stores, schools, hotels, supermarkets, tourist attractions and large leisure venues are legally required to have AEDs in Taiwan now.

### C. ECG Signals of Sudden Cardiac Death

Abnormalities on a 12-lead electrocardiogram raise the suspicion of underlying structural or genetic heart diseases associated with SCD. Pathologic Q waves or dynamic ST-segment changes on electrocardiography are indicative of CHD, whereas increased R-wave voltage or prolonged QRS duration are signs of LV hypertrophy and cardiomyopathy, respectively. Left bundle (but not right bundle) branch block or LV hypertrophy on electrocardiography are associated with a mildly increased risk of SCD (hazard ratio ~1.5 for both) [57, 58]. In addition, prolonged QRS duration was associated with SCD and ventricular tachyarrhythmias in two large clinical trials [59, 60], and Das et al. have suggested that fragmented QRS on electrocardiography is a marker of structural heart disease and predicts SCD [61].

The electrocardiogram is particularly helpful in diagnosing primary arrhythmogenic disorders, such as the long and short QT syndromes, Brugada syndrome, arrhythmogenic right ventricular cardiomyopathy, and Wolff–Parkinson–White syndrome, all of which are associated with SCD [62-64]. These conditions are rare inthe community; however, QT-interval prolongation anddispersion, which are more common and indicate prolongedrepolarization, have also been associated withSCD in the general population [27, 65, 66]. Individuals with a corrected QT interval of greater than 440 ms have a 2.3-fold higher risk of SCD than those with corrected QT interval of less than 440 ms, independent of age, sex, heart rate, and drug use [63].

Many measures of cardiac autonomic modulation have been proposed to risk stratify patients for SCD [48]. These include heart rate variability (HRV), baro-reflex sensitivity (BRS), heart rate turbulence (HRT), and deceleration capacity of heart rate. In the ATRAMI study [67] low HRV & BRS significantly predicted a high risk of cardiac mortality independently of LVEF and spontaneous VTs. In a recent study low heart-rate turbulence was significantly associated with increased risk of cardiac death in older adults otherwise considered low risk for cardiovascular events [68].

### D. Patient Monitoring and Mobile healthcare system

According to the U.S. Census Bureau, worldwide population of elderly people aged 65 and over is expected to more than double by 2020, and more than triple by 2050. Moreover, more than 1 billion people in the world nowadays are overweight, at least 300 million of those are clinically obese, and more than 246 million people suffer from diabetes, a number that is expected to rise to 380 million by 2025 [69], whereas over 600 million people worldwide have chronic diseases as reported by a World Health Organization study. Besides, Cardio Vascular Disease (CVD) is the main cause of death in the world, representing 30% of all global deaths. Statistics have also confirmed the trend of women giving first-time births later in their adult lives. These deaths can often be prevented with proper healthcare from continuous or prolonged monitoring. It already illustrates the need for continuous monitoring and the usefulness of WBANs. These applications in future can be considered as an indicator for the size of the market for WBANs [3, 15].

WBAN technology could provide the connectivity to support the elderly in managing their daily life and medical conditions [70]. A WBAN allows continuous monitoring of the physiological parameters. Whether the patient is in the hospital, at home or on the move, the patient will no longer need to stay in bed, but will be able to move around freely. Furthermore, the data obtained during a large time interval in the patient's natural environment offers a clearer view to the doctors than data obtained during short stays at the hospital [16].

In recent years, the electronic health (e-health) concept has evolved from tele-health into a mobile health (m-health) paradigm, enabling long-term ambulatory monitoring, and point-of-care. Moreover, research projects using WBANs have produced implantable or wearable devices for patients, the disabled, aging people, pregnant women, and neonates. The European MobiHealth project [71] is the first project that introduced the mobile health monitoring for ambulant patient, it is a health service platform based on a mobile phone as a base station for the wireless sensors worn on the body. The MobiHealth user is equipped with different sensors that constantly monitor vital signals, e.g. blood pressure, heart rate and electrocardiogram (ECG). It forwards their measurements wirelessly using UMTS or GPRS to a service center, it provides three services: collecting and storage of the received data, forwarding of data to a doctor or medical center, and analysis of the data received and the sending of feedbacks to a predefined destination using SMS. Communication between the sensors and the personal device is Bluetooth or ZigBee based and is single-hop. Some overviews of existing WBAN projects proposed in recent years in the field of m-healthcan be found in previous studies [3, 15].

## III. Methods

### A. System Design

The concept of this system is to wear unobtrusive wirelesssensors on a person’s body to form a wireless network that provides the interoperability layers to access patient’s physiological signs between sensors and mobile devices, and route to the cloud data server for further monitoring and management. This WBAN based prototype contains three following components: (1) sensing node, (2) mobile node and (3) cloud node as shown in Figure 1.

1) Sensing Node

The core of sensing node includes wireless sensor and wearable devices such as chest-belt ECG, electrode-type ECG and pulse oximeter. The sensing node responds to and gathers data on physical stimuli, processes the data if necessary and transmits this information wirelessly.

2) Mobile Node

Mobile node that aggregates all collected vital signs acquired by the sensors to monitoring program and informs the user, and then relayed all the information to the cloud node. In our implementations, a smart phone or tablet computer can be used. Only suspicious SCD vital signs will be immediately transmitted to the alarm module for emergency notification.

3) Cloud Node

Smartphone is still not powerful enough as desktop computer due to limitation of memory resource and cost of data transmission. The cloud node includes a web server and a database server to handle and store all the received vital signs and respond the request from the mobile node. An administrating program in the server is used to manage, analyze and demonstrate all the information of patient continuously. In addition, Google Map can provide the positioning service for the SCD patient and the nearest AED locations, and Google Play can offers CPR teaching APP service. Grasping the golden ten minutes can effectively rescue the patient suffering from the sudden deathsyndrome.

In the prototyping system, the communication between the sensor node and the mobile node is employed by IEEE 802.15.1 (Bluetooth) technology, and IEEE 802.11 (WiFi) and 3G networks are used to transmit data between the mobile node and the cloud node.

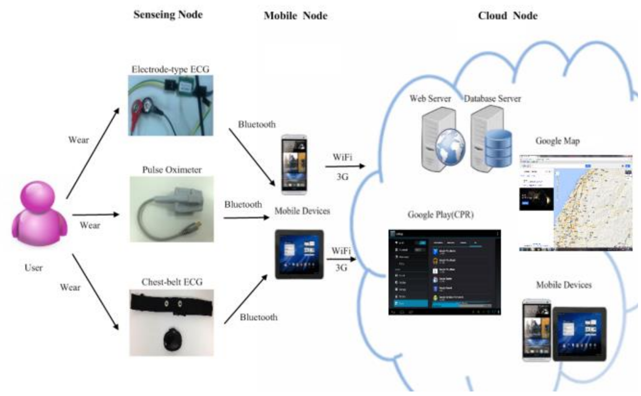


Fig. 1. Design system architecture

### B. Arrhythmic Beat Classification Algorithm

Tsipouras et al. [72] proposed an arrhythmic beat classification algorithm using only the RR-interval signal extracted from ECG recordings. A three RR-interval sliding window is used in arrhythmic beat classification algorithm (as shown in Figure2). Classification is performed for four categories of beats: normal, premature ventricular contractions, ventricular flutter/fibrillation and 2° heart block.The beat classification is used as input of a knowledge-based deterministic automatonto achieve arrhythmic episode detection and classification. Six rhythm types are classified: ventricular bigeminy, ventricular trigeminy, ventricular couplet, ventricular tachycardia, ventricular flutter/fibrillation and 2° heart block.

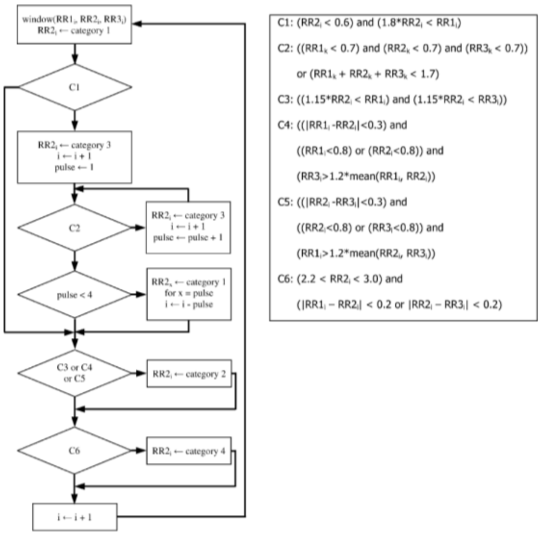


Fig. 2. Arrhythmic beat classification algorithm [72]

## IV. Result and Demonstration

There are two main types of heart rhythm for patients suffering from sudden cardiac death. The most common type in adult sudden cardiac death is ventricular fibrillation (as shown in Figure 3), about 25%-40%, that ECG showed wide QRS complex and irregular frequency pattern. Ventricular tachycardia (as shown in Figure 4) is the other type which ECG also showed a wide QRS complex but regular frequency pattern. In this study, we focus on the detection of ventricular fibrillationand ventricular tachycardiaby using the real-time RRI beats.


Fig.3.ECG of ventricular fibrillation

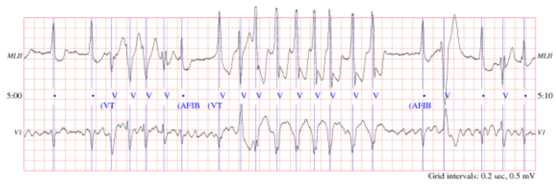


Fig.4.ECG of ventricular tachycardia

### A. System Verification

Based on 48records in the MIT-BIH Arrhythmia Database (MITDB), we finally extracted 288 cases with five minutes RRI signals from MITDB to verify the overall accuracy of the proposed system.

To detect ventricular fibrillation and ventricular tachycardia, 280 cases are correct classified and eight cases are misclassified by using the original arrhythmic beat classification algorithm [72]. The test result shows that the overall accuracy is 88.54%.

In the present study, an improved algorithm is developed by using threshold optimization to enhance the overall accuracy up to 97.22% only with two misclassified cases.

### B. System Demostration

In this study, a sudden cardiac death monitoring system is developed by using Eclipse platform and Javalanguage based on Android operation system.

Using a Bluetooth chest-belt ECG sensor (as shown in Figure 5), instantaneous RRI signals and pulse rate are collected on user'smobile devicefor analysis, monitoring and notification. In addition, Google Map and Google Play services are embedded in the proposed system. The primary functions are demonstrated as follows:

Fig.5.Bluetooth chest-belt ECG sensor

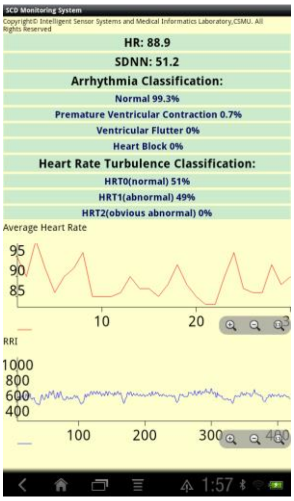


Fig.6.Real time monitoring of RRI signals

Figure 6 shows a snapshot of real time ECG monitoring conditionwith additional information available such as HRV values, suspecteddisease, average HR variations and RRI variations.

The system will automatically generate a summary report every once in a while as shown in Figure 7. If the system detects suspicious vital signs for sudden cardiac death, it will immediately generate an alarm message to alert the user. If the user has no any response, the system will then send loud alarm sound alert nearby pedestrians and simultaneously locate the patient's current position. Moreover, the system will send an alert notification message to the patient’s families, the caregivers andthe 119 report line. Figure 8 and 9 illustrate the patient’s location and the nearest AED locations by using Chinese Google Map Service, respectively.

The golden ten minutes before sudden death is the best rescue time. In order to automatically aid nearby pedestrians to implement CPR forthe sudden death patientof rescue, some CPR teaching APPs can be embedded in this system as shown in Figure 10.

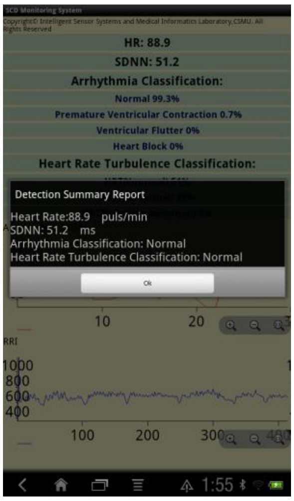


Fig.7.Summary report for SCD detection


Fig.8.Patient’s location


Fig.9.Nearest AED locations (in Chinese)


Fig.10.CPR teaching

## V. Conclusion and Future Work

In this study, an ubiquitous mobile health system is presented for continuous monitoring of elderly patients suffering from sudden cardiac death syndromes. The system provides the architecture for collecting, gathering and analyzing data from biosensors, smartphones and cloud servers. The result of system verification confirms that the multiple clinical criteria can be used to detect the sudden cardiac death syndromes. The demonstrated prototype system monitors health status anytime and anywhere through the use of a Bluetooth chest-belt ECGas sensing node and an Android smartphone asmobile node. By using the proposed system, the nearby pedestrians can implement CPR and AED for the patient suffering from the sudden death in the golden ten minutes. Besides, the family members and the caregivers are alerted in a timely manner when the state of patient's health changes for the worse.

Understanding the potential users' experiences about this system is important. In the future, a study will be runfor assessment of the effectiveness of this prototype by using the technology acceptance model. Using a wireless chest-belt ECG sensor is widely available and better than an electrode-ECG sensor, and provides users with real time feedback of their beat-to-beat heart rate. But wearing a telemetric strap around the thoracic region is not very comfortable. Developing a wireless, inexpensive, miniature and user-friendly design HR monitor device is also the future work.

## Conflict of Interests

No competing financial interests exist.

## Acknowledgments

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# 科技部補助計畫衍生研發成果推廣資料表

日期:2014/12/22

| | | | |
|---|---|---|---|
| 科技部補助計畫 | 計畫名稱: 睡眠呼吸障礙之監測與矯正輔助系統研發 | | |
| | 計畫主持人: 曾明性 | | |
| | 計畫編號: 102-2218-E-040-003- 學門領域: 銀髮族專屬資通訊設備 | | |
| 研發成果名稱 | (中文) 睡眠呼吸障礙之監測與矯正輔助系統 | | |
| | (英文) A monitoring and correction auxiliary system for sleep-disordered breathing | | |
| 成果歸屬機構 | 中山醫學大學 | 發明人(創作人) | 曾明性 |
| 技術說明 | (中文) 一人的一生有三分之一的時間用在睡眠上，不良的睡眠品質對於生理及心理健康皆會造成不良的影響，高齡者更常為了不同程度的睡眠呼吸障礙感到困擾。根據調查統計，在台灣估計有約52%會打鼾，超過五十萬人患有阻塞性睡眠呼吸中止症候群。本研發利用整夜進行PSG診斷之長時間血氧飽和濃度序列資料集共544筆，透過實數型基因演算法完成睡眠呼吸障礙偵測演算法之改良開發；繼之以系統晶片接收血氧脈搏探針之即時感測數據以偵測人體睡眠生理訊號傳送至系統晶片；當演算法分析判斷為產生睡眠呼吸障礙時，系統晶片可驅動警示感測單元；協助使用者改變睡姿，並偵測睡姿改變的有效性，對於睡眠呼吸障礙者將可產生矯正作用。 | | |
| | (英文) This research develops a better sleep disordered breathing detection algorithm at first. We integrate this system chip with an oxygen pulse to receive human sleep physiological signals, to detect sleep disordered breathing, to drive alarm sensing unit to help users change their sleep position, and to identify the effectiveness of sleeping position changing. | | |
| 產業別 | 其他服務 | | |
| 技術/產品應用範圍 | 銀髮族醫療照護產業/睡眠呼吸障礙患者 | | |
| 技術移轉可行性及預期效益 | 可將技術移轉給有興趣的廠商，進行雛型系統之後續加值與商品化，可提供全球廣大的睡眠呼吸障礙患者，一個低成本、非侵入式、又具可攜性的睡眠輔助的簡易設備。 | | |

註：本項研發成果若尚未申請專利，請勿揭露可申請專利之主要內容。

# 102 年度專題研究計畫研究成果彙整表

| 計畫主持人：曾明性 | | | 計畫編號：102-2218-E-040-003- | | | | |
|---|---|---|---|---|---|---|---|
| 計畫名稱：睡眠呼吸障礙之監測與矯正輔助系統研發 | | | | | | | |
| 成果項目 | | | 量化 | | | 單位 | 備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等） |
| | | | 實際已達成數（被接受或已發表） | 預期總達成數(含實際已達成數) | 本計畫實際貢獻百分比 | | |
| 國內 | 論文著作 | 期刊論文 | 0 | 0 | 100% | 篇 | |
| | | 研究報告/技術報告 | 1 | 1 | 100% | | |
| | | 研討會論文 | 2 | 3 | 100% | | 其中一篇為去年度計畫的延伸成果。 |
| | | 專書 | 0 | 0 | 100% | | |
| | 專利 | 申請中件數 | 0 | 0 | 100% | 件 | |
| | | 已獲得件數 | 0 | 0 | 100% | | |
| | 技術移轉 | 件數 | 0 | 0 | 100% | 件 | |
| | | 權利金 | 0 | 0 | 100% | 千元 | |
| | 參與計畫人力（本國籍） | 碩士生 | 2 | 2 | 100% | 人次 | |
| | | 博士生 | 0 | 0 | 100% | | |
| | | 博士後研究員 | 0 | 0 | 100% | | |
| | | 專任助理 | 0 | 0 | 100% | | |
| 國外 | 論文著作 | 期刊論文 | 1 | 1 | 100% | 篇 | |
| | | 研究報告/技術報告 | 0 | 0 | 100% | | |
| | | 研討會論文 | 0 | 0 | 100% | | |
| | | 專書 | 0 | 0 | 100% | 章/本 | |
| | 專利 | 申請中件數 | 0 | 0 | 100% | 件 | |
| | | 已獲得件數 | 0 | 0 | 100% | | |
| | 技術移轉 | 件數 | 0 | 0 | 100% | 件 | |
| | | 權利金 | 0 | 0 | 100% | 千元 | |
| | 參與計畫人力（外國籍） | 碩士生 | 0 | 0 | 100% | 人次 | |
| | | 博士生 | 0 | 0 | 100% | | |
| | | 博士後研究員 | 0 | 0 | 100% | | |
| | | 專任助理 | 0 | 0 | 100% | | |

| | |
|---|---|
| 其他成果<br>(無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。) | 無 |

| | 成果項目 | 量化 | 名稱或內容性質簡述 |
|---|---|---|---|
| 科教處計畫加填項目 | 測驗工具(含質性與量性) | 0 | |
| | 課程/模組 | 0 | |
| | 電腦及網路系統或工具 | 0 | |
| | 教材 | 0 | |
| | 舉辦之活動/競賽 | 0 | |
| | 研討會/工作坊 | 0 | |
| | 電子報、網站 | 0 | |
| | 計畫成果推廣之參與（閱聽）人數 | 0 | |

# 科技部補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

　　□實驗失敗

　　□因故實驗中斷

　　□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：■已發表 □未發表之文稿 □撰寫中 □無

專利：■已獲得 □申請中 □無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

本年度計畫經費補助下，共發表 4 篇期刊論文(其中 3 篇是 SCI 期刊論文，1 篇是期刊單頁論文)，3 篇國內研討會論文。

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

學術成就:本研究利用中山醫學大學附設醫院睡眠中心提供之 554 筆整夜 PSG 量測的血氧飽和濃度（SpO2）記錄，來評估利用血氧飽和濃度演變歷程開發 OSAS 偵測演算法的效能。由研究結果可知，改良血氧飽和濃度偵測 OSAS 演算法的相關係數值為 0.88，相對於過去前人常用的血氧濃度特徵之指標（DI_β 之相關係數值為 0.32、TI_α 之相關係數值為 0.28、Delta Index 之相關係數值為 0.35、ODI-B-D-L 之相關係數值為 0.64）有更優良的預測效能。

技術創新:本研究整合 PSoC 系統晶片、生理訊號測量單元(血氧脈搏探針)、回饋單元(震動器)、重置單元(位移感測器)、記憶模組(micro-SD)等完成雛型系統整合開發，整體雛型系統經 30 位受試者實際操作使用後，各構面接受程度達到三以上滿意的比率介於 85%~98%，顯見受試者對本研發雛形產品接近滿意程度。

社會影響: 根據統計在台灣約有超過五十萬人患有阻塞性睡眠呼吸中止症候群(OSAS)，高齡者更常為了不同程度的睡眠呼吸障礙感到困擾。本計畫研發的睡眠呼吸障礙之監測與矯正輔助的雛形系統，可以協助使用者改變睡姿，並偵測睡姿改變的有效性，對於睡眠呼吸障礙者將可產生矯正作用。