專題

畢業專題-手勢居家助理

介紹

摘要

本專題是一款結合物聯網的手勢助理，利用手勢辨識和即時互動介面，幫助聽語障人士更方便的控制家電、實現智慧生活，並減少其與普通人在生活科技中的不平等。

手勢居家助理

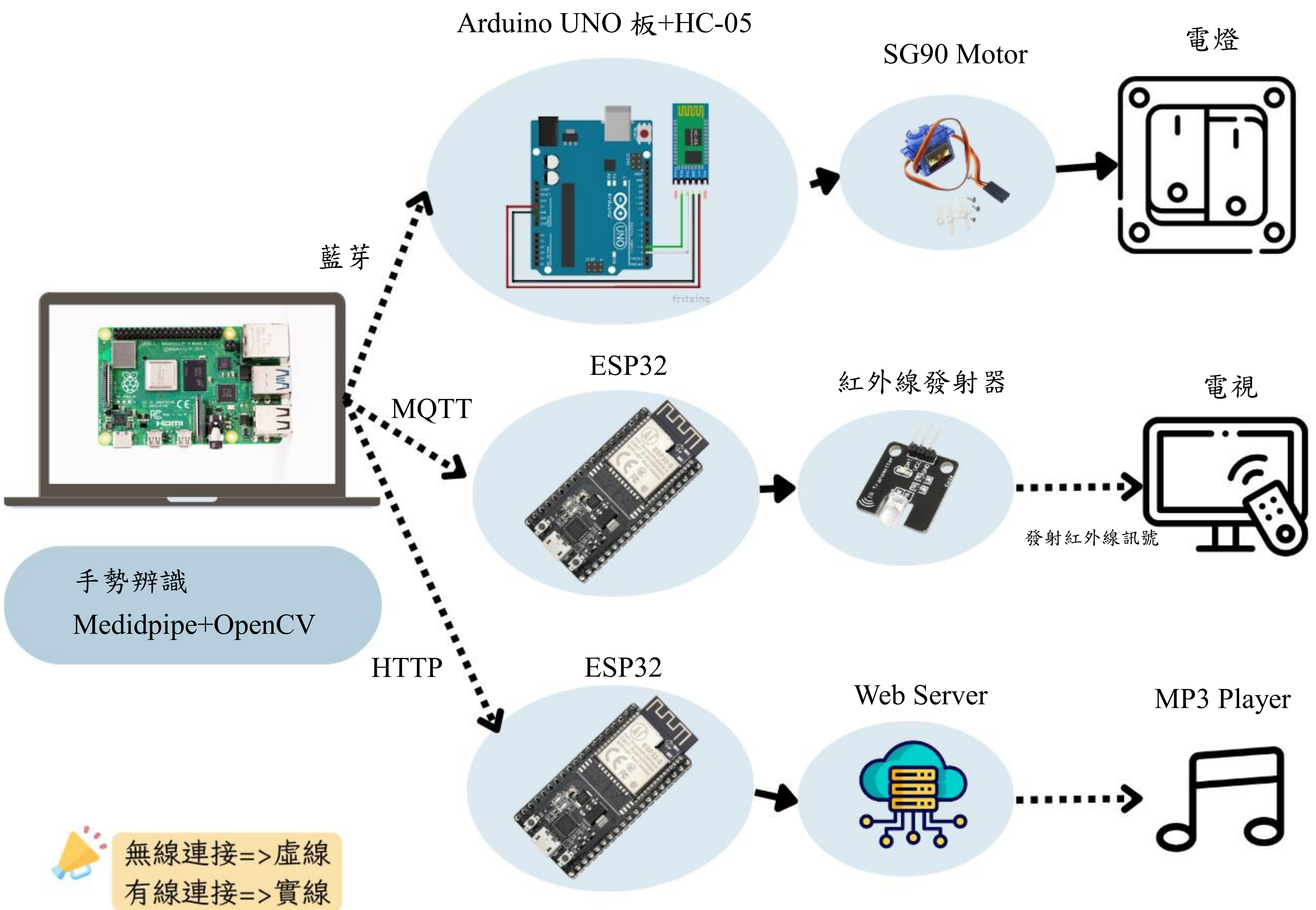
方法

- 手勢辨識=>Mediapipe
- 連接方式=>MQTT、HTTP、藍芽

優點

- 所有指令只需一隻手
- 無聯網的家電也能控制
- 多種控制方式

架構圖



無線連接=>虛線
有線連接=>實線

貢獻(參與程度)

姓名	貢獻程度	負責部分
胡郡珍	**34%**	**Raspberry Pi 運作控制、MQTT 通訊、HTTP 通訊、手勢辨識、ESP32 控制**
吳家萱	33%	手勢辨識、人臉辨識、Raspberry Pi 控制
凃宛汝	33%	Raspberry Pi 運作控制、HTTP 通訊、藍芽通訊、ESP32 控制

摘要

在這個網路普及的時代，許多家庭會使用語音控制的居家助理來管理家電。然而，現有的語音控制系統對於聽力失能者並不友好，也仍有很多電器無法被整合控制。為了解決這一問題，本研究以手勢辨識系統做為基底，利用 OpenCV 進行影像處理，並結合 MediaPipe 進行手勢偵測與辨識。通過計算手指角度及比較座標來判斷使用者的手勢，並使用 MQTT、HTTP 協定傳遞訊號給 ESP32 微控制器，或利用藍芽協定傳遞訊號至 Arduino，使其控制伺服馬達，進而間接控制家電。實驗結果表明，此系統能準確的辨識手勢並透過多種連接及傳訊方式，有效整合並控制不同的家電。未來將致力於提高手勢辨識的準確性，並增加更多的電器控制功能和連接方式。

壹、 研究方法

本研究運用 Opencv、Mediapipe 模組來進行影像處理及辨識，並利用 MQTT、HTTP 及藍芽協定傳送資料實現物聯網控制。

當鏡頭開啟時，利用 OpenCV 擷取影像，並將影像進行縮小及灰階處理，接著將處理過後的影像交給 MediaPipe 手勢辨識模型，其偵測到手掌之後，會將偵測到的手掌與手指，轉換為 21 個節點並回傳座標。接著我們計算出每根手指的角度，並根據這些角度及座標，判斷出使用者不同的手勢變化。

使用者在鏡頭開啟時，透過選單提示選擇想要控制的電器，再接著選擇該電器的控制功能選項。系統會根據使用者選擇的家電，用對應的方式傳遞訊號去控制該電器。本研究選定電視、電燈以及 MP3 Player 這三種家電做為模擬，並分別利用 MQTT 協定和 HTTP 協定傳遞訊號給 ESP32，使其利用紅外線發射器間接控制電視及 MP3 Player，或利用藍芽協定傳遞訊號至 Arduino，使其控制伺服馬達，進而間接控制電燈。

辨識完使用者的手勢後，若使用者想要控制電視，樹莓派就會使用 MQTT 協定，發布主題是「TV」的訊息，而控制電視的 ESP32 在最初就訂閱了「TV」主題，所以會收到來自樹莓派的訊息，並透過此訊息發射紅外線訊號，進而切換電視頻道。若使用者想要控制 MP3 Player，樹莓派則會使用 HTTP 協定傳送請求給 ESP32，ESP32 解析請求後，播放或停止歌曲。使用者若想控制電燈，樹莓派利用官方藍芽套件 BlueZ 發送控制訊息給 Arduino，Arduino 則透過接上藍芽模組 HC-05 來接收訊息，接收到訊息後，進而控制伺服馬達轉動指定角度，使馬達上的旋臂開啟或關閉電燈按鈕，進而達到間接控制的功能。

貳、 初步成果

本研究模擬了三種控制家電的情境，並分別用 MQTT、HTTP 及藍芽協定間接控制。

1.MQTT 切換電視頻道

鏡頭開啟時，進入手勢辨識系統，使用者先根據選單選擇電視，再選擇切換頻道的功能，最後再分別比出對應的頻道數字。假設使用者想轉台至第 62 台，依照自定義的手勢，使用者依序比出 6、2 的手勢。系統擷取影像後，利用手部節點座標計算每根手指的角度，並比較 y 座標判斷出相對應的手勢(呈現結果如圖 1、圖 2 中的筆電螢幕)，接下來樹莓派透過 MQTT 協定傳遞訊號至 ESP32，其接收到訊號後發射相對應的紅外線訊號控制電視，使電視成功切換至使用者想要的頻道，如圖 1、2。

圖 1 轉台手勢 6 示意圖

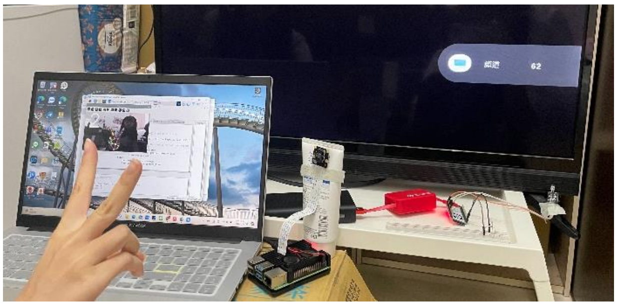


圖 2 轉台手勢 62 示意圖

2.HTTP 撥放音樂

鏡頭開啟時，進入手勢辨識系統，使用者先根據選單選擇欲撥放的歌曲，再選擇撥放。系統擷取影像後，利用手部節點座標計算每根手指的角度，並比較 y 座標判斷出相對應的手勢，接下來樹莓派透過 HTTP 協定發送控制命令給 ESP32，在 ESP32 解析命令後，控制網頁伺服器，進而撥放使用者選擇的歌曲，如圖 3。若是使用者想要停止撥放歌曲，則可比出手勢零，以停止歌曲，圖 4。

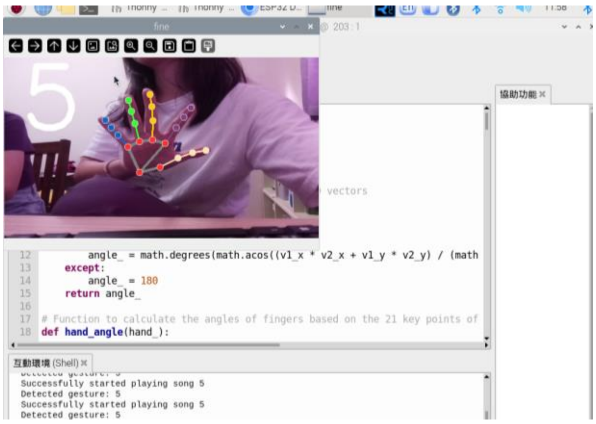


圖 3 播放歌曲 5 手勢示意圖

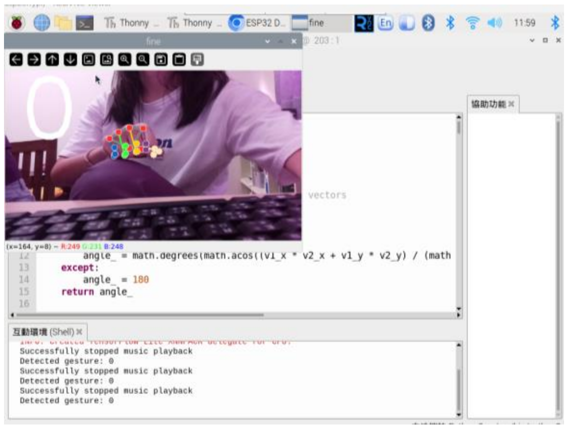


圖 4 停止歌曲手勢 0 示意圖

3. 藍芽開關燈

鏡頭開啟時，進入手勢辨識系統，使用者先根據選單選擇開燈或關燈，系統擷取影像後，利用手部節點座標計算每根手指的角度，並比較 y 座標判斷出相對應的手勢，接下來樹莓派利用官方藍芽套件 BlueZ 發送控制訊息給 Arduino，Arduino 則透過接上藍芽模組 HC-05 來接收訊息，接收到訊息後，進而控制伺服馬達轉動指定角度，使馬達上的旋臂開啟或關閉電燈按鈕，進而達到間接控制的功能。如圖 5。若使用者想要關燈，比出相對應的手勢，樹莓派就會傳送藍芽訊號使 Arduino 上的馬達旋臂關燈，如圖 6。

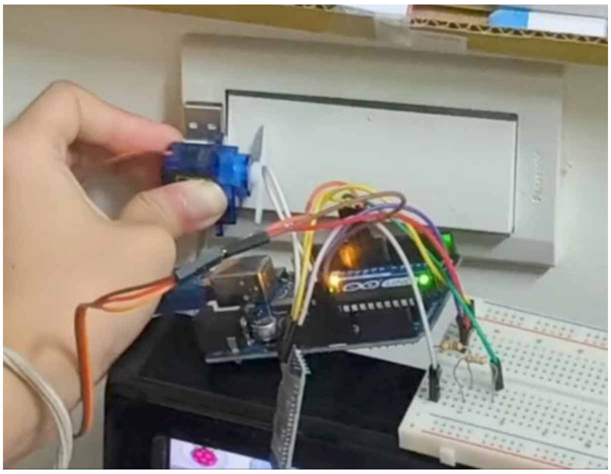


圖 5 開燈示意圖

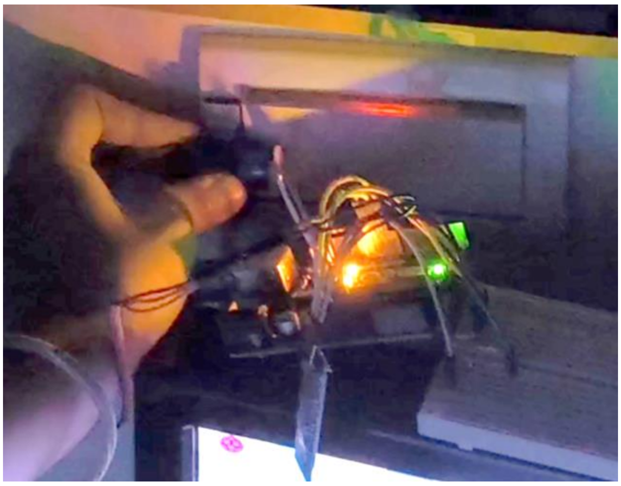


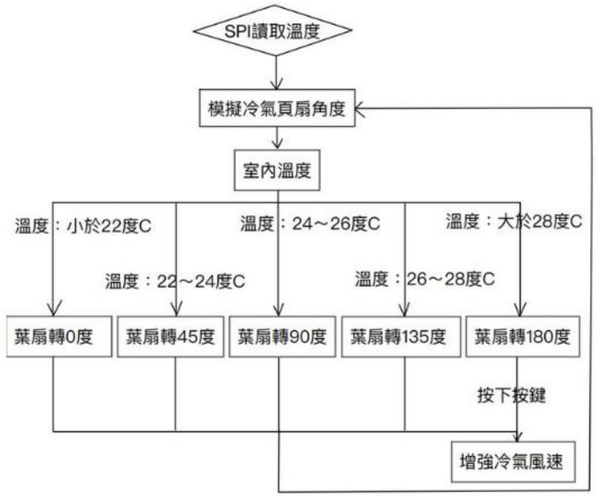
圖 6 關燈示意圖

參、 結論

本研究使用手勢辨識以及物聯網作為基底，利用 OpenCV 作為影像處理的主要工具，搭配 Mediapipe 去偵測手勢節點，並透過計算其回傳的手勢座標來辨識手勢，最後結合 MQTT、HTTP 以及藍芽協定傳遞訊號，並透過 ESP32 或 Arduino 間接控制家電，發展出一套使用手勢辨識控制家中家電的手勢居家助理。讓使用者能方便的利用此系統整合並操控家中家電。

微處理機實驗專題-智慧冷氣

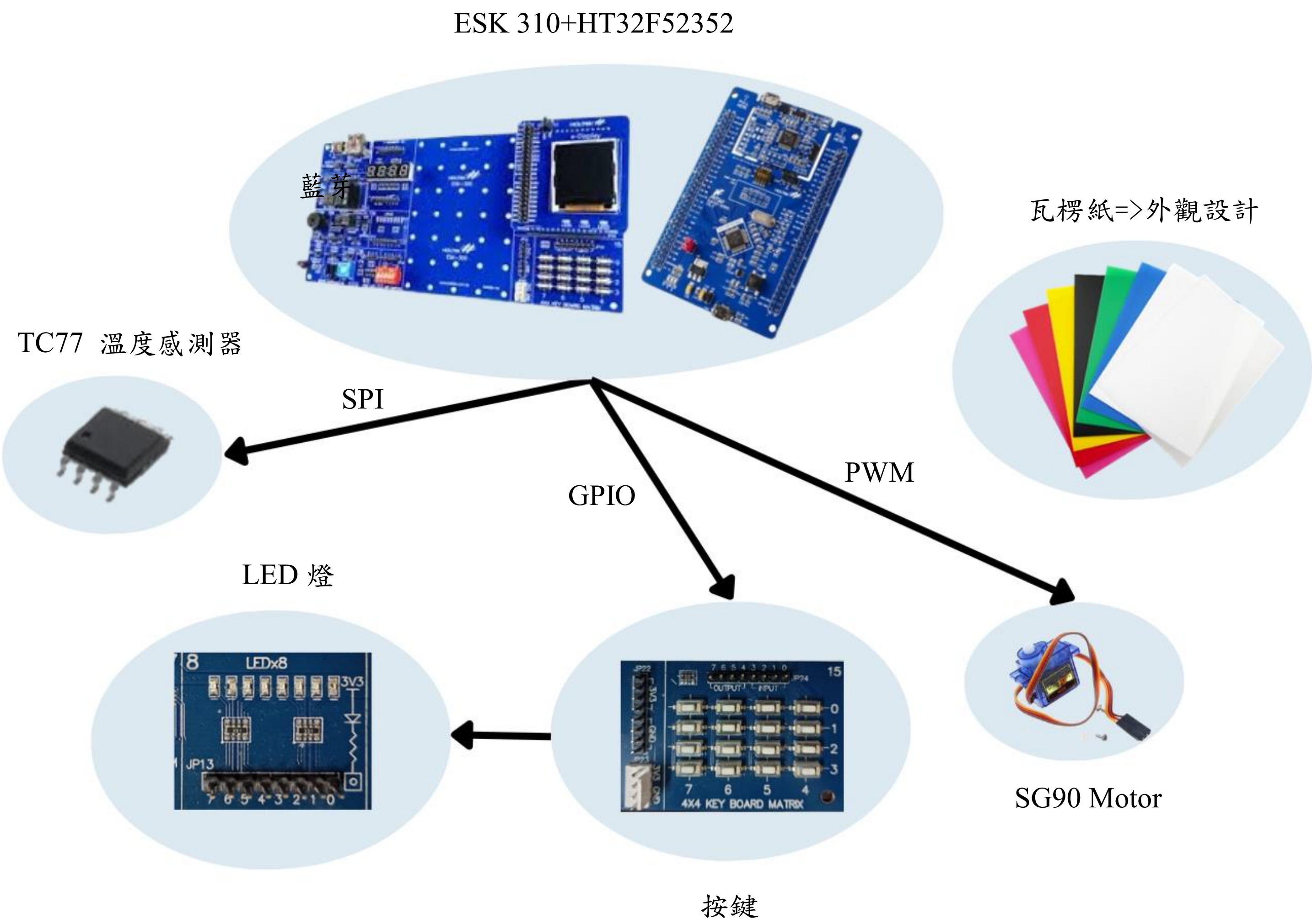
流程圖



摘要

雖然現今冷氣的設置十分普遍，卻還是沒辦法做到最適合當下氣溫的設定，例如葉扇角度、風速等。因此本專題設計出一款能根據室內溫度自動調節葉扇的冷氣。

架構圖



報告精簡內文

鄭裕評

貢獻(參與程度)

姓名	貢獻程度	負責部分
胡郡珍	**70%**	**腳位設置、UART、SPI 的使用 、伺服馬達的控制**
劉彥妤	30%	硬體連接、溫度控制

摘要

因應現在受到地球暖化的影響，冷氣對於我們而言已是生活必需品，雖然現今冷氣的設置十分普遍，卻還是沒辦法做到最適合當下氣溫的設定，例如葉扇角度、風速等。因此我們設計出一款能根據室內溫度自動調節葉扇的冷氣。我們使用盛群 HT32F52352 開發板進行軟硬體設計，因應當時溫度，去控制智慧冷氣要開啟的葉扇角度大小，或是調整冷氣的風速。

壹、 工作原理

本作品主要計算與控制由 HT32F52352 作為核心，首先做腳位的設定開啟 UART，以電腦螢幕上的 Tera Term 顯示溫度，一組 SPI 給溫度感測模組 TC77 用，一組 PWM 給馬達驅動模組用、一組 GPIO 給按鍵用。

1. MCU 核心功能

本作品主要控制與計算由盛群 HT32F52352 作為核心，首先做腳位的設定開啟 UART，一組給溫度感測器以及一組 PWM 給馬達驅動模組做驅動，一組 GPIO 腳位給按鍵連接到 LED 燈用。將 SPI、GPIO 與 PWM 所要用到的腳位都錯開，使其不互相干擾，利用迴圈的概念將溫度感測器讀到的數值去進行判斷，再由 UART 顯示溫度於 Tera Term。最後將判斷結果對應到的伺服馬達，送至 PWM 函式中。按照當時所量測到的溫度去產生結果。

2. 硬體架構

硬體架構由一個盛群 HT32F52352 開發板、一個 ESK-310 實驗板、一個溫度感測器 TC77、一個伺服馬達、按鈕裝置結合而成。HT32F52352 開發板上的 TC77 溫度感測器，運用 SPI 的特性，去偵測溫度，溫度會顯示於 Tera Term 上面，再根據 PWM 調整伺服馬達旋轉角度。另外使用 GPIO 的特性，接腳可以供使用者由程式去設計並自由使用，而我們以按鈕去控制 LED 燈，用途是高於臨界溫度 28 度時會調整風速使空間達到適合的空調強度。

貳、 實驗結果

1. 溫度調節情境

本作品的溫度需要精準地控制，因為具有三段式調節，因此在調整溫度以便溫度感測器測量是這次實驗中較困難的部分，起初我們為了使溫度達到 22 度，使用手去做加溫的動作，但手無法持續加溫使得溫度停滯在 26 度左右，而後我們使用了吹風機去做測試，由於吹風機加熱速度又太過於快速，因此我們最後使用暖暖包去做輔助。降溫的部分則是使用冰敷用的保冷袋(有做好防水措施)，實驗才能夠順利去進行。

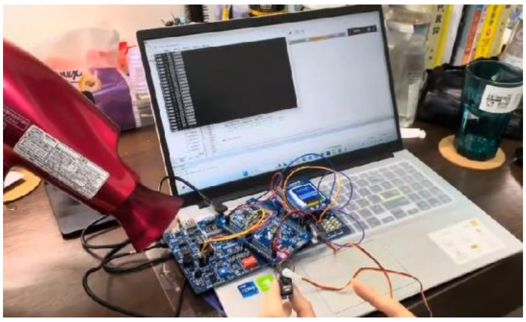


圖 1 加溫示意圖

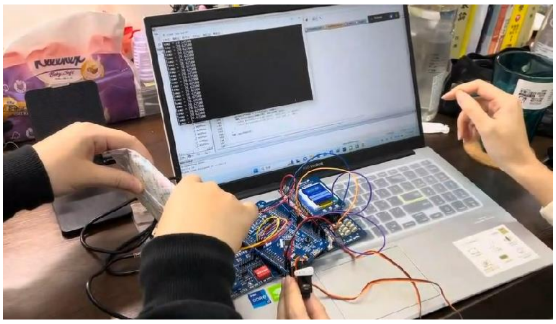


圖 2 降溫示意圖

2. 按鈕測試

這顆按鈕的目的是為了要在溫度持續超過 28 度時，讓使用者能藉著按按鈕去調整冷氣的風速，當室溫達到 28 度時即可使 LED 燈成功亮起。

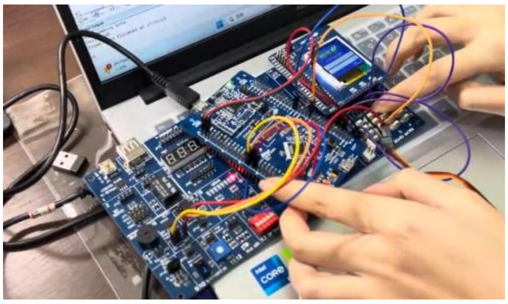


圖 3 按鈕測試示意圖

參、 結論

本作品使用盛群 HT32F52352 開發版做為核心，根據室內溫度調整冷氣葉扇角度，並且若溫度高於 28 度時，使用者可以自行調整風速。

本作品在現今四季越不分明的時代裡，會是一個有其重要性的商品，也能夠在有限的能源裡節省電能的使用，在我們平常使用冷氣的時候，感覺不夠冷的第一直覺就是調溫度，卻忽略了出風口的大小、風速的調整也會影響到整體的體感溫度，因此我們此次報告的主題除了能廣案應用在生活之中，也能配合政府目前極力呼籲的節省能源的浪費。

課堂專題

通訊序列設計

摘要

本專題透過尋找具有良好自相關特性的序列 PCP，探討其在實際通訊系統中對於同步偵測、降低多使用者干擾與提升系統穩定度之應用價值。

方法

- 二元序列建構與表示（±1）
- 自相關與交相關性質分析
- C 語言實作序列驗證程式
- 以程式計算並檢查序列是否滿足理論條件
- 比較不同序列在同步與干擾抑制上的特性

優點

- 可應用於通訊系統之同步與干擾抑制
- 序列具備明顯自相關主峰，利於接收端偵測
- 理論可驗證，亦能以程式實際實作差異

架構圖

定義良好相關性的序列

↓

序列參數設定(以±1 表示)

↓

理論性質確認

↓

C 語言實作 （序列生成與資料表示）

↓

相關性計算 （各位移下的自相關）

↓

結果分析(計算 PAPR)

- 自相關主峰高=>同步容易抓到
- 非零位移相關低=>多徑 / 多用戶干擾小

互補序列

- 時間域的峰值會彼此抵銷
- PAPR 下降
- 發射效率穩定、硬體設計複雜度較低

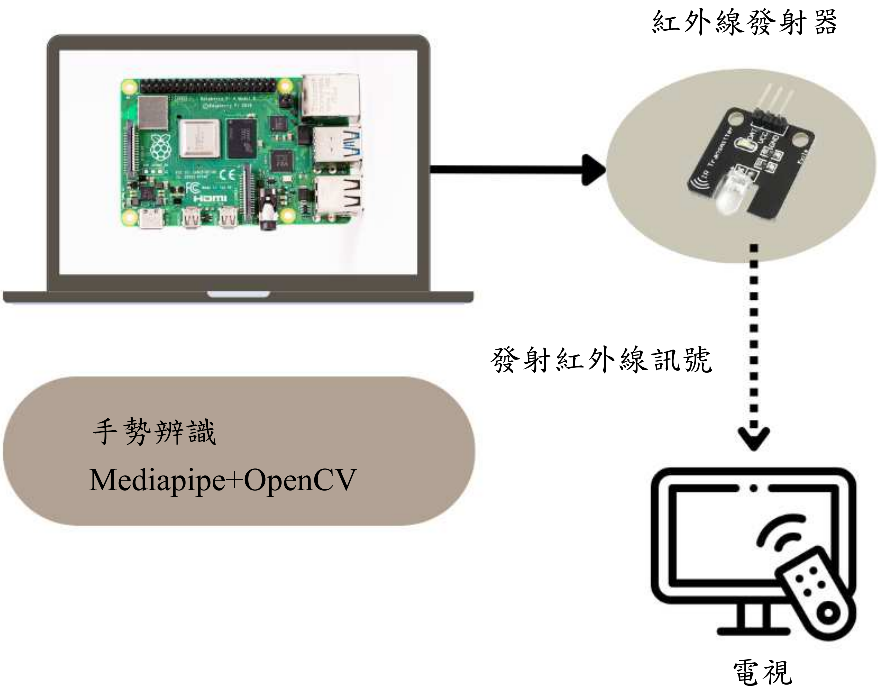
學術研究

國科會大專生計畫

前提情要

由於我國科會研究是從大二開始做的，而畢業專題是由國科會的想法做延伸的，因此國科會所作的內容不那麼全面，只有操控電視而已，尚未加上物聯網部分。

架構圖



摘要

本研究為透過影像識別技術進行手勢辨識，發射紅外線訊號，達成轉台。

研究報告精簡內文

詳情如下頁數

摘要

在現今電視普及的時代下，每人家中都至少有一台電視，不過家中可能有不識字的老人，導致他無法自己轉台。本研究為透過影像識別技術進行手勢辨識，達成轉台。

我們使用手勢辨識系統作為此研究的基底，其中利用 OpenCV 作為影像辨識的主要工具，搭配鏡頭去做影像的偵測。並透過模擬與假設的方式，發展出一套能利用使用者的手勢變化，達到遙控器所呈現的效果。

使用者能利用此裝置進行轉台，並且將電視關機。未來希望能夠更精進此裝置的應用，例如能夠透過語音辨識系統，進行音量調整。

壹、 研究動機與研究問題

1. 研究動機：

在我國中之前，一直都跟外婆住在一起，因為我外婆不識字，每次看電視時，都必須叫我和弟弟幫忙轉台，所以當我們不在家時，我外婆就無法看電視了。有一次我外婆好不容易打開電視，卻無法順利轉台和關機，就這樣讓電視持續開了一整天，直到我們放學回家時，這個狀況才解決。因此，我希望能研究出一款直覺性的遙控器，讓像外婆這樣不識字的老人家也可以方便的觀賞電視節目。

2. 研究問題：

目前操控家電的系統，大部分是語音辨識系統，雖然在近幾年，有一些利用手勢辨識系統去操控電視的應用，但他們皆無法直接轉台到使用者想觀賞的電視節目，只能依照台數的大小上下轉台。而且在網路發達的現代，出現了各式各樣的電視盒，像是常見的 MOD 機上盒、安博盒子、小米盒子等，每一種都有其對應的遙控器，因此我們計劃設計出一款能直接利用手勢辨識來控制電視達到切換節目、音量、不同輸入源等等功能，且能讓使用者可以透過同一個手勢辨識系統控制不同的電視盒。

貳、 文獻回顧與探討

1. 台北科技大學陳文輝教授的研究團隊

台北科技大學自動化科技研究所教授陳文輝的研究團隊，於 2011 年開發出一款手勢辨識系統，只要招手或揮手就可以控制電視進行轉台。此裝置是將「即時動態手勢辨識系統」的硬體介面嵌入電視機，再搭配電視機旁的攝影機去判別，而他們是利用軟硬體協同系統，做影像處理。

2. XBox

此裝置是採用 Light Coding 技術去獲取圖像，利用連續光對環境進行編碼，相當於產生散斑，經由感測器讀取訊號後，晶片運算會進行解碼，最後產生出一張具有深度的圖像。

獲取圖像後，接下來就是要進行影像辨識的工作，此裝置是利用骨架追蹤系統去做辨識，而該系統可以偵測 6 人的影像並同時辨識 2 人的動作，並且可以追蹤軀幹、四肢、手指的動作。而微軟也利用機器學習技術，建立出龐大的資料庫，目的是為了盡量讓此裝置讀懂使用者的動作。

参、 研究方法及步驟

首先利用 OpenCV 偵測手掌，之後在手指與手掌的部分產生出 21 個節點，透過這 21 個不同 x、y、z 軸座標的節點，比較這些節點座標之間的關係，進而判斷使用者的手勢。由於我們的手勢會辨識到兩隻手，所以我們使用交錯偵測的方式，在短時間內偵測兩次，一次只偵測一隻手，這樣就可一直維持 21 個節點數據。

辨識完手掌並產生出節點後，我們開始比較節點的座標並計算出當前使用者比出的手指數，首先我們先分別辨識出左手和右手，比較大拇哥上 3、4 節點的 x 軸座標，當第三節點的 x 座標小於第四節點時，則辨識為左手，反之則辨識為右手。接下來則分別辨識食指、中指、無名指及小指是否舉起，比較每根手指的 TIP 節點和 PIP 節點的 y 座標，當 TIP 節點的 y 座標小於 PIP 節點的 y 座標時，則辨識為舉起。全部辨識完後就能得到當前使用者比出的手指數。

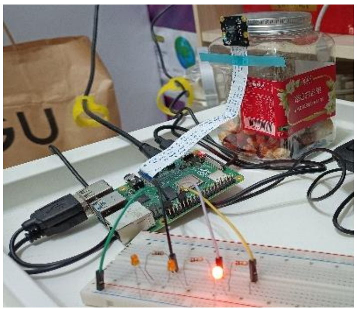
完成上述步驟後，我們開始利用 LIRC 套件使 Raspberry pi 4 發射紅外線訊號。我們先利用 LIRC 套件錄製電視遙控器的紅外線訊號，並將這些訊號記錄下來存檔，接下來將檔案匯進 python 程式，利用 LIRC 套件使其發射紅外線訊號。最後將其加入我們原本的程式碼內，利用先前程式碼辨識及計算出來的手指數，發射相對應數字的紅外線訊號。

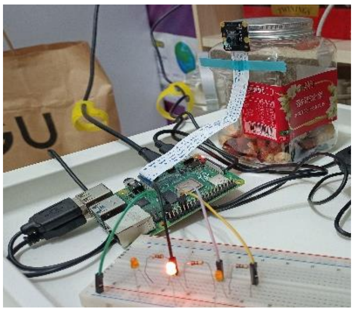
肆、 實驗結果

首先，進入手勢辨識系統，由使用者比出數字，假設使用者想轉台至第 620 台，依照自定義手勢，使用者依序比出 6、2、0 的手勢，讓系統辨識到，呈現結果如圖 1-1、圖 1-2、圖 1-3。

圖 1-1 轉台手勢 6 偵測圖　　圖 1-2 轉台手勢 2 偵測圖　　圖 1-3 轉台手勢 0 偵測圖

接下來，利用手勢辨識計算出的手指數量，發射相對應的紅外線訊號，在這裡我們利用 led 燈呈現，若系統成功辨識出正確的數字並發射出相對應的紅外線訊號，對應的 led 燈會亮起，反之則不亮起，如圖 2-1、圖 2-2、圖 2-3。





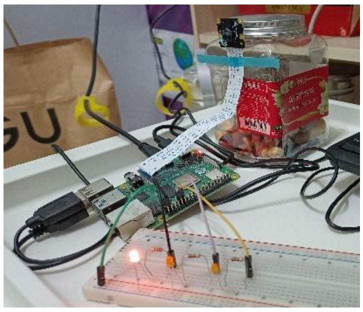


圖 2-1 轉台手勢 6 燈號反應圖　　圖 2-2 轉台手勢 2 燈號反應圖　　圖 2-3 轉台手勢 0 燈號反應圖

最後則是對應的紅外線發射出去後，電視機成功接收並轉台，圖 3-1、圖 3-2、圖 3-3。

圖 3-1 轉台手勢 6 反應圖

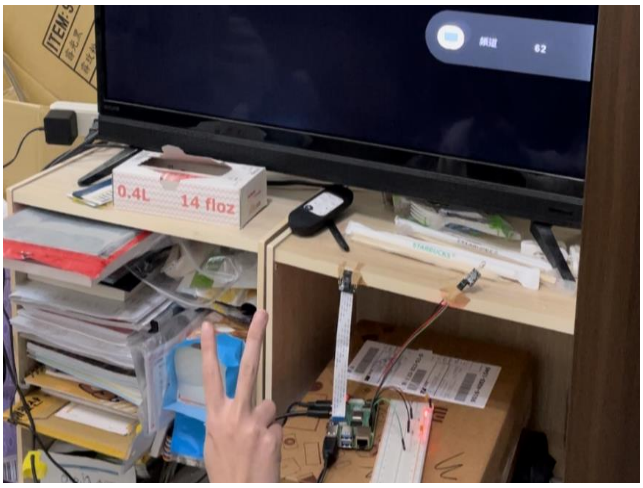


圖 3-2 轉台手勢 62 反應圖

圖 3-3 轉台手勢 620 反應圖

伍、 結論

本研究提出的手勢遙控器系統，使用多平台相容的 OpenCV 及 MediaPipe，提供一個相容性高且簡單方便的環境，幫助不識字的老人不需要依靠其他人，自己也能輕鬆轉台。另外，也能使時常找不到遙控器的使用者更方便的使用，不需再花大把時間東翻西找的找尋遙控器，而是直接利用此系統快速的達成轉台功能。

由於現在有越來越多種廠牌電視盒，例如：MOD 機上盒、安博盒子、小米盒子等等，未來我們希望可以將使用範圍擴大到多個電視盒、電視機，利用物聯網的方式控制並整合，使這項系統可以透過簡單的設定或是按鈕切換，就能在不同廠牌的電視機、電視盒所使用。另外，我們也希望未來能夠透過 WIFI 或是藍芽等訊號代替紅外線訊號，使訊號的傳送更不受環境因素影響。

InCIT 會議論文

前提情要

會議論文則是依照畢業專題一部分內容去投稿的。

培養科技論文撰寫能力

INCIT 2024: The 8th international conference on information technology - Japan
→以「Prototyping a Gesture-Controlled Smart Home Assistant- an IoT Integration Approach」參加國際研討會，分享畢業專題之成果，也藉此讓我培養了科技論文撰寫能力。

Prototyping a Gesture-Controlled Smart Home Assistant - an IoT Integration Approach

Chun-Chen Hu
Department of Electrical Engineering
Chung Yuan Christian University
Taoyuan, Taiwan
s11028110@cycu.edu.tw

Drixter Velayo Hernandez
Department of Electrical Engineering
Chung Yuan Christian University
Taoyuan, Taiwan
drixter.hernandez@cnsrl.cycu.edu.tw

Chia-Hsuan Wu
Department of Electrical Engineering
Chung Yuan Christian University
Taoyuan, Taiwan
s11028128@cycu.edu.tw

Wan-Ju Tu
Department of Electrical Engineering
Chung Yuan Christian University
Taoyuan, Taiwan
s11028202@cycu.edu.tw

Yu-Kuen Lai
Department of Electrical Engineering
Chung Yuan Christian University
Taoyuan, Taiwan
ylai@cnsrl.cycu.edu.tw

***Abstract*—The rise of IoT has revolutionized appliance management, but current voice-controlled systems face limitations in noisy environments and for individuals with hearing or speech impairments. Additionally, integrating different connectivity methods for various appliances remains a challenge. This paper presents a gesture-controlled smart home assistant designed to address these issues. By integrating MQTT and HTTP protocols, the system offers flexible control of diverse smart home devices. Utilizing a Raspberry Pi 4B with OpenCV and MediaPipe for gesture recognition can increase accessibility for individuals with hearing or speech impairments. Experimental results validate its effectiveness in accurately recognizing gestures and managing appliances, improving user interaction with smart home technologies in varied environments.**

***Index Terms*—Internet of Things (IoT), Gesture Recognition, Household Appliances, MQTT, Home Assistant, Hearing and speech Impairments**

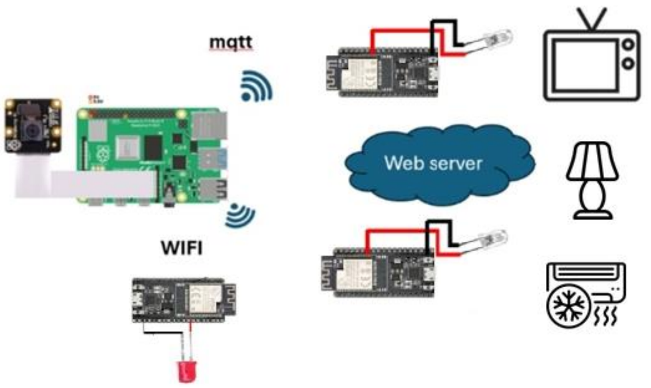


Fig. 1. Proposed System Architecture for Gesture-Controlled Smart Home Assistant.

I. Introduction and Background

The widespread of internet connectivity has facilitated the development of the Internet of Things (IoT). It fundamentally transform how we interact with household appliances. Many households now use voice-controlled home assistants to manage and control their devices to enhance convenience and efficiency within the home [1]. However, these voice-controlled systems have limitations, particularly in their design for individuals with hearing and speech impairments. The accuracy of these systems is heavily reliant on speech clarity where noisy environment is one of it's problem [2], and many appliances remain incompatible with such control methods. Another issue is there is a market gap for home automation solutions that employ different connectivity methods for different types of appliances [3].

One of the practical and common alternative for controlling appliances is through hand gestures [4]. Gesture recognition can be implemented through two main approaches: wearable and non-wearable. Past studies focuses on wearable devices. Alemuda and Lin [5] develop a wearable product that utilizes accelerometer and gyroscope to detect hand gestures based on data from the sensors. The authors employs an Android smartphone as a gateway to analyze gestures on a OneM2M-compatible IoT platform. However, the wearable approach is often inconvenient and costly. In contrast, the non-wearable approach has gained some traction in this past years. The study by Yu [6] employed deep learning methods, such as YOLOv4 and Faster-RCNN, to detect and track hand models. They collected data from various hand types and skin colors but later they transitioned to Google's MediaPipe Hands API due to low model performance. For a low-cost, flexible, and reliable home monitoring and control system, the study by Pravalika and Prasad [7] utilized an ESP32 microcontroller. This system leverages IP connectivity via local Wi-Fi to monitor and control the home through an Android smartphone application, offering an economical solution for home automation. Sobiya et al. [8] proposed an IoT-enabled hand gesture-controlled wheelchair although this solution primarily benefits individuals

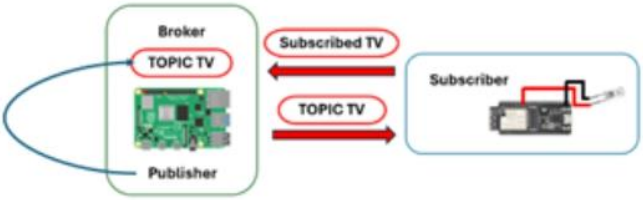


Fig. 2. MQTT-based communication model.

with mobility impairments. In the study of Tulenkov et al. [9] introduced a Smart House System utilizing an Android application to assist people with special needs. However, this study faced limitations due to its reliance on Bluetooth and Wi-Fi communication. In areas with weak signals or interference, the system's performance could be hindered. Another study by Yang et al. [10] integrated Google's MediaPipe hand tracking system to detect 21 critical points on the hand using a mobile device camera. The system calculates the angles formed by these key points using vector angle formulas to identify hand gestures and tests recognition accuracy across various gesture habits. However, this study only incorporates HTTP protocols in the system makes some of the IoT devices incompatible.

In relation, this paper proposes a gesture-controlled smart home assistant to enhance accessibility for individuals with hearing and speech impairments by enabling hand gesture control of household devices. The system integrates HTTP and MQTT communication protocols to accommodate different appliances with smooth and combined signal transmission. The study conducts comprehensive assessments of the system's performance in real-world scenarios. This approach aims to significantly improve the quality of life for users by providing a more inclusive and intuitive method of interacting with smart home technologies.

II. Proposed System

The proposed system aims to design a gesture-controlled smart home assistant that utilizes hardware and IoT devices to ensure efficient wireless control of smart home appliances. The system captures hand gestures through a camera and sends control signals wirelessly to a micro-controller. The micro-controller receives these signals and manages connected electronic devices, such as lights or infrared emitters, to execute user commands based on the hand gestures.

A. System Architecture

The system's hardware mainly consists of a Raspberry Pi 4B and an ESP32 micro-controller which is wirelessly connected using specific protocols as shown in Figure 1. The Raspberry Pi 4B is a single-board computer equipped with a NoIR Camera to capture hand movements for gesture recognition. Once a gesture is recognized, the Raspberry Pi 4B processes the data and transmits the corresponding control signal to the ESP32 micro-controller. The ESP32 is a versatile micro-controller with built-in Wi-Fi. Upon receiving control signals from the Raspberry Pi 4B via HTTP or MQTT protocols, the ESP32 controls the connected devices, such as an LED light or an infrared emitter, using its GPIO (General Purpose Input/Output) pins.

B. Network Protocols

The system supports MQTT and HTTP protocols to enable control of appliances with various connection methods. This adaptability allows the gesture-based home assistant to integrate and manage a wider range of devices. By incorporating these protocols, the system aims to accurately interpret user gestures to enhance the quality of life for individuals with hearing and speech impairments. It facilitates the integration of appliances with different types of connectivity to contribute to the advancement of accessible smart home technology.

1) MQTT is a lightweight protocol primarily used for IoT devices and allows the control of the same type of appliance simultaneously. It follows a "publish/subscribe" model that requires a publisher, a broker, and a subscriber to transmit signals. The publisher can send messages on various topics to the broker, while subscribers subscribe to the relevant or same topics. The broker manages and distributes the corresponding topic messages to the subscribers. This protocol is ideal for IoT devices with limited resources or bandwidth. As shown in Figure 2, the Raspberry Pi acts as both a publisher and broker in the MQTT protocol, publishing relevant topics followed by numeric messages after recognizing user hand gestures. The subscriber, which is the ESP32, subscribes to the same topic, which receives signals from the Raspberry Pi 4B, and further controls an infrared emitter to change TV channels.
2) HTTP is an application layer communication protocol used for transmitting information between networked devices and commonly used in smart home devices. Most of the home devices use HTTP to communicate with cloud platforms for data storage, processing, and remote control. In the system, we develop a network server on the ESP32. When a specific gesture is detected, the Raspberry Pi sends a control request to the ESP32 using the HTTP protocol. The ESP32 then processes the request and controls the connected device, such as turning an LED light on or off.

C. System Pipeline

The system pipeline begins with image acquisition through a camera to capture raw input data for gesture recognition. The image goes through initial processing method of resizing and converting to grayscale image to simplifies and enhances the accuracy of the model results. The image processing package we use is OpenCV, that is an open-source computer vision library use for image processing. The preprocessed image is feed as the input to gesture recognition model to detect and track the 21 critical points on the palm and fingers shown in Figure 3 to accurately classify the hand gesture.

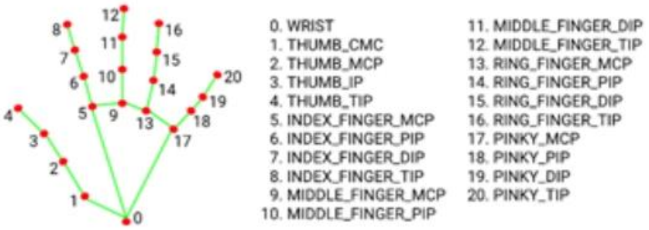


Fig. 3. Mediapipe's 21 Hand Key Points by Google [11].

The gesture recognition model that we used is from MediaPipe API [11], a versatile machine learning framework developed by Google for various platforms and applications. The system calculates finger angles using dot product computation and classifying a finger as bent when the angle exceeds 50 degrees. Adding the comparisons of Y-coordinates, enables the identification and classification of various hand gestures. Once a gesture is recognized, the system determines the appropriate action. For example, to control a television, the Raspberry Pi uses the MQTT protocol to publish a message with the topic "TV." The ESP32 then sends control signals to the television and subscribes to the "TV" topic, receives the message and emits an infrared signal to change the channel. For controlling an LED light, the Raspberry Pi sends a request to the ESP32 using the HTTP protocol, which then processes the request and controls the light. The integration of OpenCV and MediaPipe ensures efficient operation across multiple platforms and supports various programming languages and operating systems, making the system suitable for real-time recognition and detection.

D. Hand Gesture Classification

Hand gesture classification involves using technology to recognize specific hand movements and interpret them as commands. This approach provides an effective way to control household devices that makes it easier for individuals with hearing and speech impairments to interact with technology using simple and natural gestures. Figure 4 presents a series of hand gestures used for interaction within the system, with each gesture corresponding to a specific command or numerical input. The gestures for numbers 0 through 9 are clearly defined, allowing for straightforward numerical input. It includes gestures for common commands such as "Open," "Confirm," "Cancel," and "Home," which are essential for navigating and controlling the system. When the camera is activated, the user selects the appliance they wish to control from a menu prompt and then chooses the desired control function for that appliance. The system transmits control signal wireless to manage the operations of the selected appliances based on the user's choice. These gestures are designed to be easily distinguishable, ensuring accurate recognition and consistent operation for a gesture-controlled smart home environment.

III. Experimental Results

The experiment is composed of two scenarios for controlling home appliances utilizing MQTT and HTTP protocols to assess the system's performance in different communication environments. The first scenario focuses on using the MQTT protocol to manage a television, specifically for changing channels. The second scenario examines the use of the HTTP protocol for controlling an LED light. Through these scenarios, we aim to demonstrate the system's flexibility and adaptability in managing various smart home appliances in diverse smart home settings.

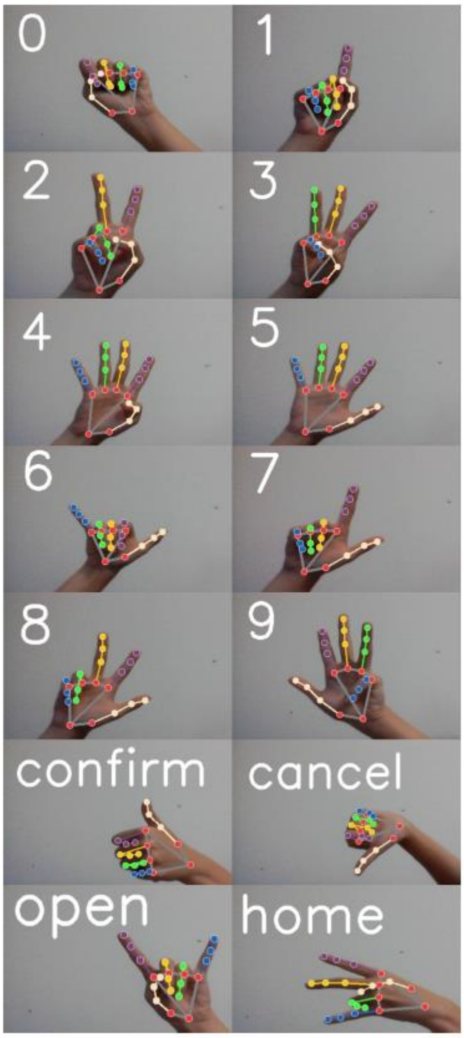


Fig. 4. Gesture definition for Smart Home control system.

A. MQTT for Switching TV Channels

In this experiment, the system employs the MQTT protocol to facilitate the changing of TV channels through gesture-based controls. This approach utilize the MQTT protocol's lightweight and efficient communication model to allow the Raspberry Pi to communicate smoothly with the ESP32 device and controls the television via infrared signals. The proposed system operates by displaying the current camera feed and offering a menu that allows the user to select the target device. When the user selects the television from the menu and chooses the function to switch channels. The system also guides the user through the corresponding gestures for each digit in the desired channel number. In this scenario to switch to channel 620, the user performs the gestures for 6, 2, and 0 sequentially. Figures 5, 6, and 7 illustrate the subsequent steps in changing the channel to 620. This provide a visual representation of this entire process, from gesture recognition to the successful execution of the channel change. This showcase the system's capability in efficiently managing gesture-based controls for television.

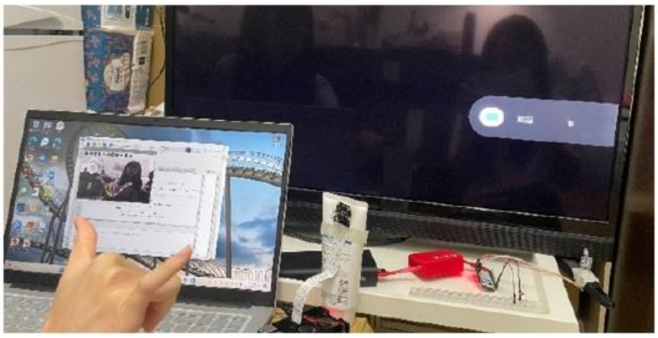


Fig. 5. Real-time gesture recognition for "6" using MQTT in Switching TV Channels.

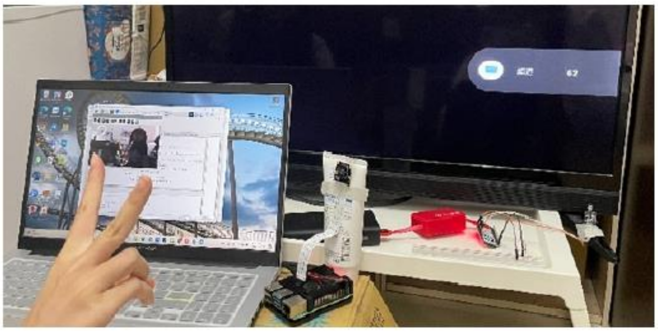


Fig. 6. Real-time gesture recognition for "2" using MQTT in Switching TV Channels.

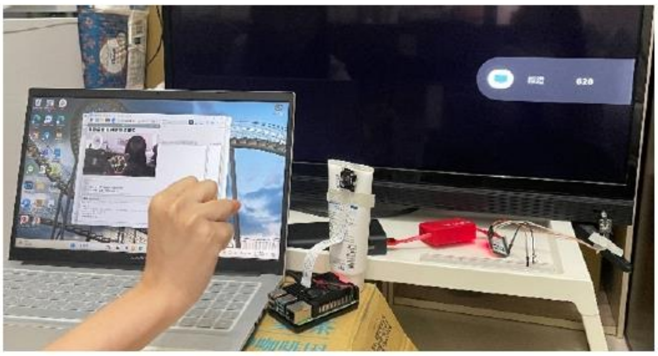


Fig. 7. Real-time gesture recognition for "0" using MQTT in Switching TV Channels.

B. HTTP for Turning On/Off the Light

Throughout this experiment the system utilizes the HTTP protocol to control a light, allowing the user to turn it on or off through gesture recognition. Upon activation of the camera, the gesture recognition system is initiated, and the user selects the light from the menu, followed by the option to either turn it on or off. The process where the user performs the gesture for "0" to turn on the light is demonstrated in Figure 8. The system captures the image and uses the gesture recognition algorithm to analyze the hand's node coordinates. The calculated angles and Y-coordinates determine that the gesture corresponds to "0," which is displayed on the laptop screen. The system then sends an HTTP request to the ESP32, which processes the command and successfully turns on the light. In Figure 9 demonstrates the process for turning the light off. The user performs the gesture for "1," which the system captures and analyzes in a similar manner to the previous example. The gesture recognition algorithm identifies the gesture as "1," as displayed on the laptop screen in Figure 9. The system then sends another HTTP request to the ESP32 that executes the command and turns off the light. This sequence of actions, from gesture recognition to HTTP-based command execution, showcases the system's ability to accurately interpret user gestures and control smart home devices, ensuring efficient and reliable operation.

The experimental results demonstrate the system's effectiveness in managing smart home appliances using both MQTT and HTTP protocols. The MQTT-based scenario for changing TV channels proved efficient, with the system successfully recognizing and executing gestures for channel selection. Similarly, the HTTP-based experiment for controlling an LED light showed reliable gesture recognition for turning the light on and off. Overall, the results confirm the system's flexibility and reliability in different communication environments, showcasing its adaptability in smart home settings.

Fig. 8. Real-time gesture recognition for "0" using HTTP in Turning On the Light.

Fig. 9. Real-time gesture recognition for “1” using HTTP in Turning Off the Light.

IV. Conclusions

This paper presents a gesture-controlled smart home assistant designed to enhance accessibility for individuals with hearing or speech impairments. Utilizing both MQTT and HTTP protocols makes the system demonstrates flexibility and effectiveness in managing various smart home devices. Experimental results show that the MQTT protocol efficiently handles TV channel changes through gesture-based controls, while the HTTP protocol reliably manages LED light switching. These findings validate the system's adaptability and performance in diverse communication environments, highlighting its potential to improve interaction with smart home technologies for users with specific accessibility needs. Future studies will focus on expanding the system to support a broader range of appliances and incorporating additional IoT-based remote control methods.

Acknowledgment

This project is funded by the National Science and Technology Commission of Taiwan under project number NSTC 112-2813-C-033-006-E.

References

[1] R. M. Roy, B. Sabu, N. A, and A. R. P, “Voice controlled home automation system,” in *2021 Seventh International conference on Bio Signals, Images, and Instrumentation (ICBSII)*. IEEE, pp. 1–6. [Online]. Available: https://ieeexplore.ieee.org/document/9445150/

[2] M. Rane, D. Kanade, O. Sonone, A. Suryawanshi, P. Solankar, and S. Ghonmode, “Voice-controlled home automation system,” in *Smart Trends in Computing and Communications*, T. Senjyu, C. So-In, and A. Joshi, Eds. Springer Nature Singapore, vol. 650, pp. 165–174, series Title: Lecture Notes in Networks and Systems. [Online]. Available: https://link.springer.com/10.1007/978-981-99-0838-7_14

[3] A. Gerodimos, L. Maglaras, M. A. Ferrag, N. Ayres, and I. Kantzavelou, “IoT: Communication protocols and security threats,” vol. 3, pp. 1–13. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S2667345222000293

[4] B. J. Boruah, A. K. Talukdar, and K. K. Sarma, “Development of a learning-aid tool using hand gesture based human computer interaction system,” in *2021 Advanced Communication Technologies and Signal Processing (ACTS)*. IEEE, pp. 1–5. [Online]. Available: https://ieeexplore.ieee.org/document/9708354/

[5] F. Alemuda and F. J. Lin, “Gesture-based control in a smart home environment,” in *2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*. IEEE, pp. 784–791. [Online]. Available: http://ieeexplore.ieee.org/document/8276839/

[6] C.-R. Yu, “Virtual touch system with assisted gesture based on deep learning and MediaPipe.” [Online]. Available: https://hdl.handle.net/11296/743479

[7] V. Pravalika and C. R. Prasad, “Internet of things based home monitoring and device control using esp32,” vol. 8, no. 1.

[8] S. K. Sobiya, M. Hema Kumar, and M. Sriram, “IoT enabled hand gesture controlled wheelchair for disabled people,” in *2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA)*. IEEE, pp. 140–145. [Online]. Available: https://ieeexplore.ieee.org/document/10220652/

[9] A. Tulenkov, Y. Yaremchenko, A. Parkhomenko, Y. Zalyubovskiy, A. Parkhomenko, and M. Kalinina, “Adaptation of smart house system for people with special needs based on wireless technologies,” in *2020 IEEE 5th International Symposium on Smart and Wireless Systems within the Conferences on Intelligent Data Acquisition and Advanced Computing Systems (IDAACS-SWS)*. IEEE, pp. 1–6. [Online]. Available: https://ieeexplore.ieee.org/document/9297072/

[10] C.-Y. Yang, Y.-N. Lin, S.-K. Wang, V. R. Shen, Y.-C. Tung, F. H. Shen, and C.-H. Huang, “Smart control of home appliances using hand gesture recognition in an IoT-enabled system,” vol. 37, no. 1, p. 2176607. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/08839514.2023.2176607

[11] C. Lugaresi, J. Tang, H. Nash, C. McClanahan, E. Uboweja, M. Hays, F. Zhang, C.-L. Chang, M. G. Yong, J. Lee, W.-T. Chang, W. Hua, M. Georg, and M. Grundmann, “MediaPipe: A framework for building perception pipelines.” [Online]. Available: http://arxiv.org/abs/1906.08172

獲獎紀錄

學業成績

中原大學獎狀

書卷獎

電機資訊學院電機工程學系學生

胡郡珍

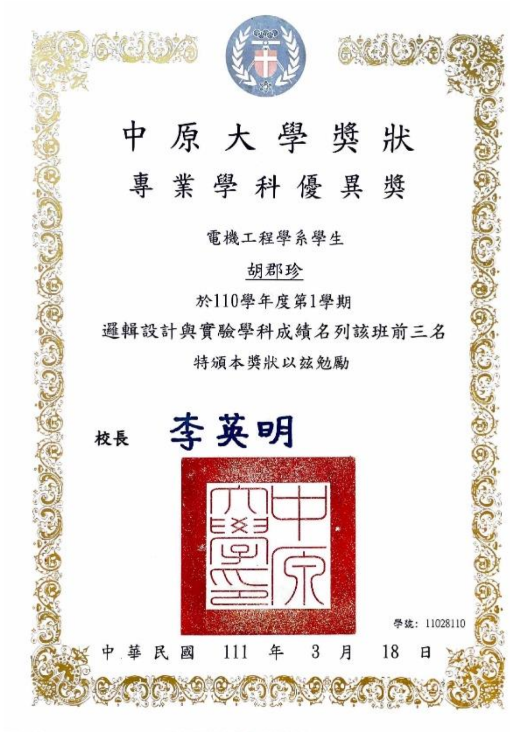
於110學年度第1學期

學業成績優異　特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 111 年 3 月 24 日



中原大學獎狀

專業學科優異獎

電機工程學系學生

胡郡珍

於110學年度第1學期

邏輯設計與實驗學科成績名列該班前三名

特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 111 年 3 月 18 日

中原大學獎狀

基本學科優異獎

電機工程學系學生

胡郡珍

於110學年度第1學期

微積分學科會考成績達電資學院前百分之二

特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 111 年 3 月 18 日

中原大學獎狀

書卷獎

電機資訊學院電機工程學系學生

胡郡珍

於110學年度第2學期

學業成績優異　特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 111 年 10 月 12 日

中原大學獎狀

基本學科優異獎

電機工程學系學生

胡郡珍

於110學年度第2學期

微積分學科會考成績達電資學院前百分之二

特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 111 年 10 月 12 日

中原大學獎狀

書卷獎

電機資訊學院電機工程學系學生

胡郡珍

於111學年度第1學期

學業成績優異 特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 112 年 3 月 16 日

中原大學獎狀

專業學科優異獎

電機工程學系學生

胡郡珍

於111學年度第1學期

電路學(二)學科成績名列該班前三名

特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 112 年 3 月 16 日

中原大學獎狀

書卷獎

電機資訊學院電機工程學系學生

胡郡珍

於111學年度第2學期

學業成績優異 特頒本獎狀以玆勉勵

校長 李英明

學號: 11028110

中華民國 112 年 9 月 22 日

中原大學獎狀

書卷獎

電機資訊學院電機工程學系學生

胡郡珍

於112學年度第1學期

學業成績優異　特頒本獎狀以玆勉勵

校長 李英明

學號：11028110

中華民國 113 年 3 月 18 日

競賽參與

中原大學電機資訊學院

入圍獎

112學年度微星盃-原力覺醒

專題暨AI創意構想競賽

學生：胡郡珍、吳家萱、涂宛汝

參加組別：AI創意構想組

作品名稱：公車輔助系統及APP應用

指導老師：賴裕昆老師

電機資訊學院 院長 張玫元

中華民國 112 年 12 月 27 日

致理科技大學

Chihlee University of Technology

獎狀

中華民國 113 年 05 月 24 日

致研發字第 1130000017 號

胡郡珍、吳家萱、涂宛汝

參加「2024 第七屆 致青春創未來全國選拔大賽」

表現優異，受評審肯定，榮獲 創意獎

參賽組別：科技應用組

團隊名稱：指尖慧思團隊

作品名稱：Helen 手勢居家助理

指導老師：賴裕昆老師

校長 陳珠龍

國立臺北護理健康大學

獎　狀

賴裕昆 老師帶領 胡郡珍、吳家萱、涂宛汝同學以主題「手勢居家助理」投稿參加本校健康科技學院主辦之「2024 全國健康科技創新創意競賽」，榮獲第二名，特頒此狀，以資獎勵。

健康科技學院

院長 洪論評

中華民國 113 年 6 月

2024全國大專校院智慧創新暨跨域整合創作競賽參賽證明書

中原大學 電機工程學系
姓名：胡郡珍、吳家萱、涂宛汝
作品名稱：手勢助理
gesture assistant
指導教授：賴裕昆 教授
參加本校舉辦之
2024全國大專校院智慧創新暨跨域整合創作競賽
報名參賽隊伍共 275 隊、 901 人次
特此證明

競賽計畫主持人
中央大學資訊工程學系 蘇木春

中華民國 113 年 08 月 09 日

研究證明

NSTC 國家科學及技術委員會
National Science and Technology Council

國家科學及技術委員會
中華民國台北市和平東路2段106號
National Science and Technology Council
Republic of China
106 SECTION 2, HEPING EAST ROAD,
TAIPEI 106214, TAIWAN, R.O.C.

June 19, 2024

To whom it may concern:

This is to certify that Ms. Chun-Chen Hu, an undergraduate in the Department of Electrical Engineering at Chung Yuan Christian University, conducted the research project funded by the National Science and Technology Council (Taiwan) from July 2023 to February 2024.

Grant Number：112-2813-C-033-006-E
Project Title："Hand" - the most convenient remote control
Amount of Grant：NT$58,000

國家科學及技術委員會 NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

中原大學
大專學生研究創作獎

本校 電機工程學系學生胡郡珍
參與 112 學年度大專學生研究計畫
「「手」-最方便的遙控器」
經電資學院評選研究成果優異，特頒此狀以資鼓勵，並可於三年內就讀本校研究所期間獲得二年期之研究助學金。

校　長 李英明

This Certification of **Undergraduate Research Award** is granted to ***HU, CHUN-CHEN*** for excellent performance in research projects. A two-year research assistantship will hence be granted in the period of her graduate study at Chung Yuan Christian University.

President

In-Ming Lee

中華民國 113 年 6 月

InCIT 2024: The 8th International Conference on Information Technology

September 30, 2024

An Official Acceptance Letter (InCIT 2024)

Dear Chun-Chen Hu, Drixter Velayo Hernandez, Chia-Hsuan Wu, Wan-Ju Tu and Yu-Kuen Lai

As you have submitted an article to participate in the 8th International Conference on Information Technology (InCIT 2024) to be held on November 14-15, 2024 in Kanazawa, Ishikawa Prefecture, Japan, under the topic "*Prototyping a Gesture-Controlled Smart Home Assistant - an IoT Integration Approach*", the Conference Executive Committee is pleased to inform you that the article has been "reviewed" and was accepted by at least 3 qualified reviewers from various institutions.

We allow you to present your academic work in the form of an Oral Presentation at the 8th International Conference on Information Technology (InCIT 2024) to be held on November 14-15, 2024 in Kanazawa, Ishikawa Prefecture, Japan.

(Chetneti Srisaan, Ph.D. Assoc. Prof.)
Chairman of the InCIT 2024 International Conference

活動證明

Certificate

of Attendance

This certificate is presented to

Chun Chen Hu
Chung Yuan Christian University

for attending the International Workshop Summer, 2024 from July 28 to August 2 at Tokyo Denki University.

Japanese Class and Drone Competition

Makoto Shishido
Director
International Center
Tokyo Denki University

August 2, 2024

Certificate of Completion

This certificate acknowledges that,

HU,CHUN-CHEN 胡郡珍

Chung Yuan Christian University,

has completed all requirements for Summer Camp Program at Chung Yuan Christian University,

offered from August 1 to August 21, 2024.

Chun-Song Chiu

Chairman Dean
College of Electrical Engineering and Computer Science
Chung Yuan Christian University

August 21, 2024