2021 Synopsys ARC 盃 AIoT 設計應用競賽
決賽作品

基於邊緣運算架構結合手勢辨識的智慧電梯

Smart elevator based on edge computing architecture combined with gesture recognition

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2021.07.25

Agenda

- 作品概述
- 難點與創新
- 設計與實現
- 作品進度
- 測試結果
- 總結展望

作品概述

Introduction

Introduction

- **Zero-contact technology**
  - Market consumption
  - Medical care
  - School education
  - Restaurant service
  - Public transportation
- **The virus spread in elevator quickly and easily**
  - 2003 SARS
  - 2019 COVID-19

Introduction

- Gesture recognition
- Always – On system
- Ultra Low Consumption
- Embedded AI Acceleration
- Edge Computing

SYNOPSYS®
Silicon to Software™

ARC DESIGN CONTEST 2021

Himax
Drive for better vision

Himax WE-I Plus

Introduction

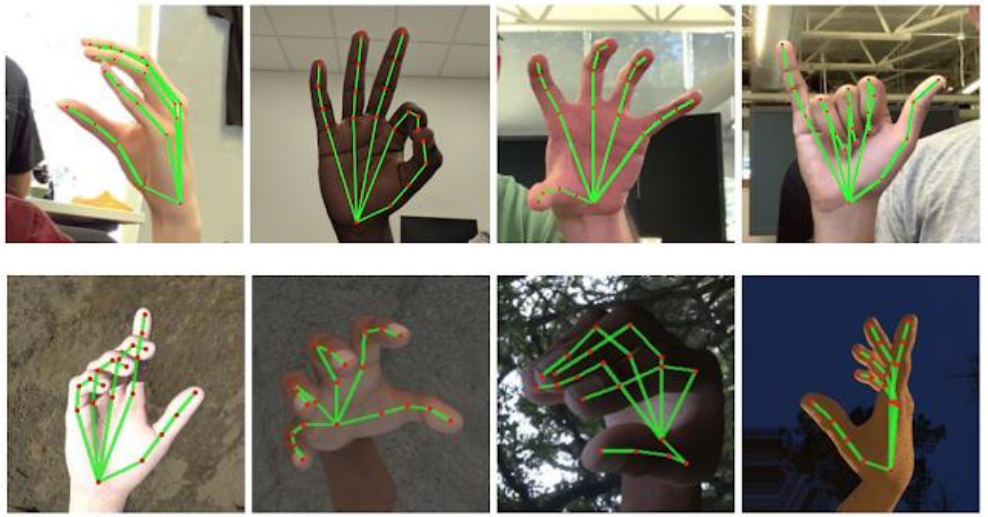
	Himax WE-I Plus	ESP8266	Raspberry Pi 4B	NVIDIA Jetson Nano
Price (NT$)	1,800	240	2,500	3,400
GPIO	4	16	40	40
Flexibility	Low	Medium	High	High
OS	X	X	V	V
Size	47 x 16 (mm x mm)	48.26 x 25.4 (mm x mm)	85.6 x 53.98 (mm x mm)	100 x 80 (mm x mm)
Clock Rate	400 MHz	160 MHz	1.5 GHz	1.5 GHz
Power	< 2.5 mW	250 mW	3.4W / 7.6 W	5W / 10W
ML	V	v	V	V

創新與難點

Innovation & Difficulties

Innovation & Difficulties

- **Difficulties**
  - Privacy
  - Multi-gesture recognition
  - Scenes variation
  - Different skin color
  - Different type of gestures
  - Handicapped unfriendly
  - 10^{+} flows control & cancelling control
  - Recognition speed leads to errors



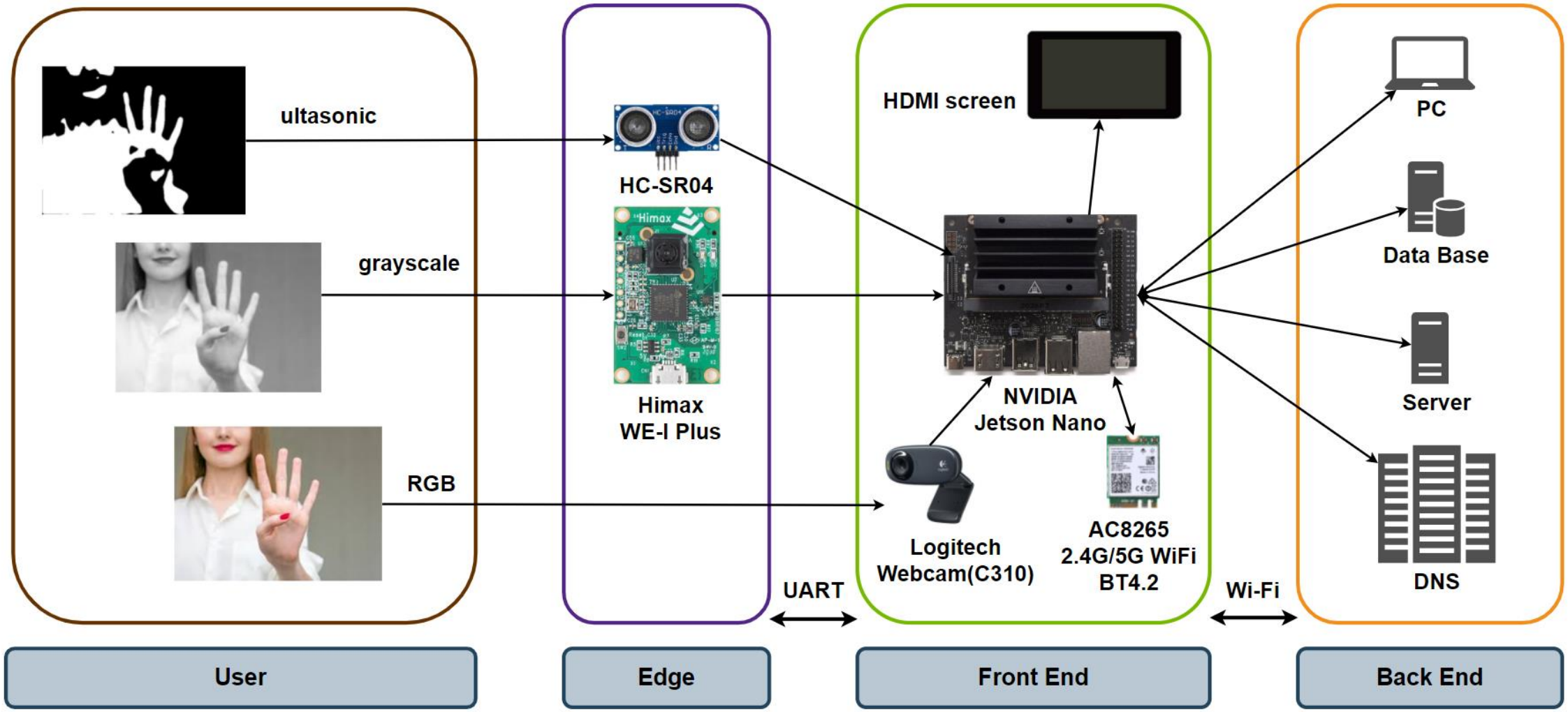
Innovation & Difficulties

- **Innovation**
  - Control the elevator with gesture recognition
  - Always-on system
  - Use ultra-low power AI ASIC (Himax WE-I Plus) as the trigger unit
  - Low latency, real-time hand detection and gesture recognition
  - Support continuous floors input
  - Simulate elevator flow control through JavaScript
  - Use gesture recognition to remotely control server
  - Combination of high OPS unit and low power edge sensor

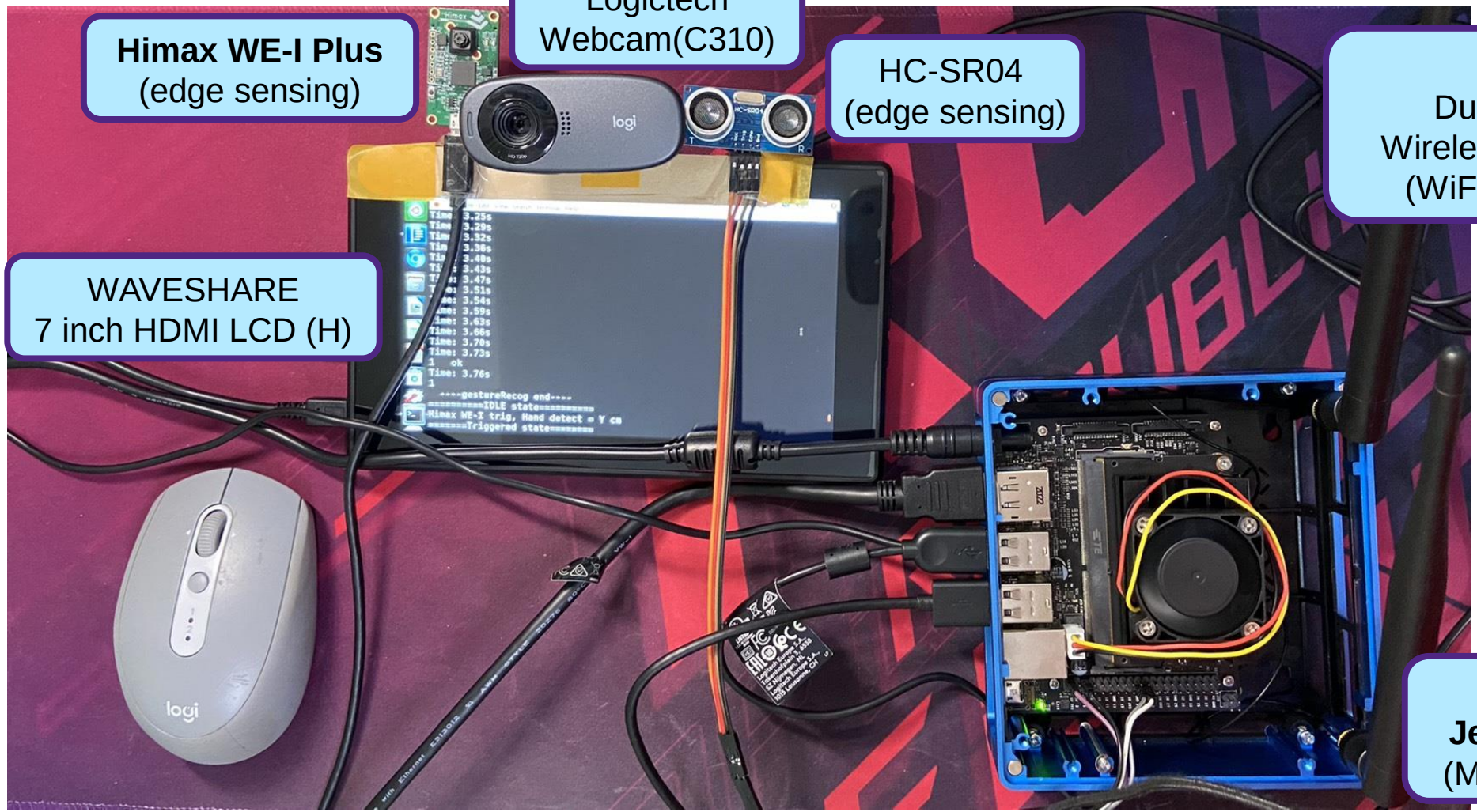
設計與實現

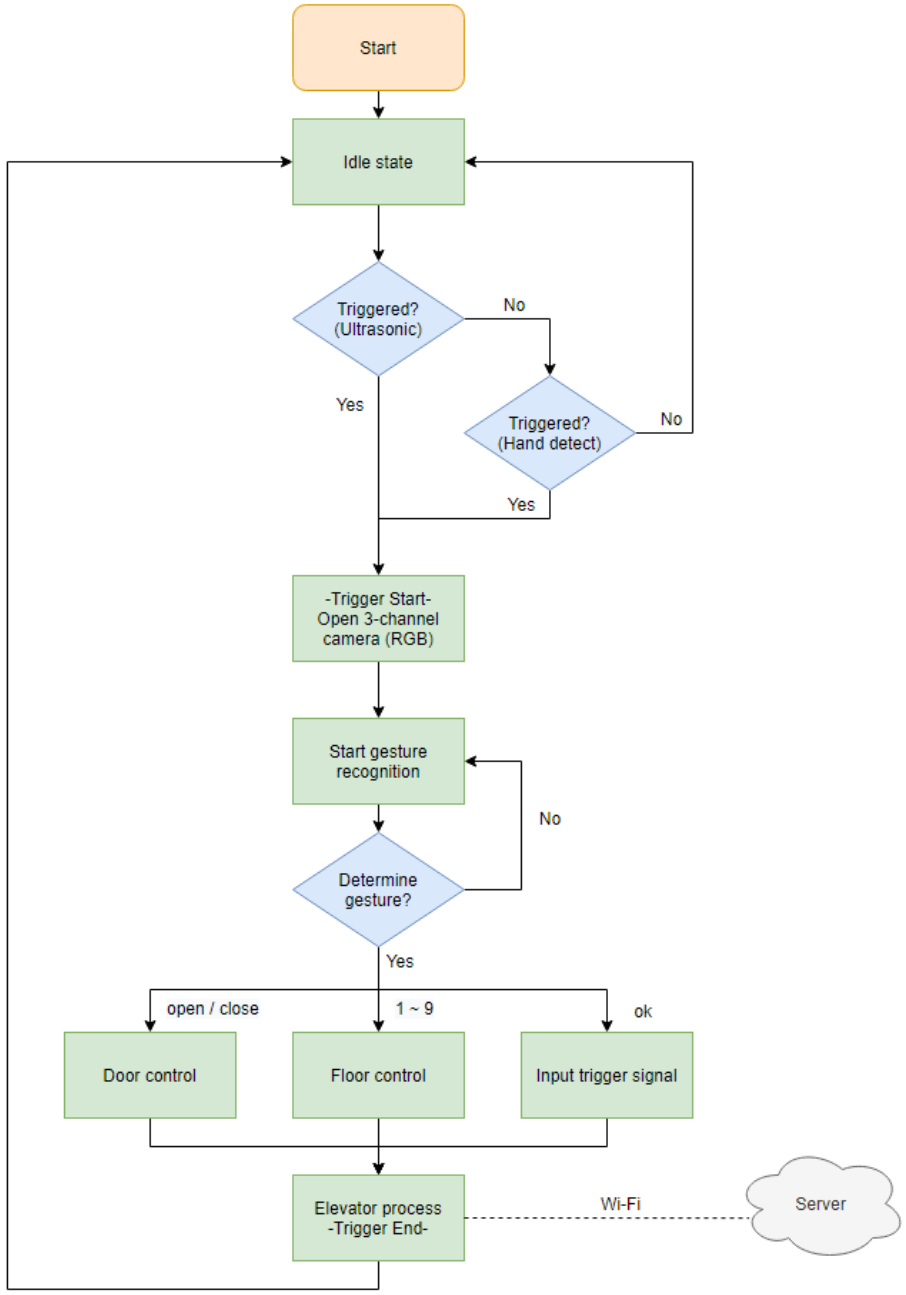
Design & Implementation

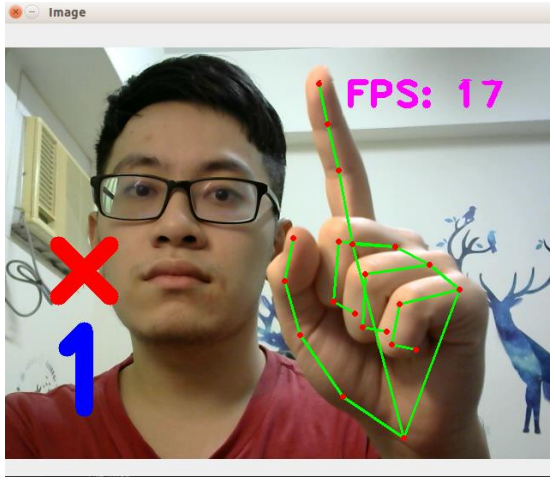
Design – System Architecture & System Flow

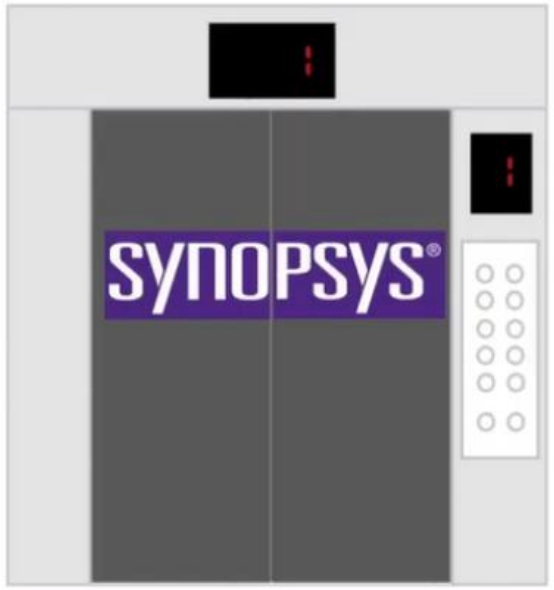


Design – Physical Design









Gesture Detection

- Himax WE-I Plus
- TensorFlow Lite
- Keras

Gesture Recognition

- NVIDIA Jetson Nano
- OpenCV
- MediaPipe API

Control Simulation

- Elevator animation
- Flask
- jQuery
- Express.js

Implementation – Hand Detection

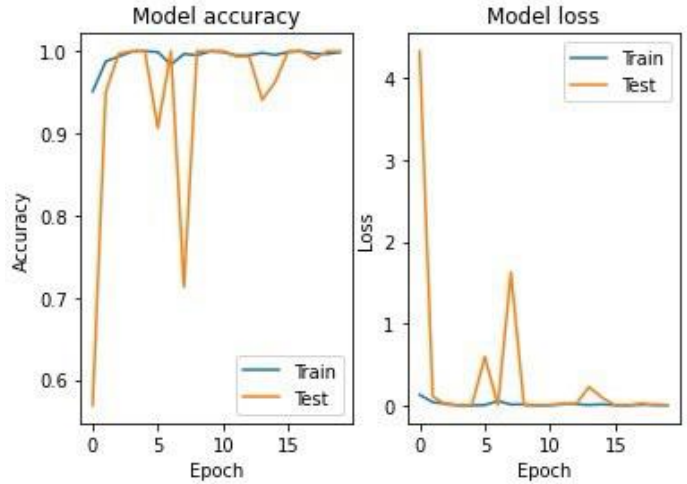
- **Always-on detector**
  - Real time hand & object detection
  - Always – on & wake up system
  - Edge computing architecture
  - Trigger high OPS units
  - Reduce power comsuption

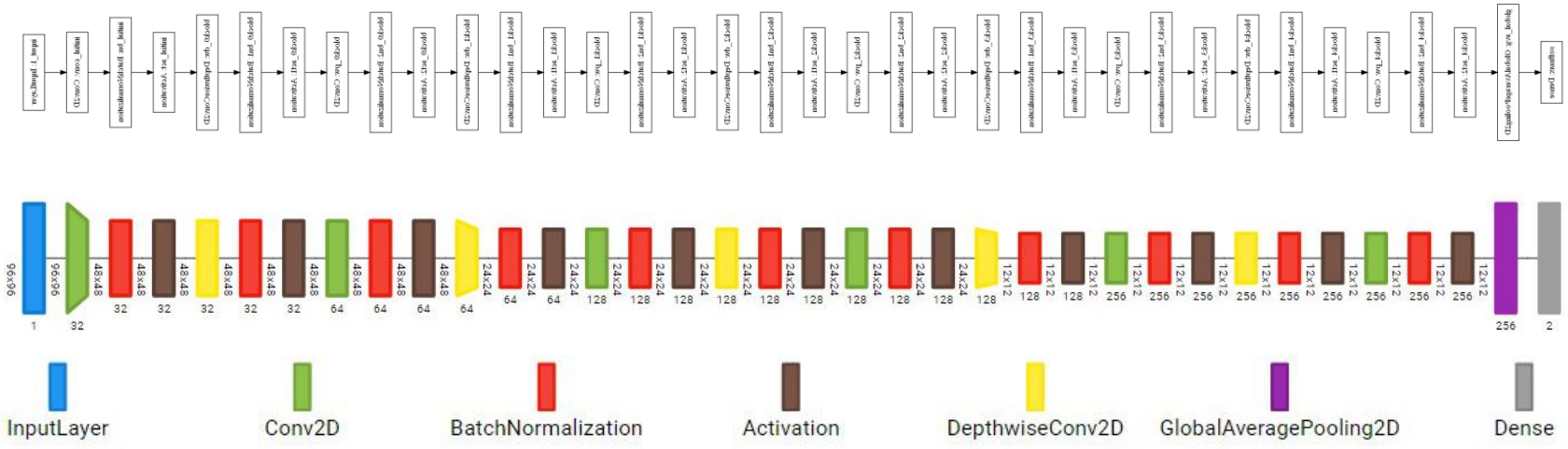
Bring Smart Everything to Life

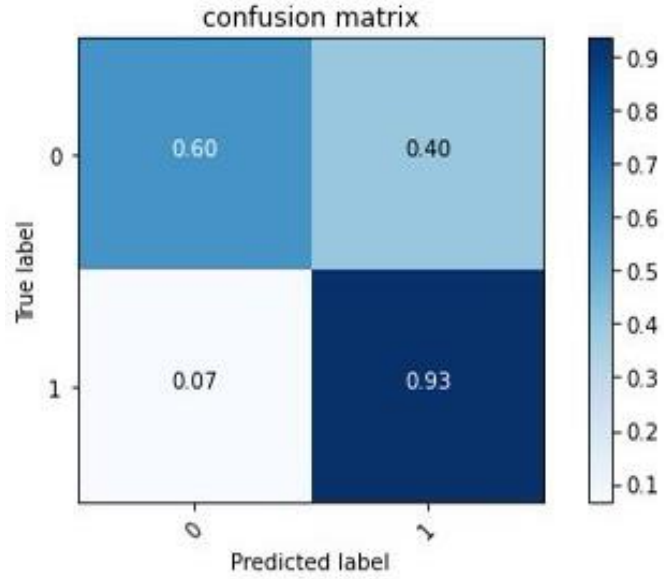
Implementation – Hand Detection

- **MobileNet**

```
Total params: 137,090
Trainable params: 134,146
Non-trainable params: 2,944
```

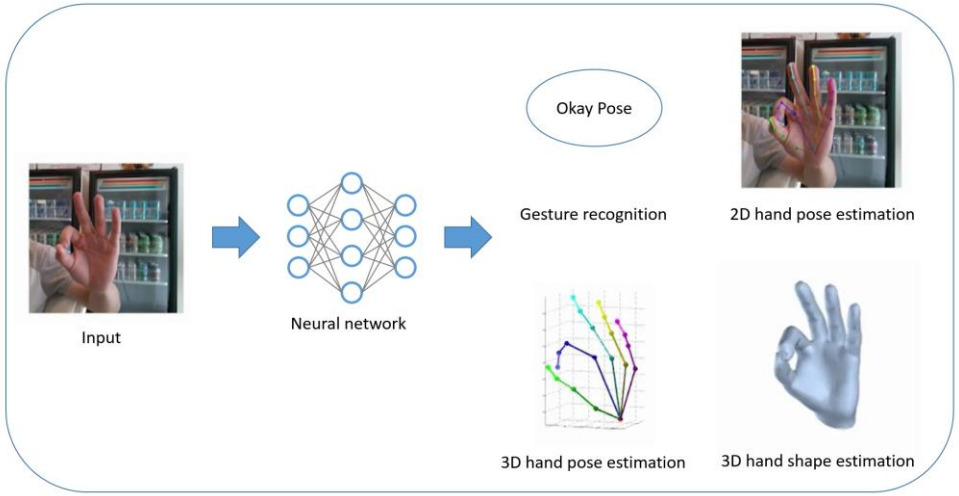




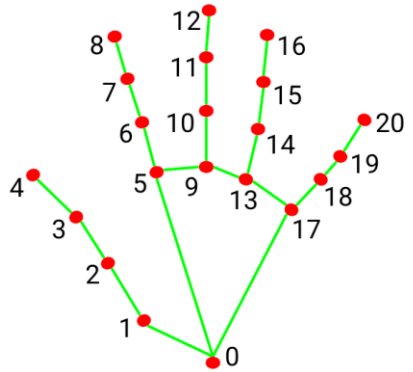


Implementation – Gesture Recognition

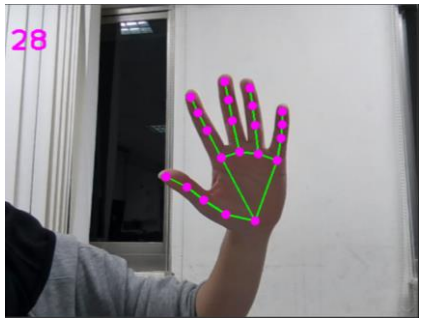
- **MediaPipe Hand**
  - Hand pose estimation & tracking
  - Hand gesture recognition
  - Robust real-time hand perception

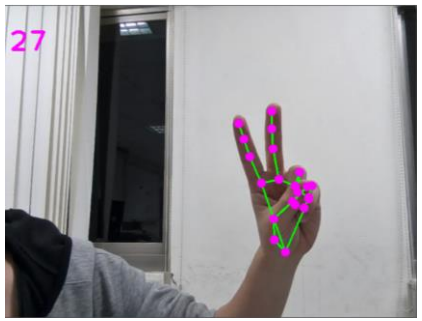


MediaPipe



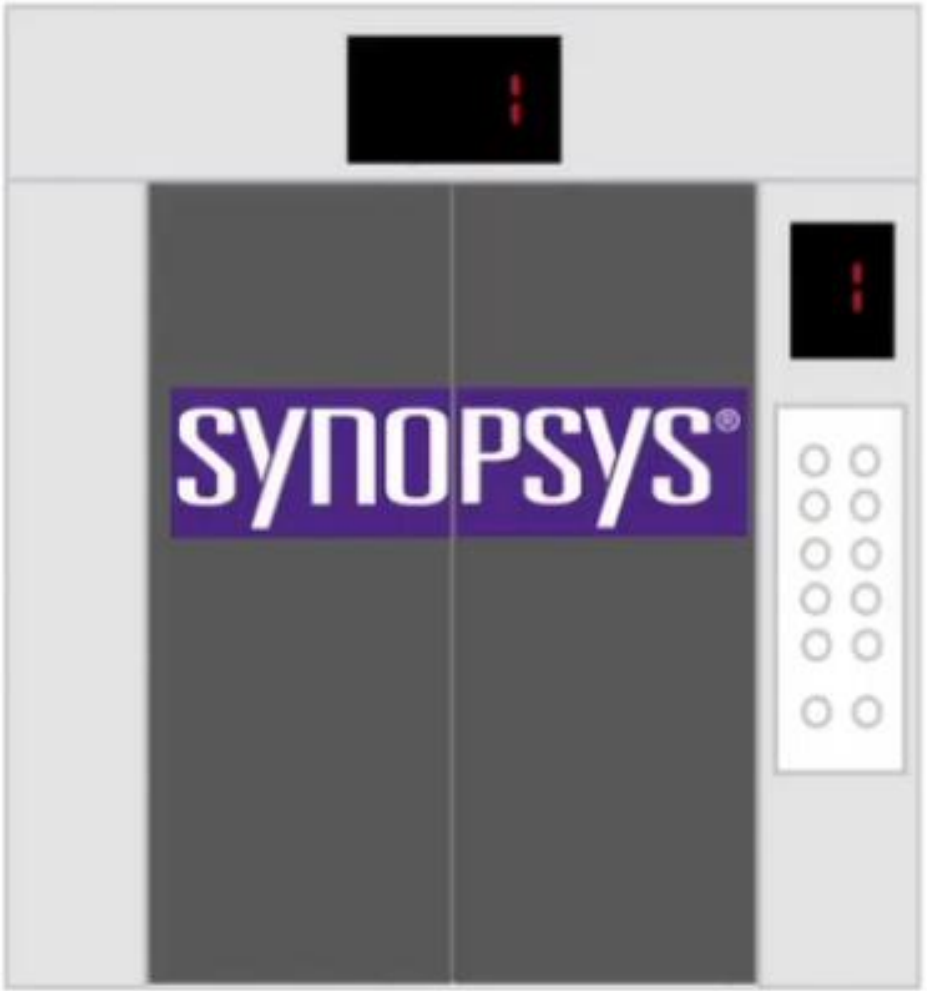
0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP



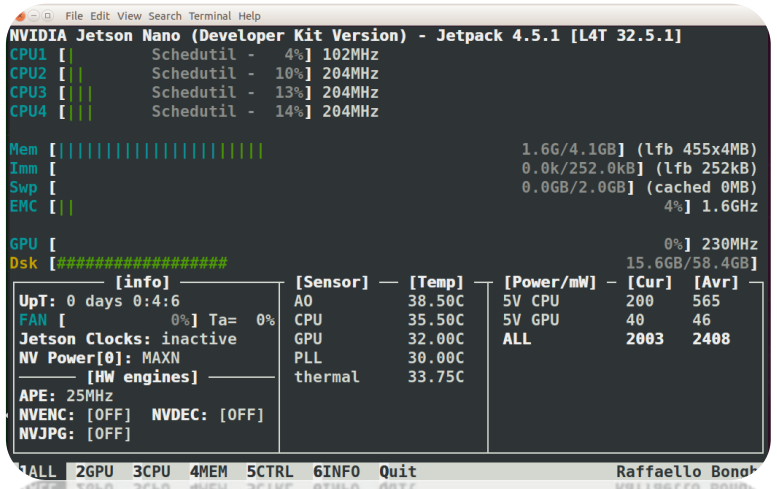


Implementation – Elevator Animation

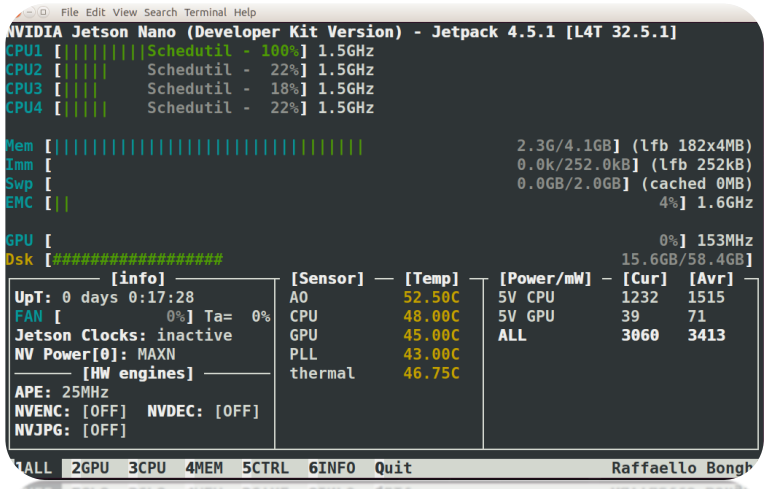
- **Simulate Animation**
  - Express.js
  - jQuery
  - Flask (for testing)
  - requests (python)
  - Talend API Tester



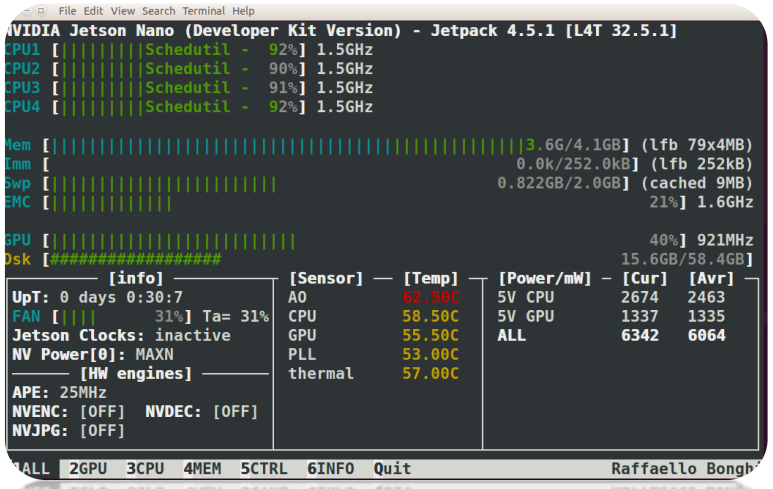
Implementation – Power Analysis



Standby



Idle



Triggered

NVIDIA Jetson Nano	Standby	Idle	Triggered
Total power consumption (mW)	2408	3413	**6064**
Always-on thermal zone temp. (AO)	38.50C	52.50C	**62.50C**
CPU clock rate (GHz)	0.204	1.5	1.5
GPU clock rare (MHz)	230	153	921

With the help of Himax WE-I

Implementation – Power Analysis

Dynamic power:

$$P_{avg} = \alpha \cdot f \cdot 1/2 \cdot c \cdot {V_{dd}}^2$$

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Power saving:

$P_{Trig} - P_{Idle} \approx$ 6000-3500 = 2500 mW

With the help of Himax WE-I
(Ultra Low Power AI ASIC)

Assume 90% idle state & 10% triggered state.

Estimate the wasted power & energy consumption over a year for one device.

$$\left[P_{Trig} - \left(P_{Idle} \times 0.9 + P_{Trig} \times 0.1\right)\right] \cdot 60 \cdot 60 \div 10^6 \approx 8.1\ kWh$$

$$\left[P_{Trig} - \left(P_{Idle} \times 0.9 + P_{Trig} \times 0.1\right)\right] \cdot 60 \cdot 60 \cdot 24 \cdot 365 \div 1000 \approx 71\ MJ$$

作品進度

Work Progress

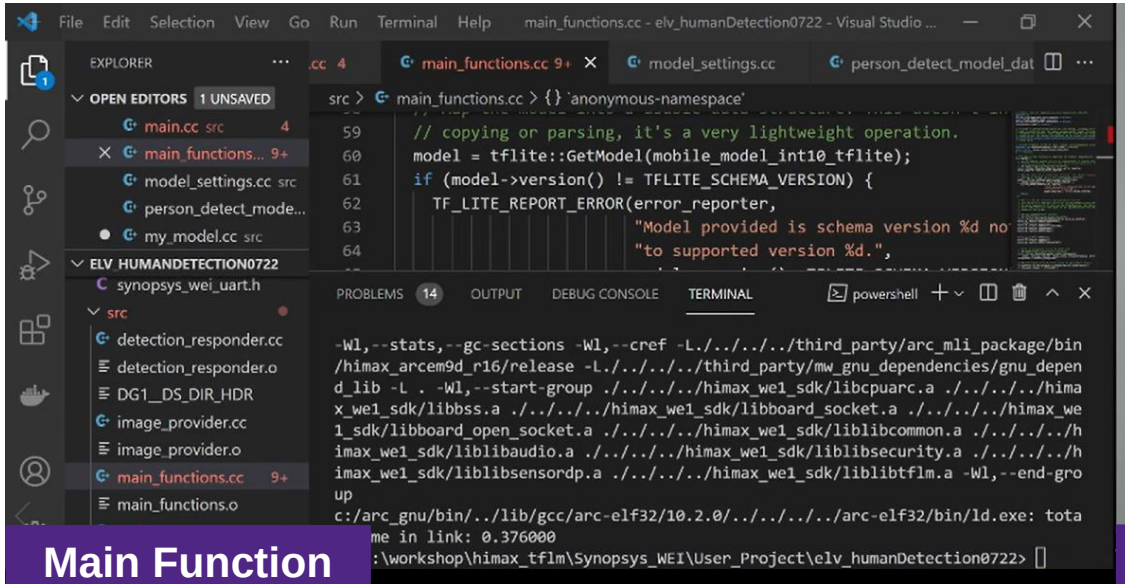
Work Progress

- **Himax WE-I**
  - Real time hand detect
  - Edge computing architecture
  - Trigger high OPS units
  - Reduce power comsuption
- **NVDIA Jetson Nano**
  - Real time gesture recognition
  - High accuracy & Quick response
- **Elevator Simulation**
  - Create elevator animation through webpage (1~9 Floors)

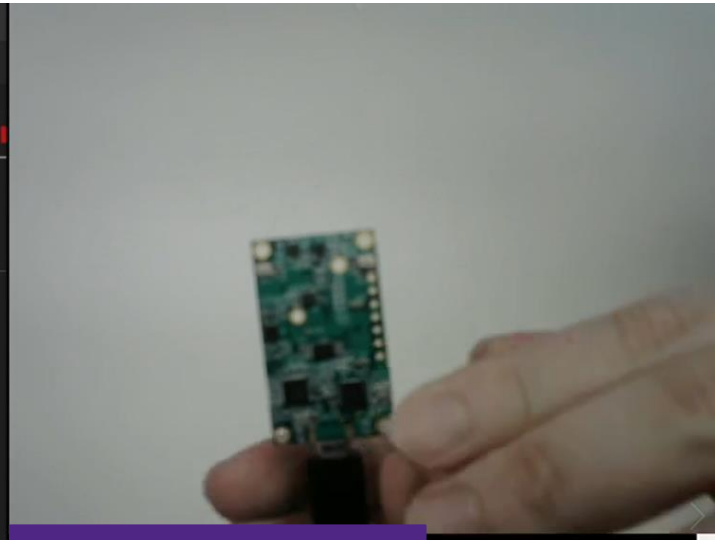
測試結果

Results & Demo

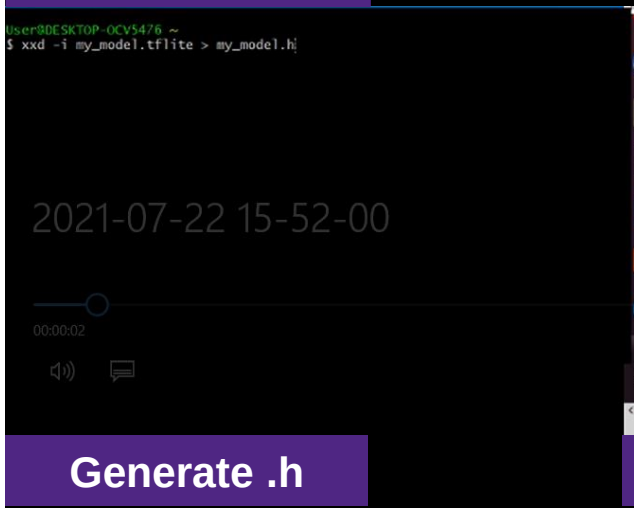
Result & Demo – Hand Detection



Main Function

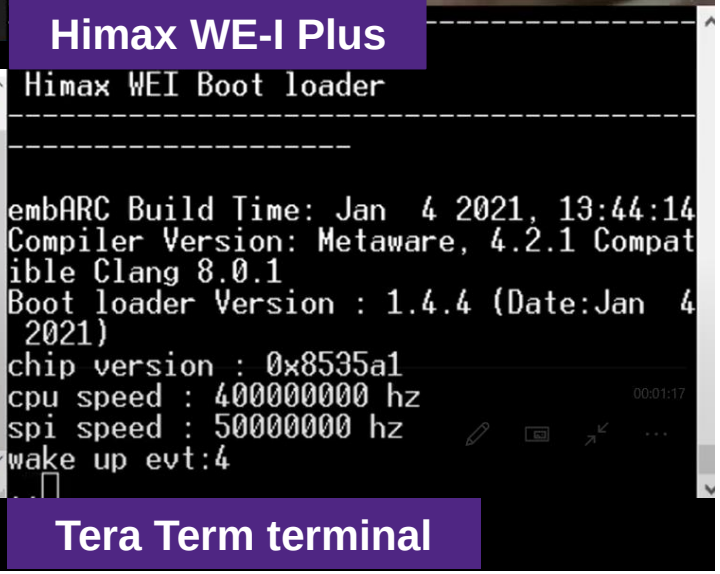


Himax WE-I Plus



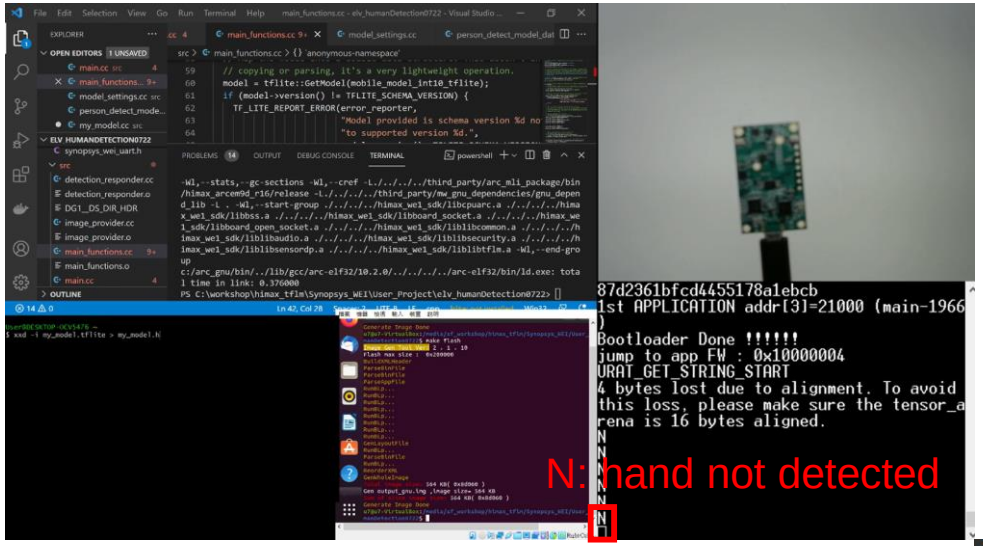
Generate .h

Make flash



Tera Term terminal

Result & Demo – Hand Detection

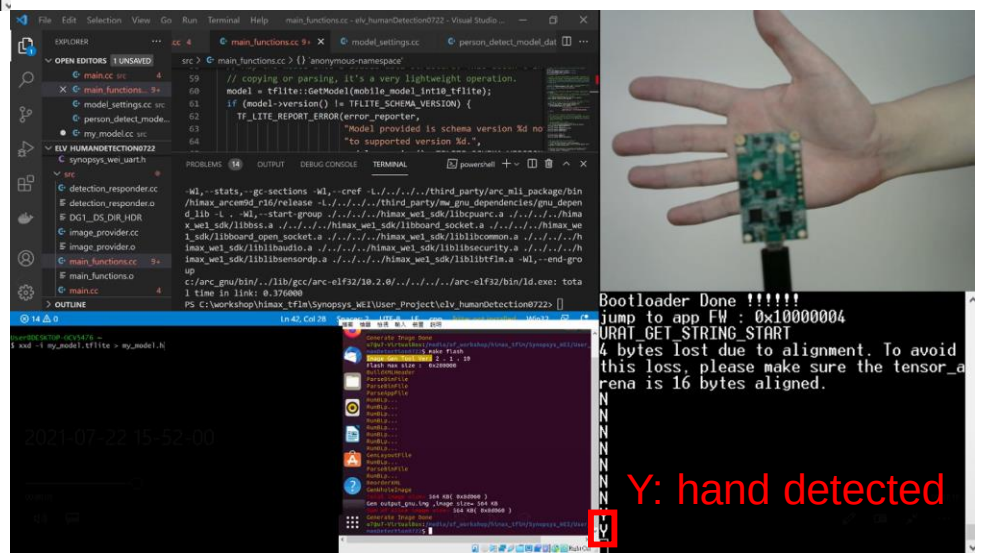


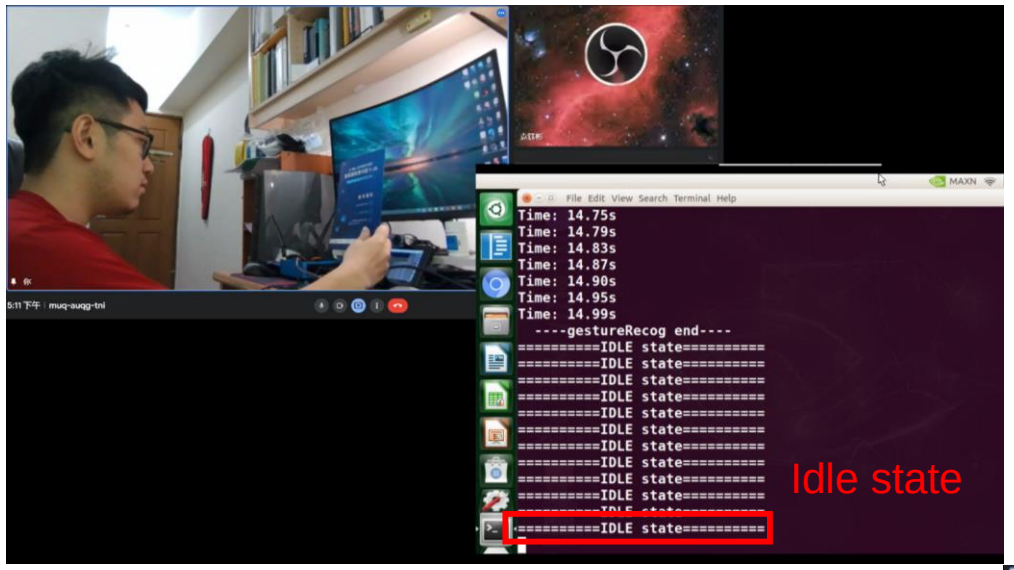
Hand NOT detected

- Simple background
- Pure background

Hand detected

- Hand detection



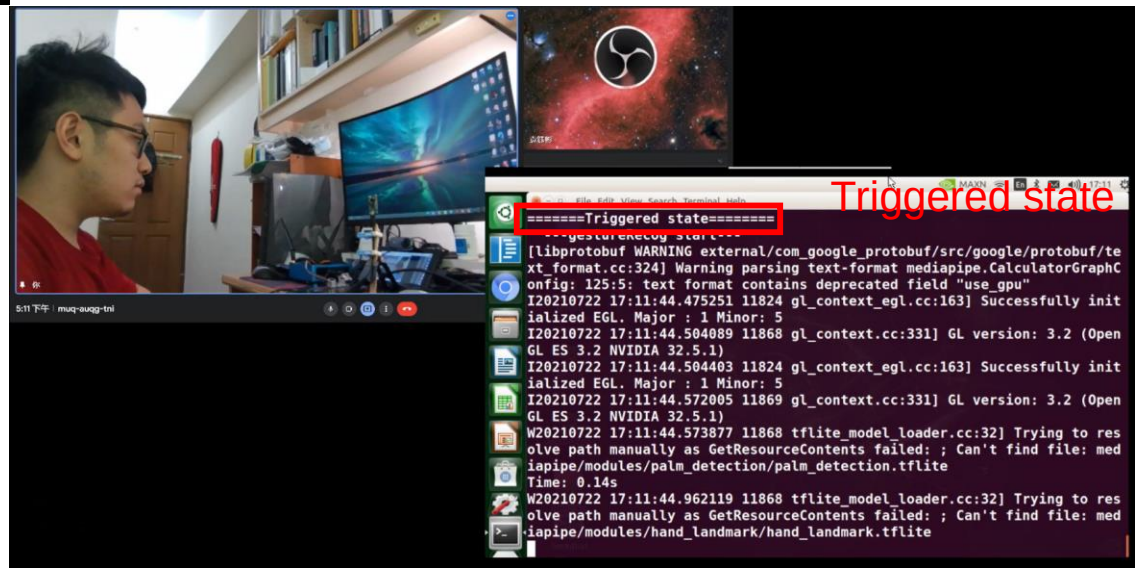


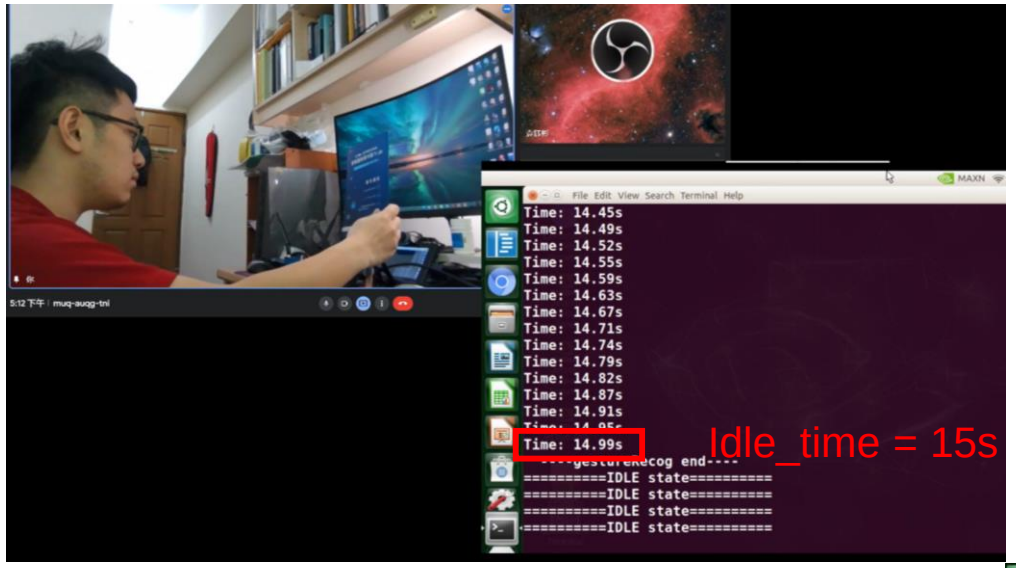
IDIE STATE (No Hand)

- HC-SR04: object detection
  - ✓ Ultrasonic distance measurement
- **Himax WE-I Plus**: hand detection
  - ✓ TinyML predict situation

TRIG STATE (With Object or Hand)

- Open camera (640,480,3)
- Start gesture recognition
- Elevator flow control
- Upload to server



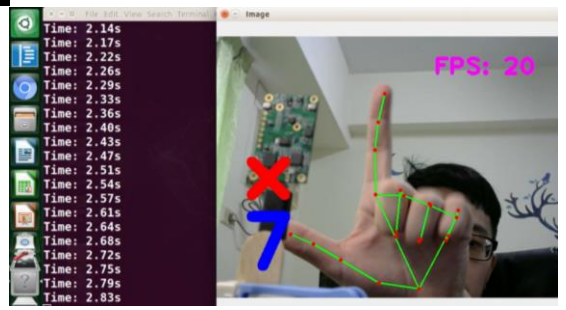


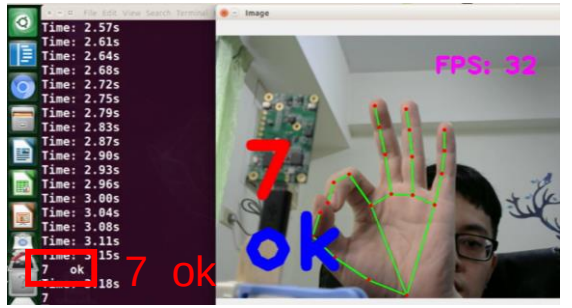
Back to IDlE STATE

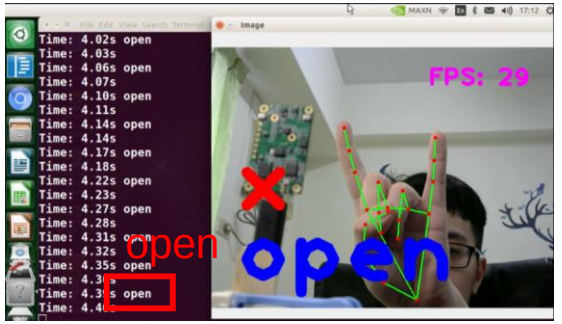
- Over the idle time
- Recognition finish

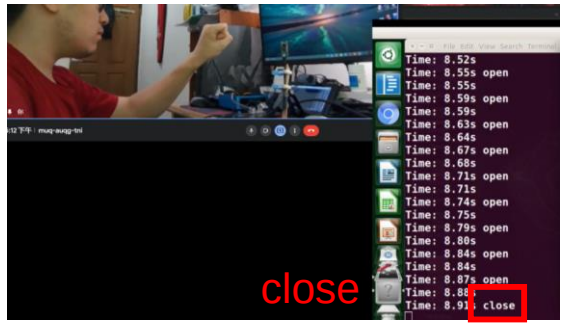
Successfully identified

- “ok” gesture as input trigger signal
- “1” ~ “9” gesture as select floors signal
- “ ☝ ” gesture as close door signal
- “ 🤘 “ gesture as open door signal
- Other gesture as unknown (x)









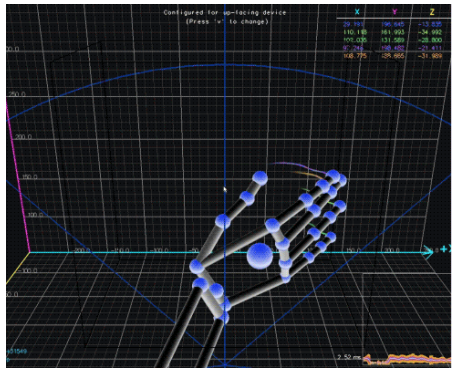
總結展望

Prospect

Prospect

Smart Elevator

- Himax WE-I Plus vs. traditional sensors → get more accurate detection results
- Gesture control vs. touch screen interface → AR, VR applications
- Combine face recognition to predict users' floor
- With the help of face recognition, we can build the visitor-management system effectively



Bring Smart Everything to Life

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Thank You


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