

# tinyML 微型機器學習

進一步理解資料

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2022 全國大專校院智慧創新暨跨域整合創作競賽



 NVIDIA.

DEEP  
LEARNING  
INSTITUTE

UNIVERSITY  
AMBASSADOR

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CAVEDU Education 負責人

MIT CSAIL 訪問學者 (2017 – 2018)

台科大 資訊工程學系助理教授(兼任)

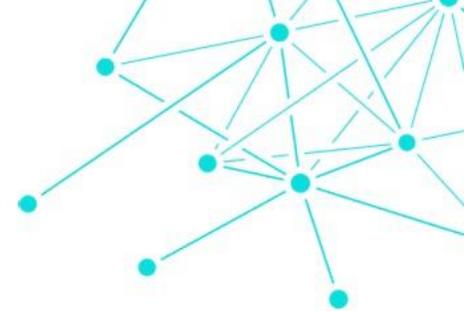
[NVIDIA Jetson AI 大使](#)

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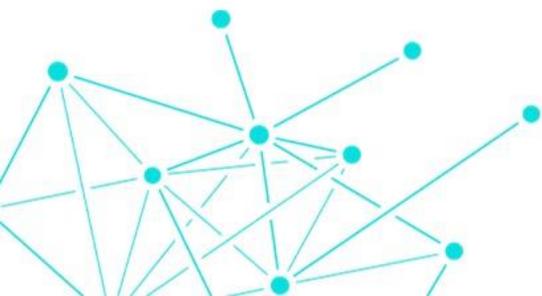


# 分享主題



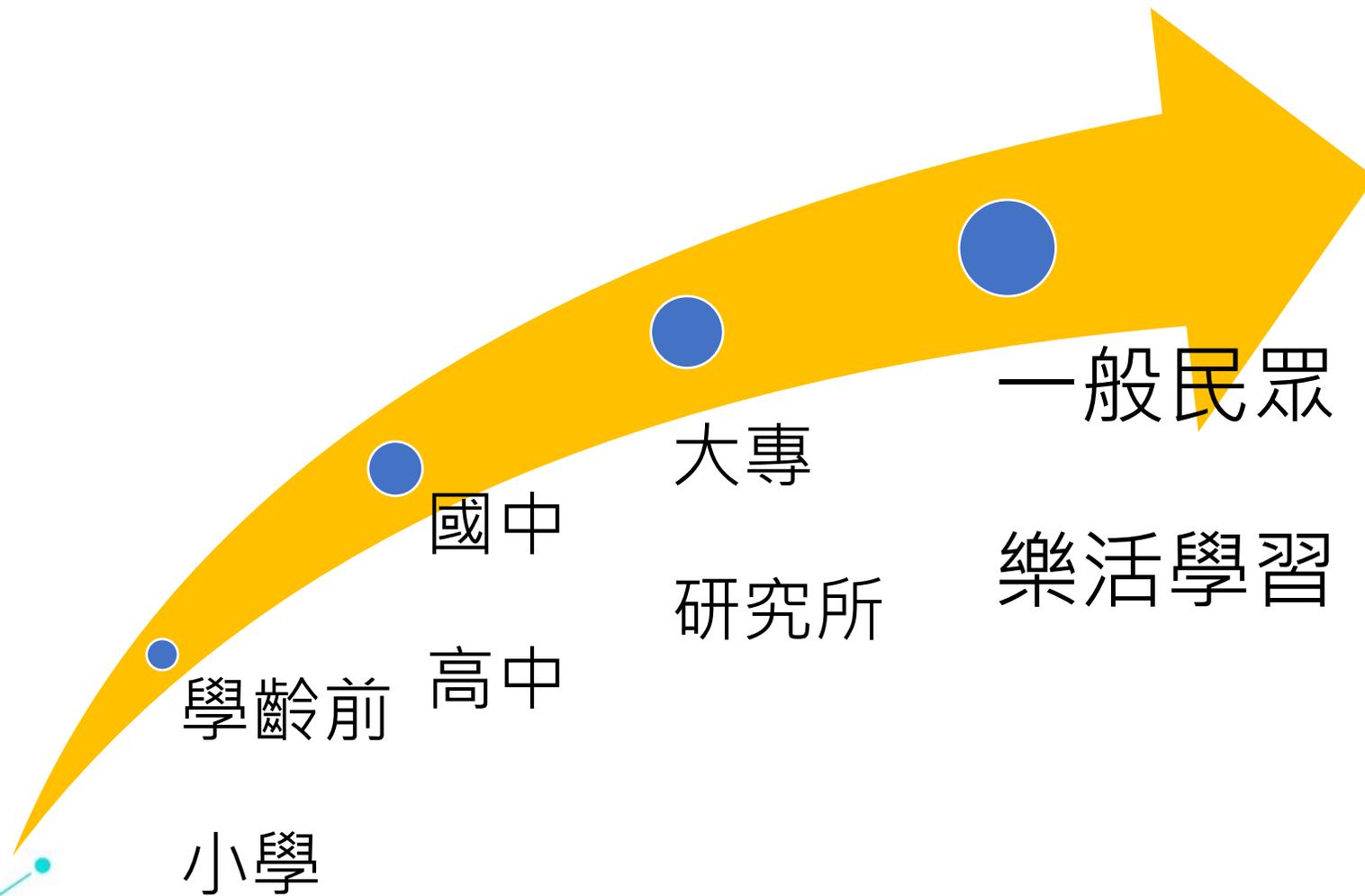
講者將分享如何將機器學習概念搭配 Wio Terminal與常見感測器帶入K12教學現場。

以動手做課程為主軸，學生將獲得對於傳統感測器資料的全新觀點，完成更有趣的專題應用

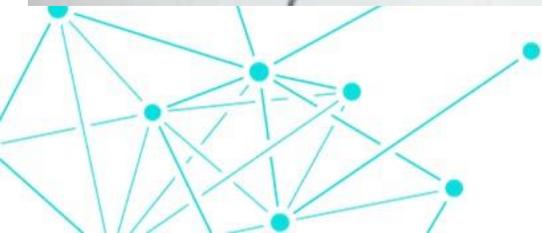
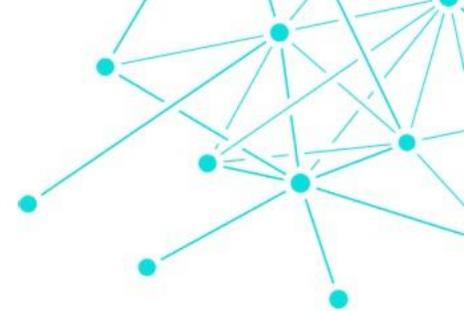




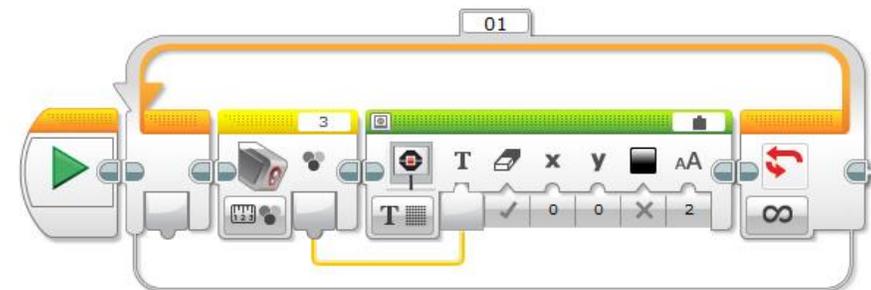
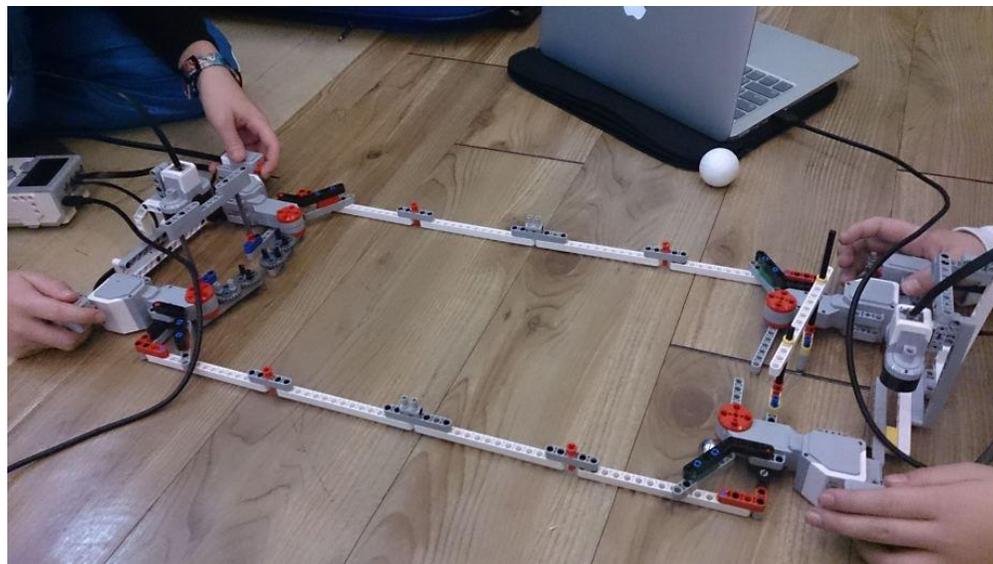
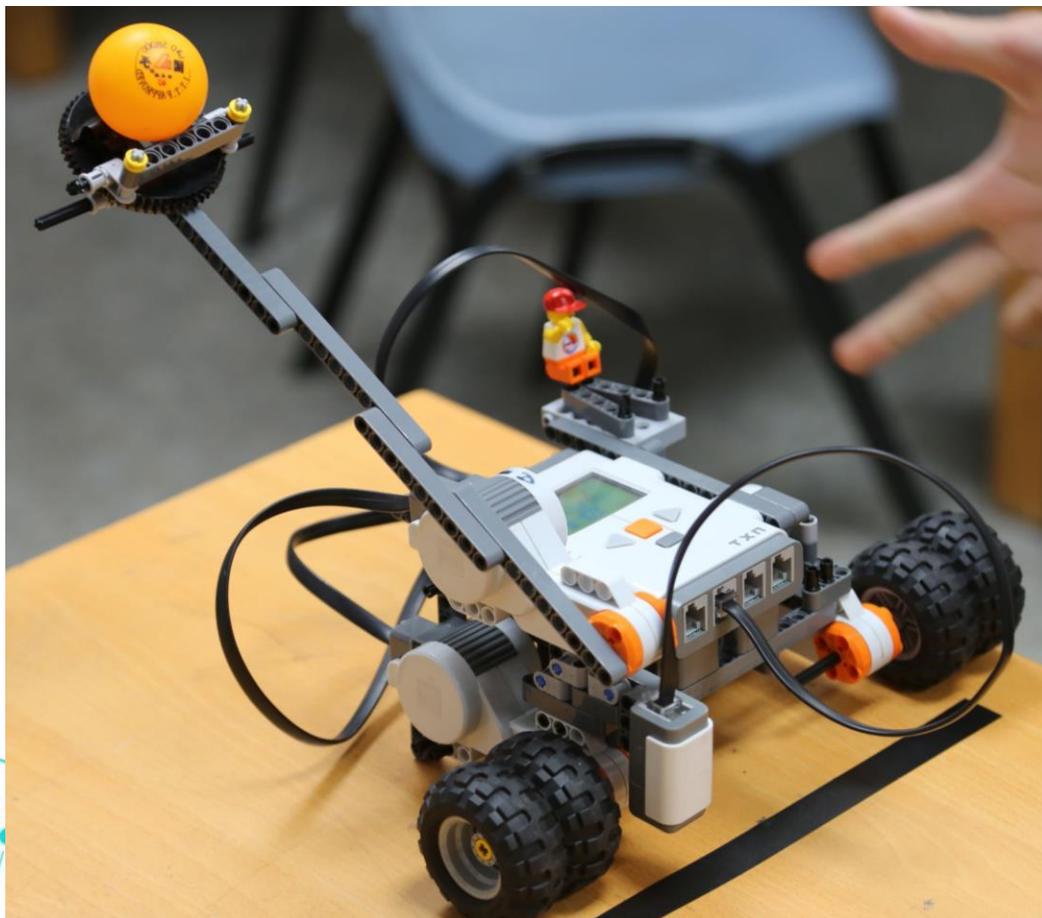
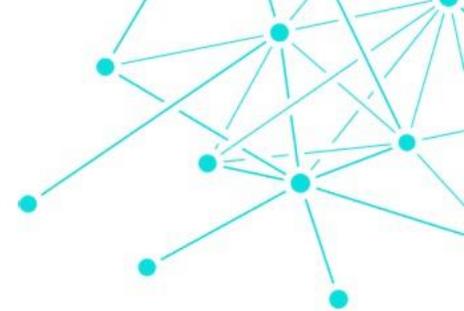
# 針對各年齡



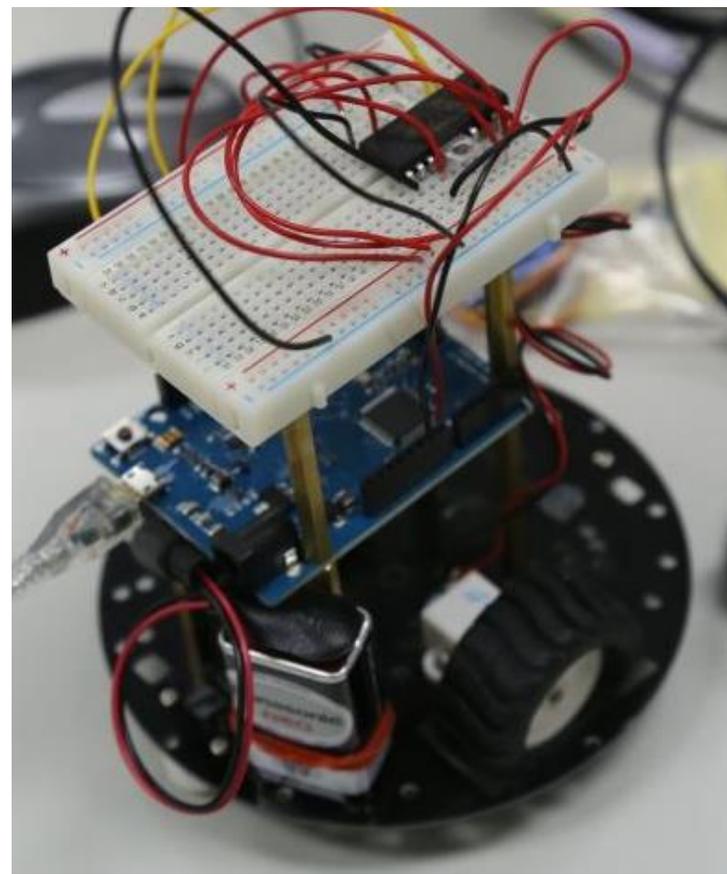
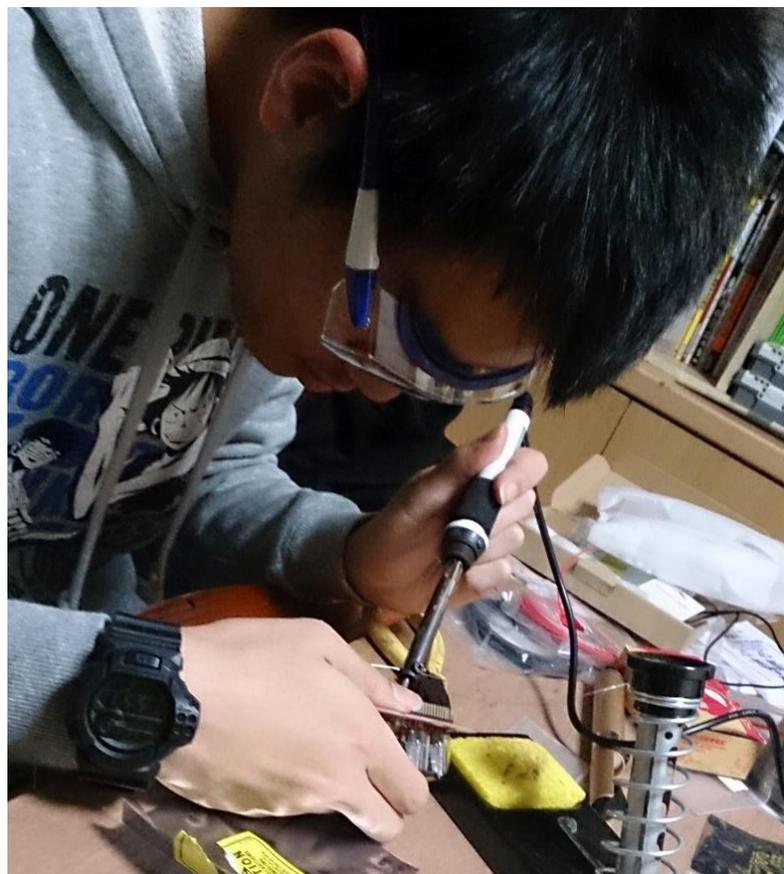
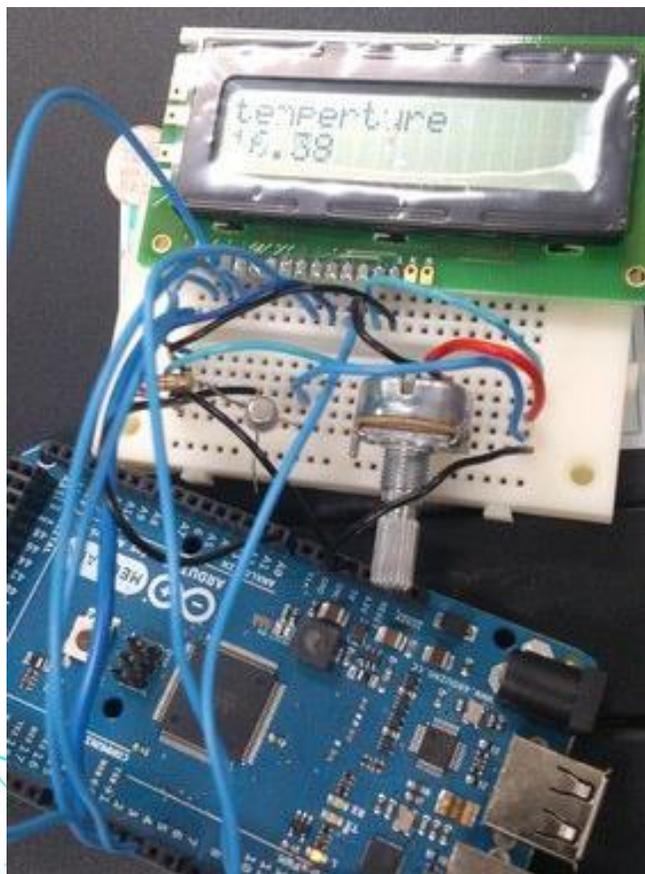
# 學齡前 / 小學低年級 創意積木與動力機械



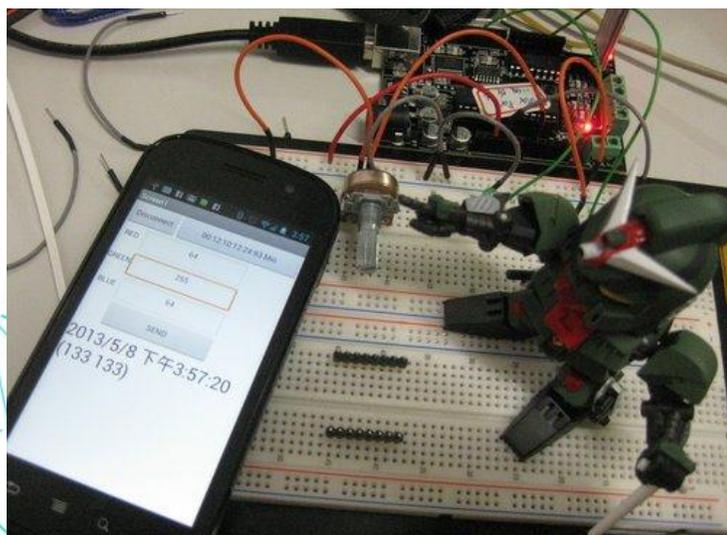
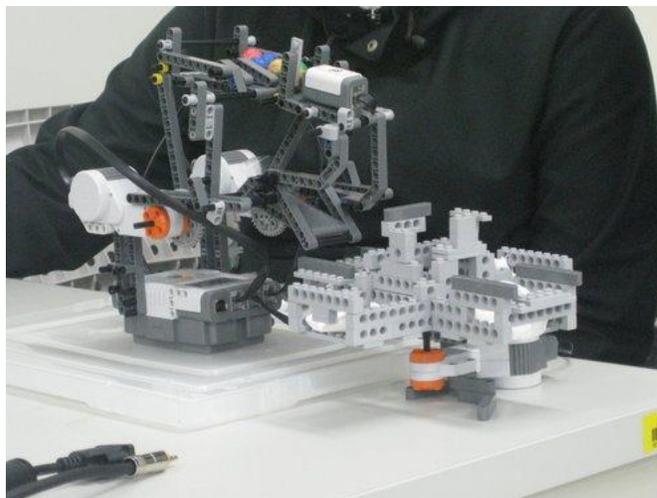
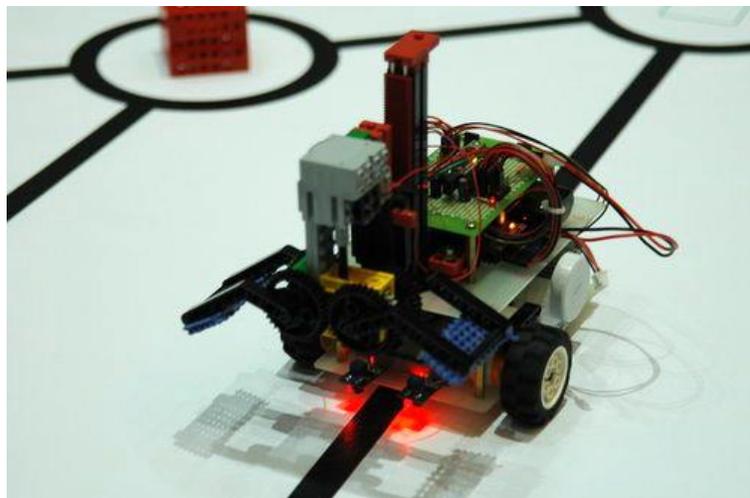
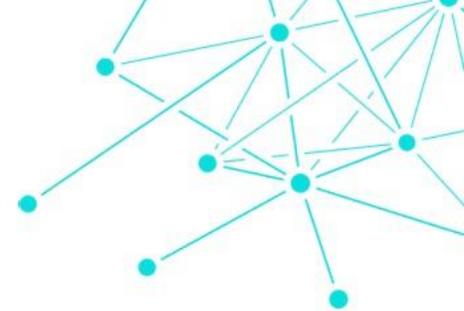
# 小學中高年級 – 模組化機器人套件



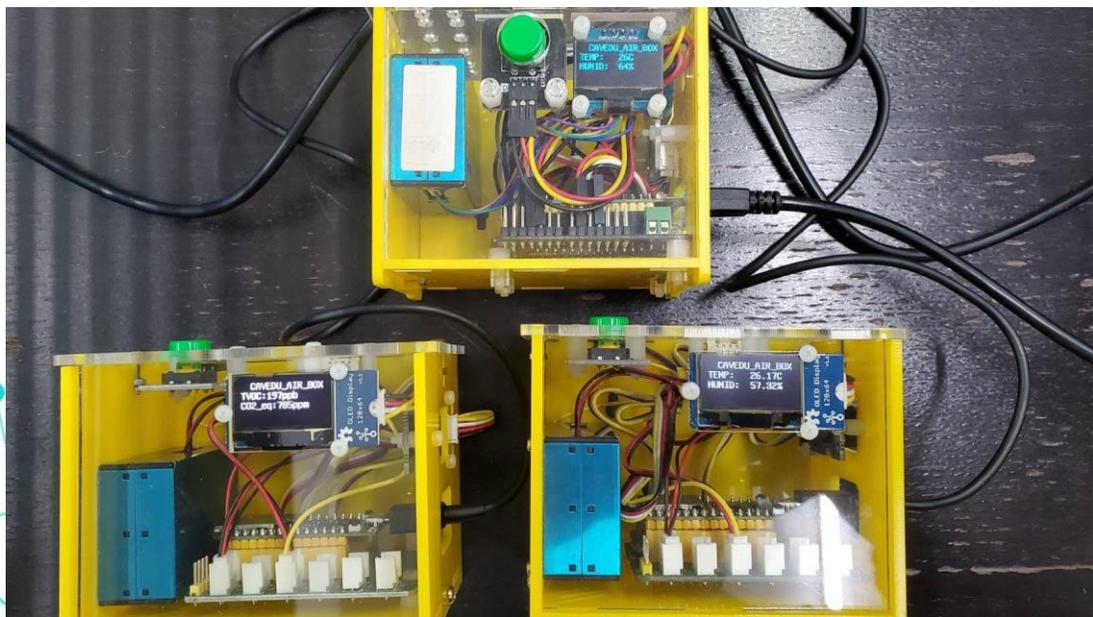
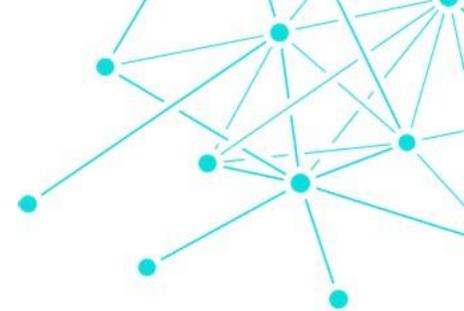
# 國中/高中 電子電路、文字式程式語言、手機程式設計



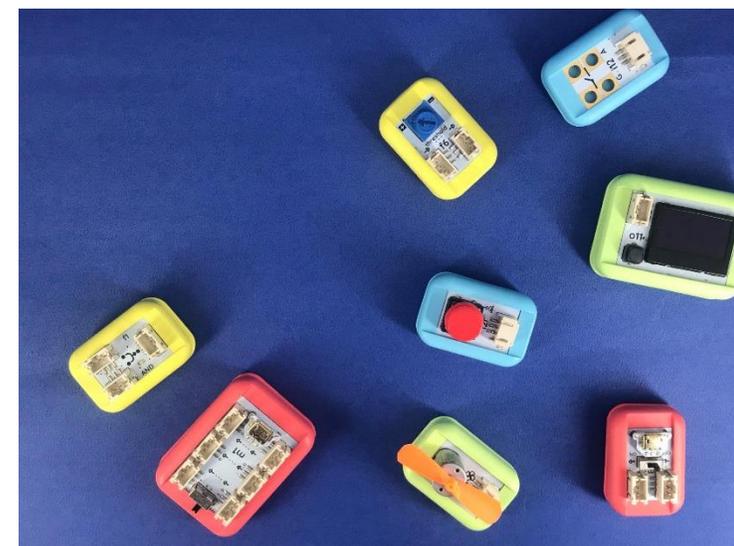
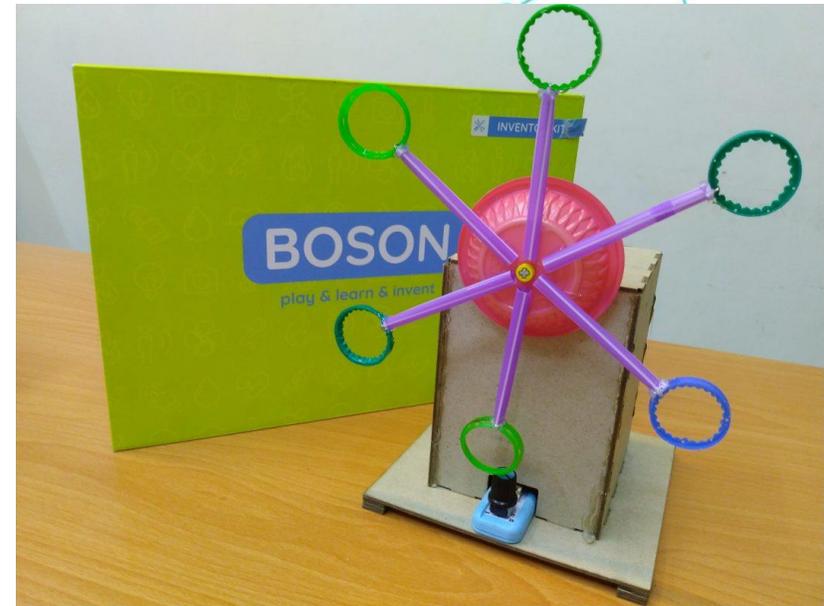
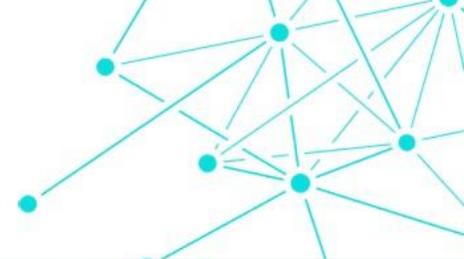
# 大專/研究所 機器人、物聯網、邊緣運算、深度學習等



# 一般民眾、職業訓練課程



# STEAM / 藝術與人文素養



# 專攻邊緣運算裝置

Raspberry Pi, RS components (2014)

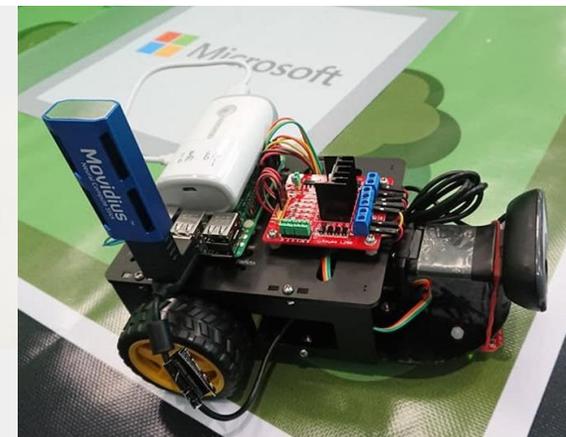
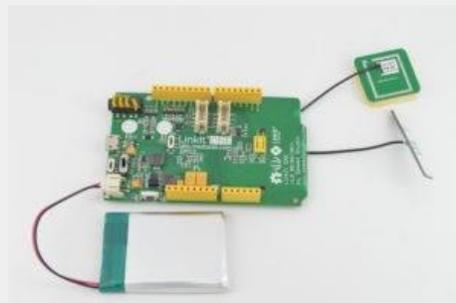
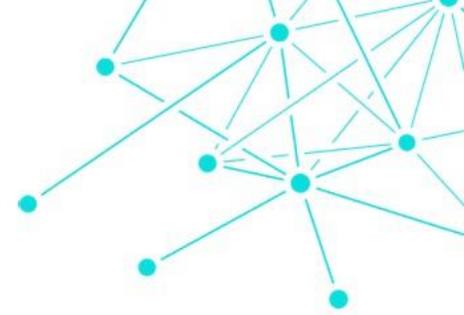
LinkIt series, MediaTek (2015)

Tinker SBC, ASUS (2017)

Movidius NCS, Intel Taiwan (2018)

Azure AI-AGV, Microsoft Taiwan (2018)

Jetson platform, NVIDIA Taiwan (2019 ~ now)



# MIT x CAVEDU 緊密連結

MIT CSAIL x App Inventor  
Dr. Hal Ableson

開發物聯網、機器人相關元件  
受邀擔任訪問學者  
新一代 iOS平台 與 AI 元件開發



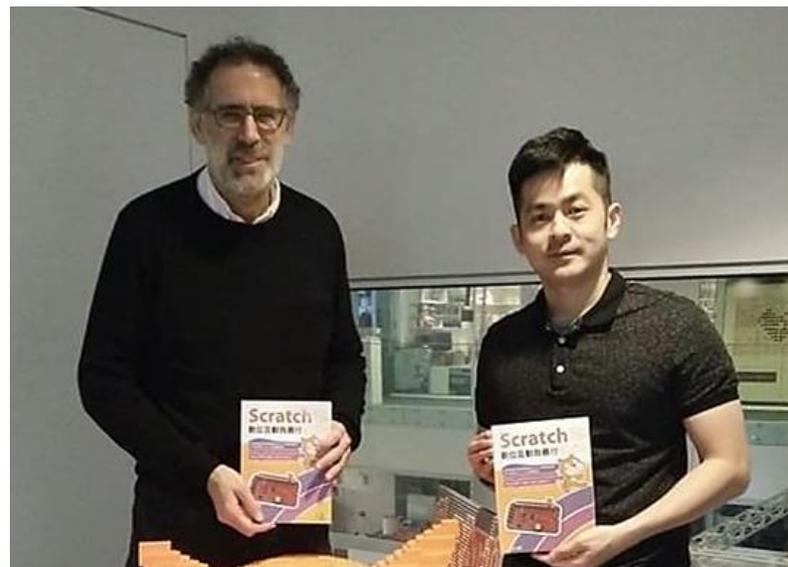
MIT Media Lab Lifelong Kindergarten  
(Scratch)

Dr. Mitchel Resnick

LCL課程中文化

Scratch 3.0 中文化

Scratch 3.0 元件測試



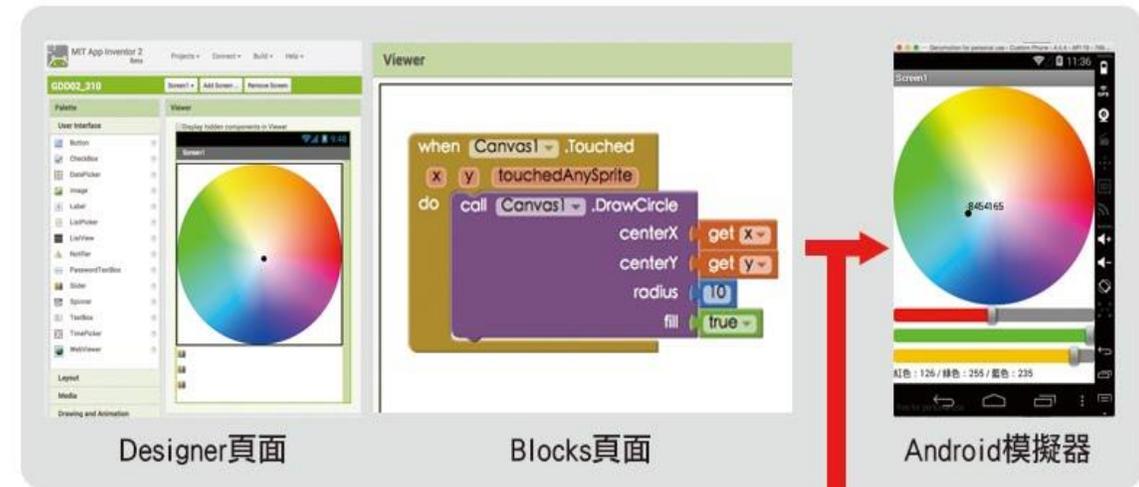
# MIT App Inventor

[www.appinventor.mit.edu](http://www.appinventor.mit.edu)

[iot.appinventor.mit.edu](http://iot.appinventor.mit.edu)

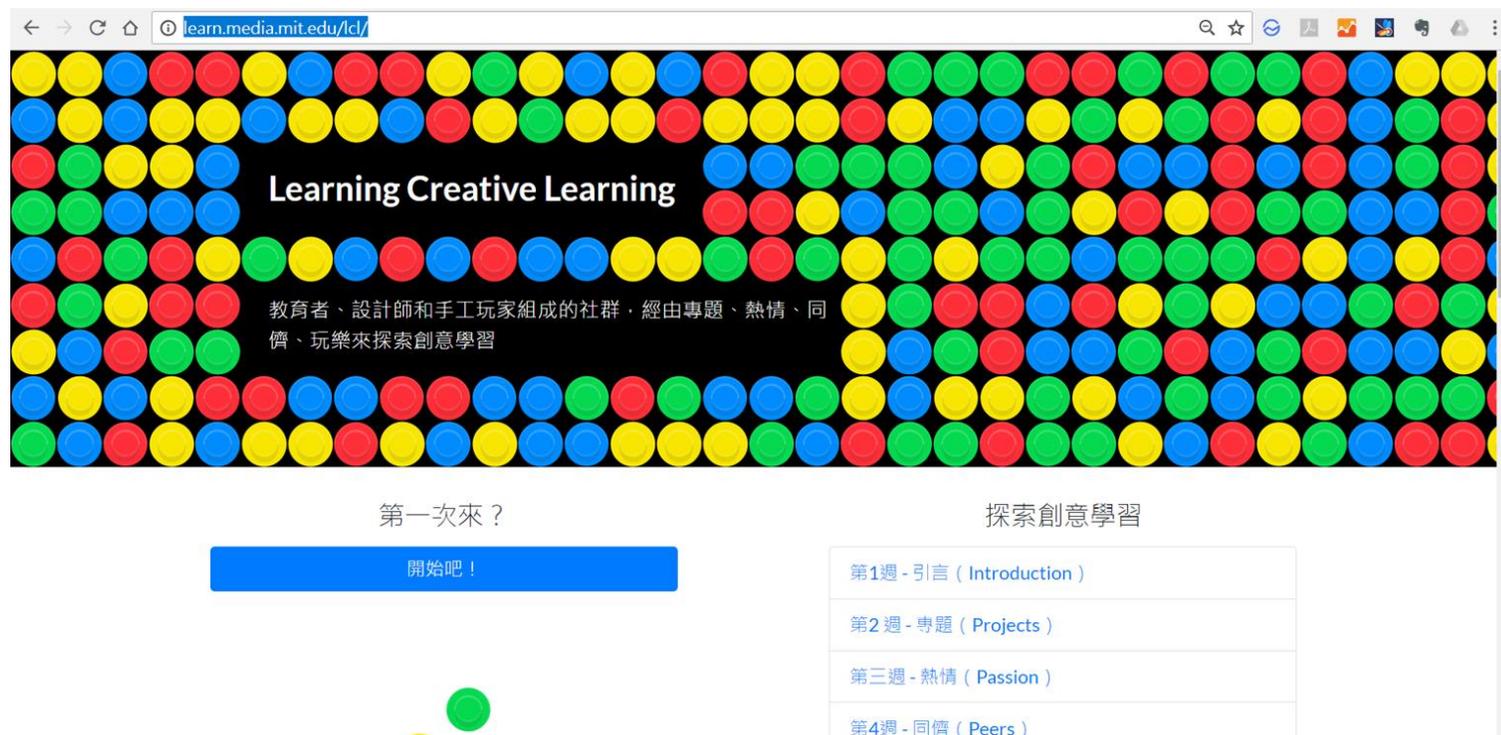
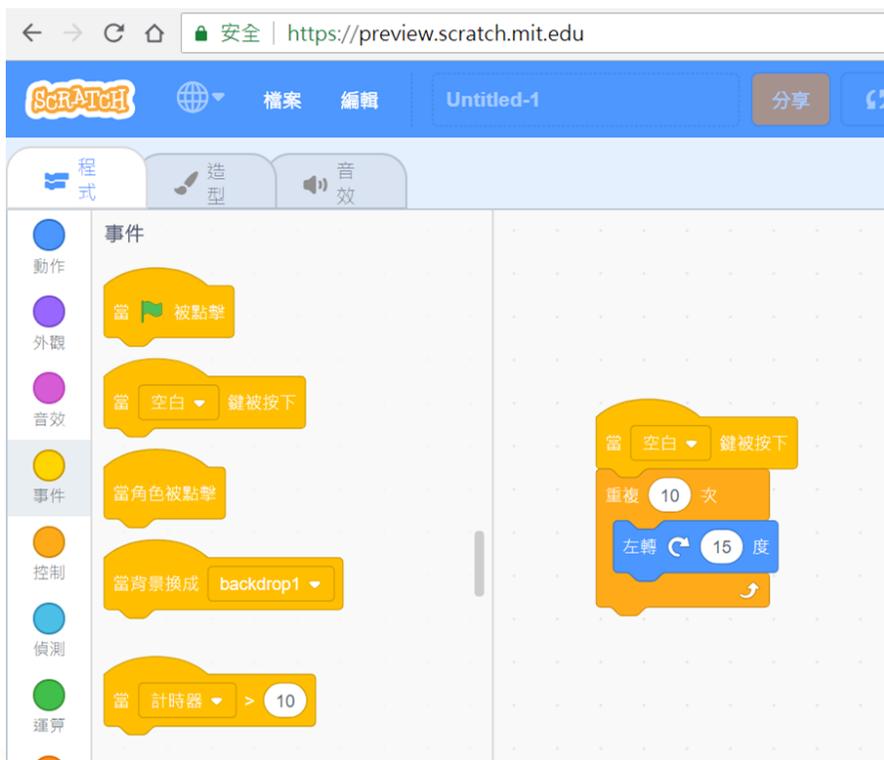


App Inventor 2 伺服器

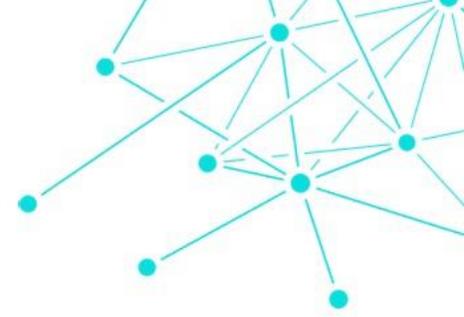


Android 手機 / 平板電腦

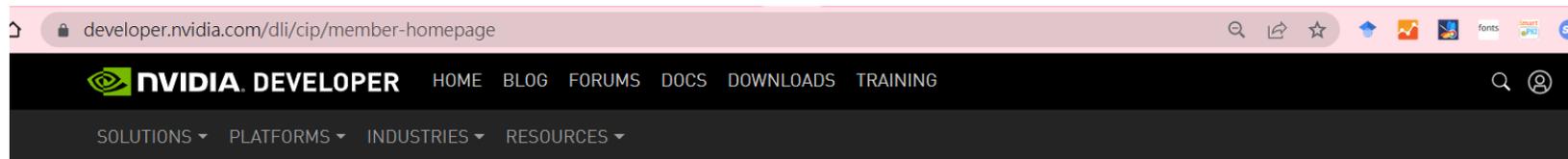
# Scratch 3.0 開發測試與 LCL 網站 繁體中文內容



# 2019 – 2022 高中職生AI扎根計畫



# 2022 NVIDIA Jetson AI 大使白金獎



## NVIDIA DLI CERTIFIED INSTRUCTOR PROGRAM

Welcome! Explore this page for everything you need to succeed as an NVIDIA DLI Instructor.

### Current Ambassador Achievements

Platinum Tier					
Gold Tier					
Silver Tier					
Specializations					
Name	Organization	Region	Deliveries	Students Trained	Students Certified
David Tseng	National Taiwan University of Science and Technology	APAC	8	416	164



# Jetson series in campus

## • 高中 / 國中

### • Jetson nano 2G(cost)

- **Jetbot** – 機器人控制
- 基礎 Python 程式設計
- 影像分類 / 物件偵測
- 感測器訊號處理



## • 大學

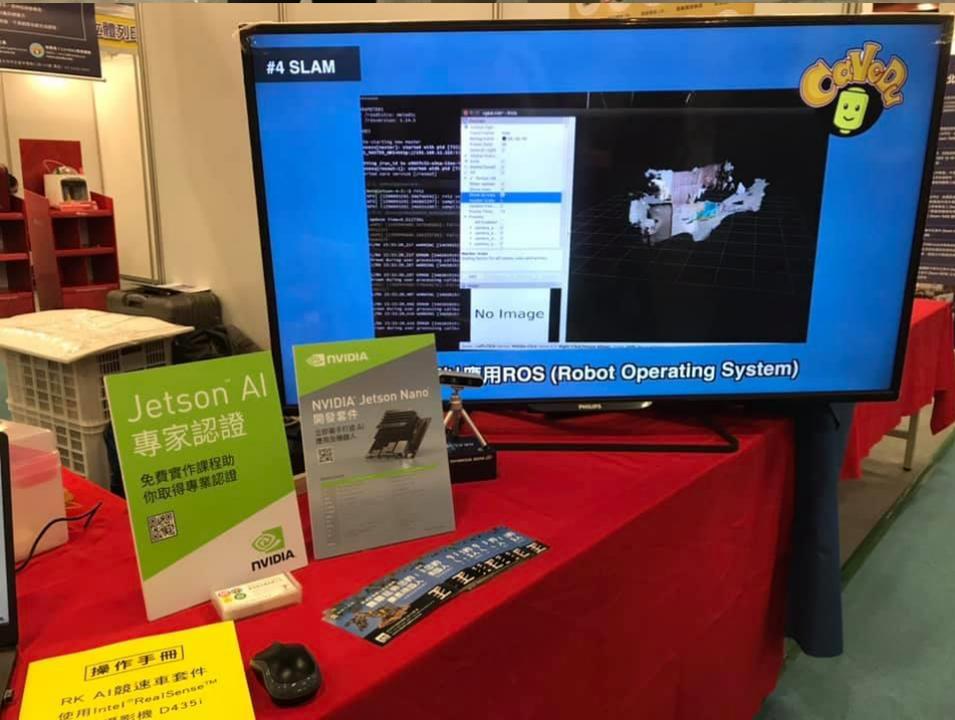
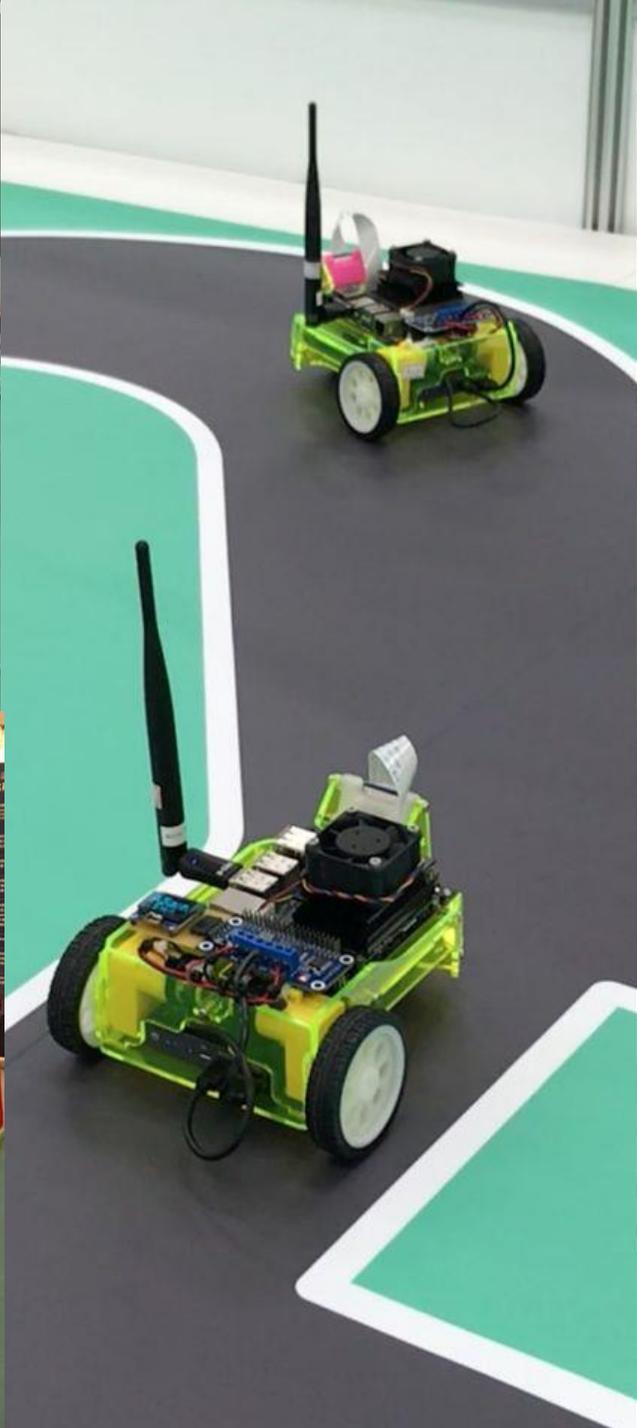
### • Jetson Nano / NX / ORIN

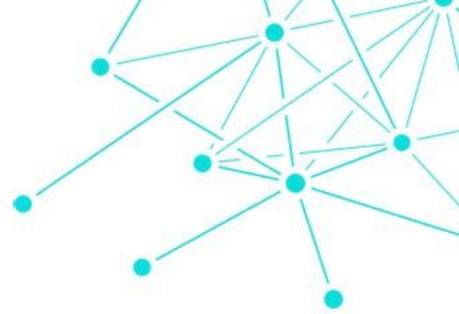
- **JetRacer** – 進階機器人控制
- ROS2
- 整合景深攝影機 (Intel RealSense / ZED)
- 影像監控應用





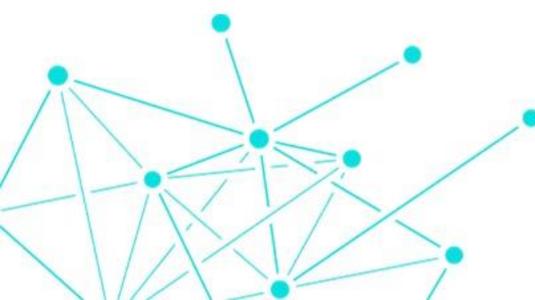
Education expo Taipei  
"RK-Jetbot ML-vision competition"





# 邊緣裝置與AIoT

IoT 裝置產生資料 / AI 需要資料

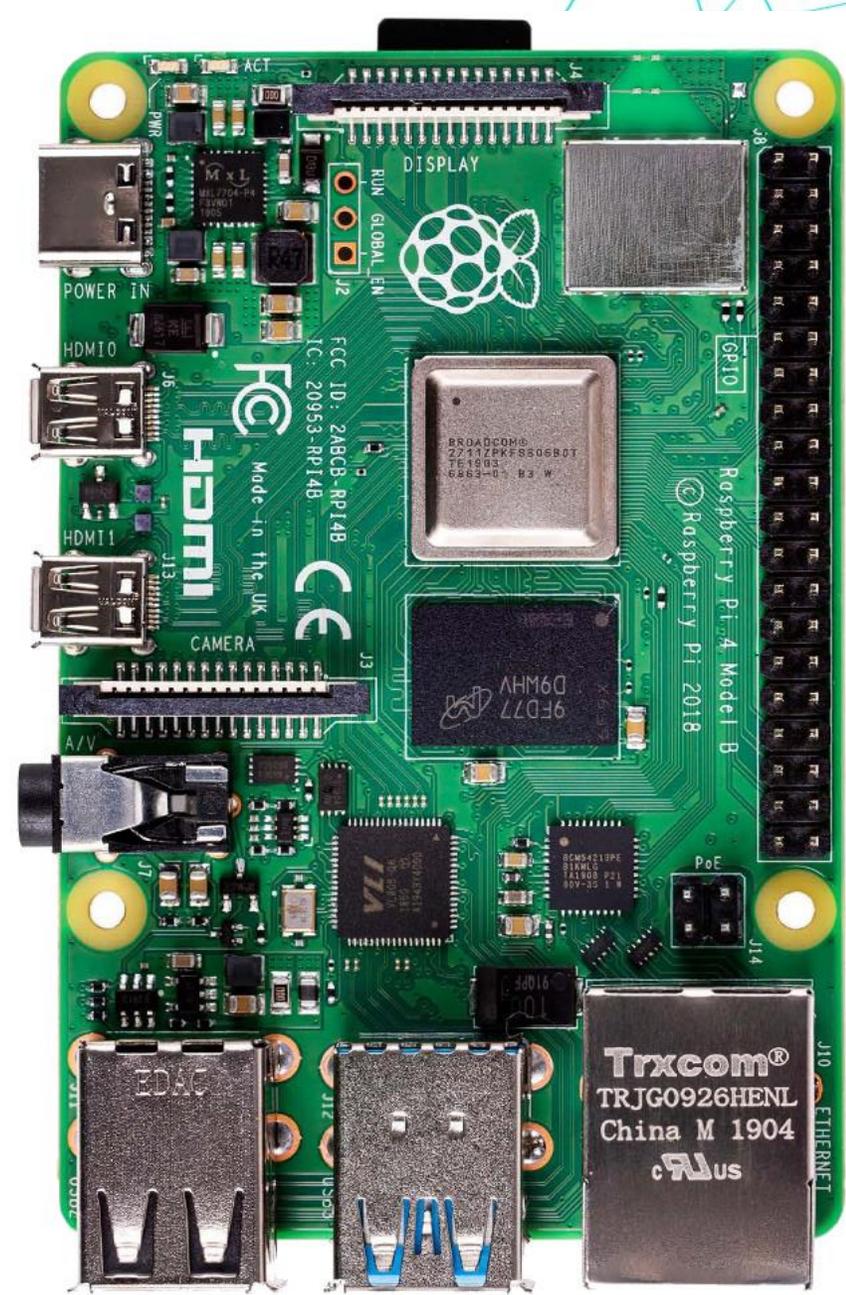


# 前言

- \$300 USD以下的單板電腦，約2014年開始以 Raspberry Pi為主流
- 2014~2016曾經流行過非常多相容板，但業餘 / 教學領域最終的選擇依然是 Rpi (資源 / 易取得 / 產品壽命)
- Rpi 3 的運算速度達到了 1.4 GHz / 1GB ram，已可執行部分小型的神經網路推論
- 2019，Google 推出了 Google TPU Edge，NVIDIA也推出了 NVIDIA Jetson nano 進入了這個價格區間帶。

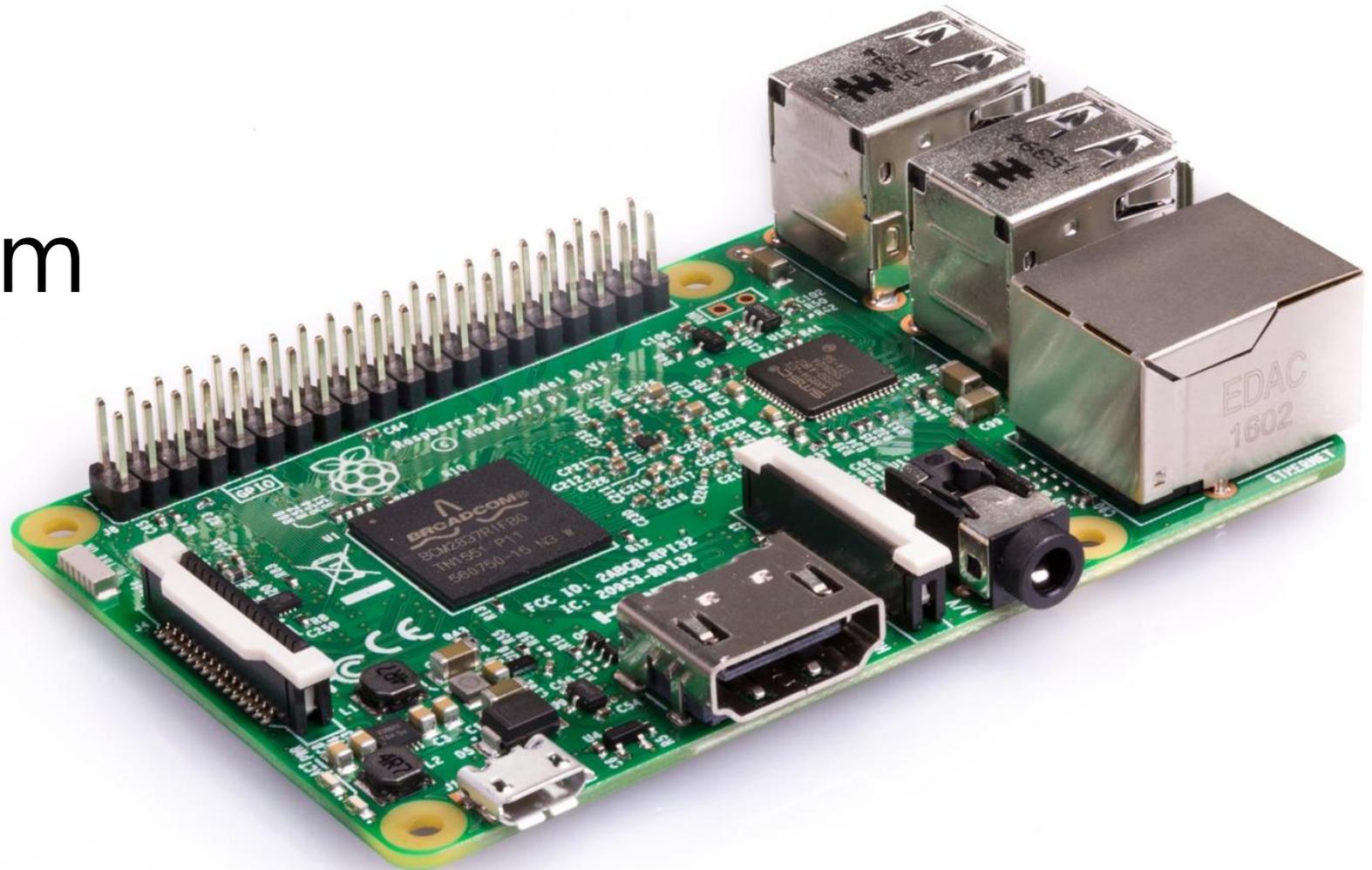
# Raspberry Pi 單板電腦

- 具備作業系統可安裝各種套件
- Python程式語言現在非常熱門
- 有機會用Python完成專案，不需要兩種語言
- 各種AI框架都有Python SDK
- Pi 3已足以執行基本的AI運算



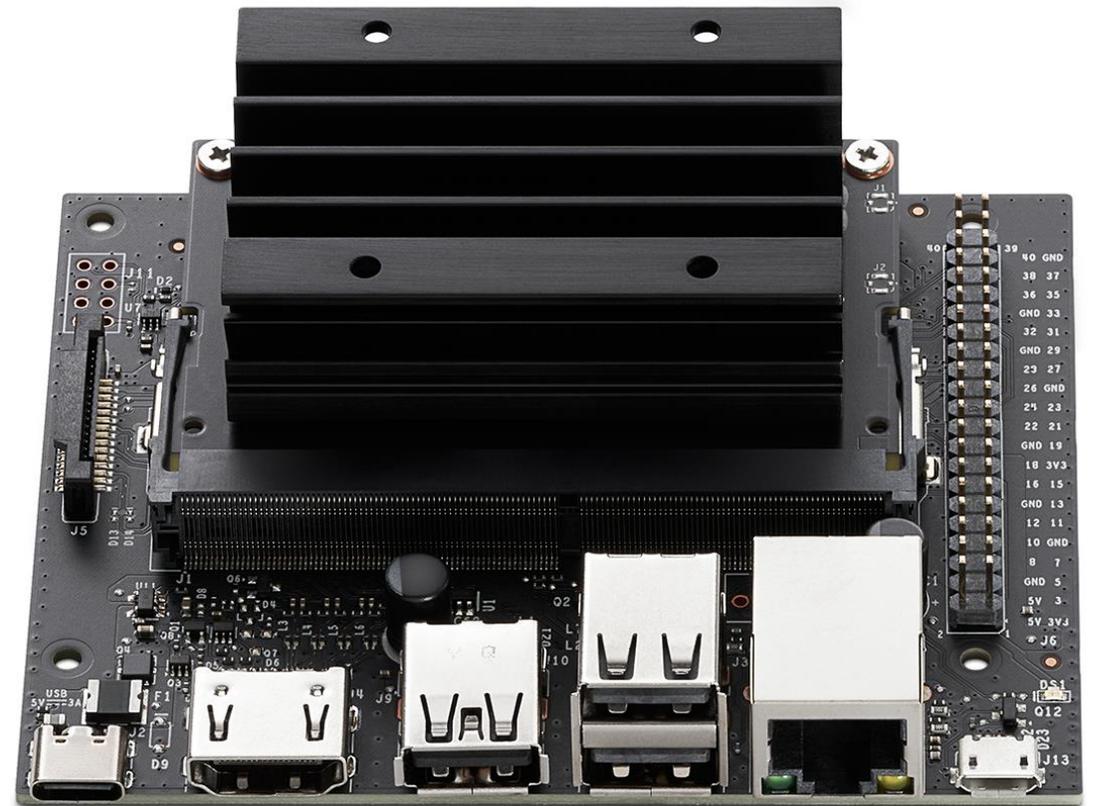
# Raspberry Pi 4 B+ (\$35-55USD)

- 1.5 GHz
- 1, 2, 4, 8GB ram
- Wi-Fi / BLE



# NVIDIA Jetson nano

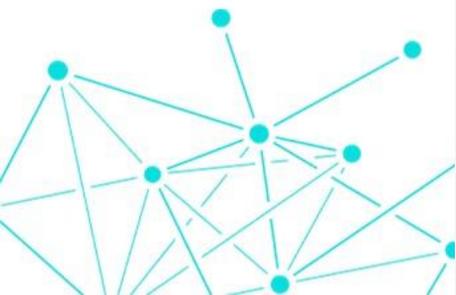
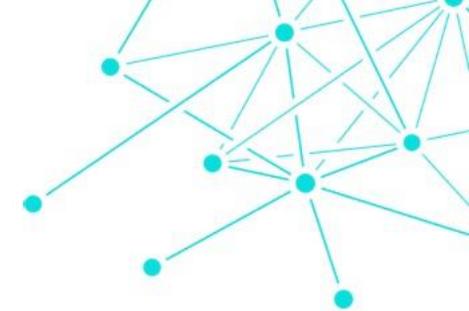
4GB(\$99) 2GB(\$59)



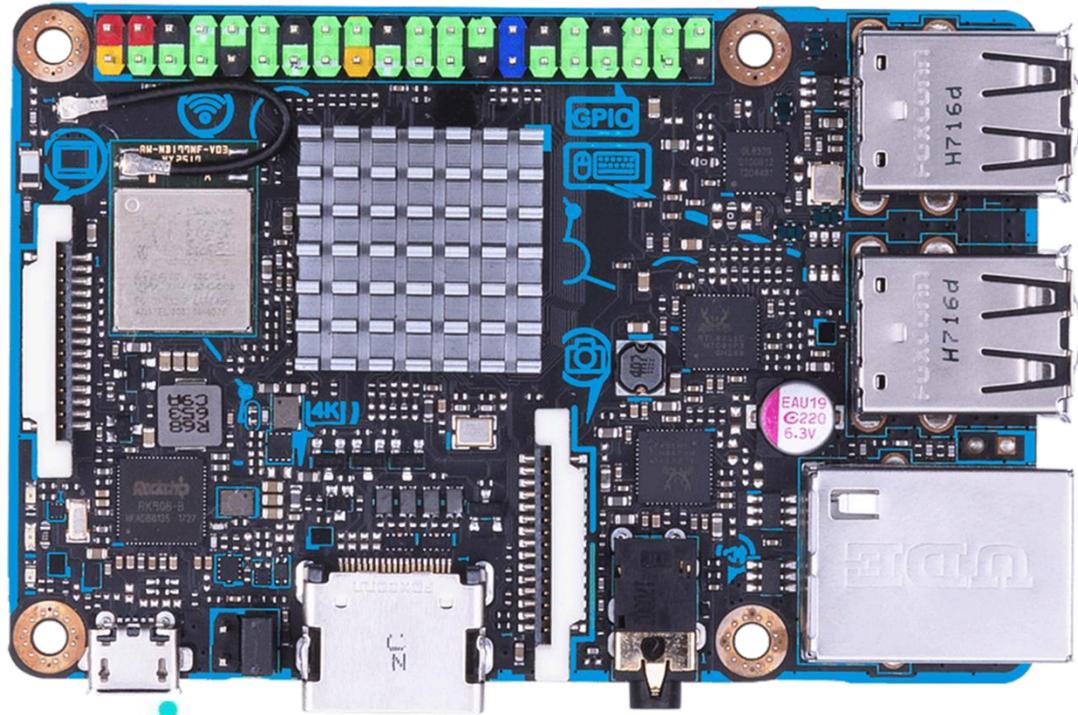
# Google TPU Edge Coral AI (\$149)USD



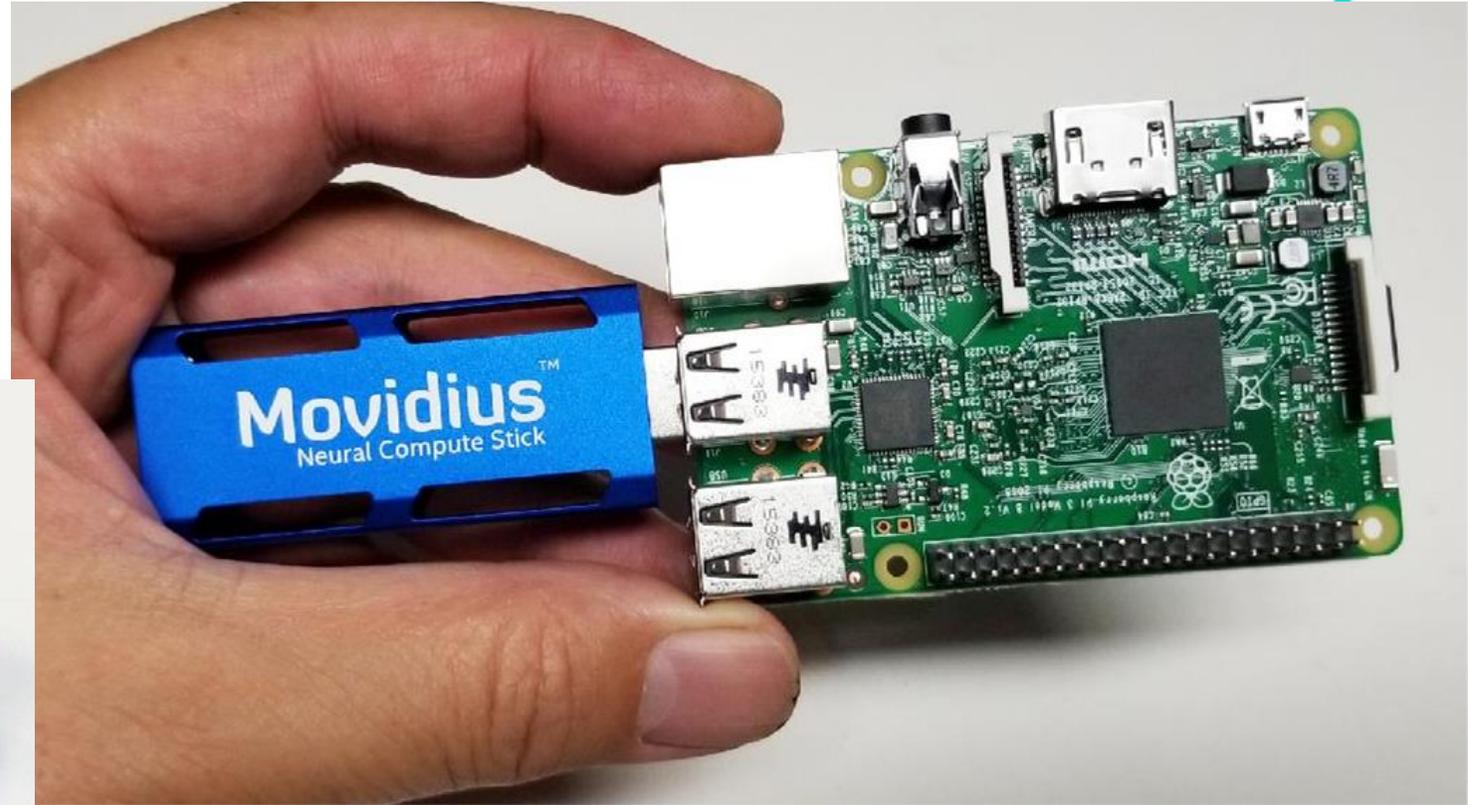
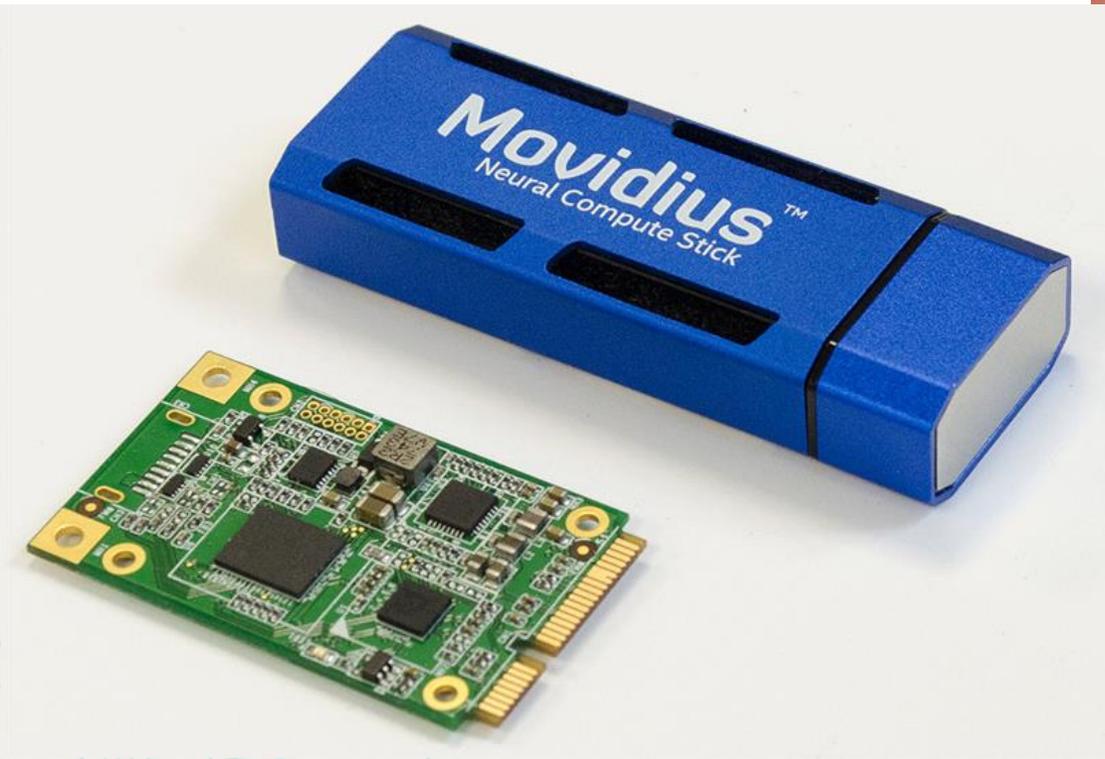
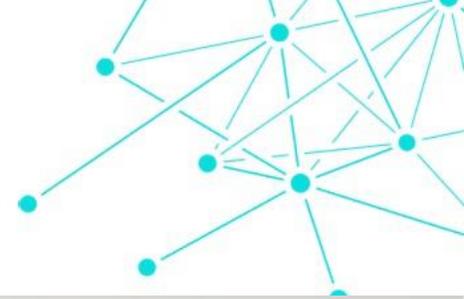
# USB Accelerator (\$75 USD)



# ASUS Tinker board

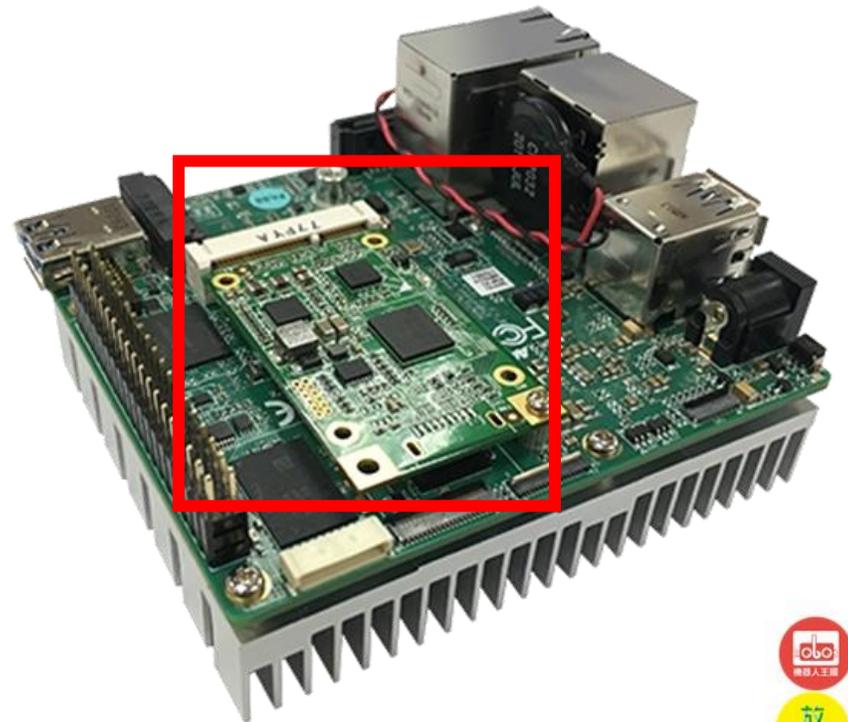
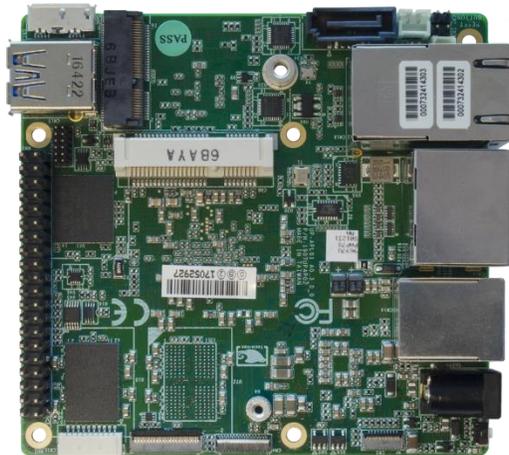
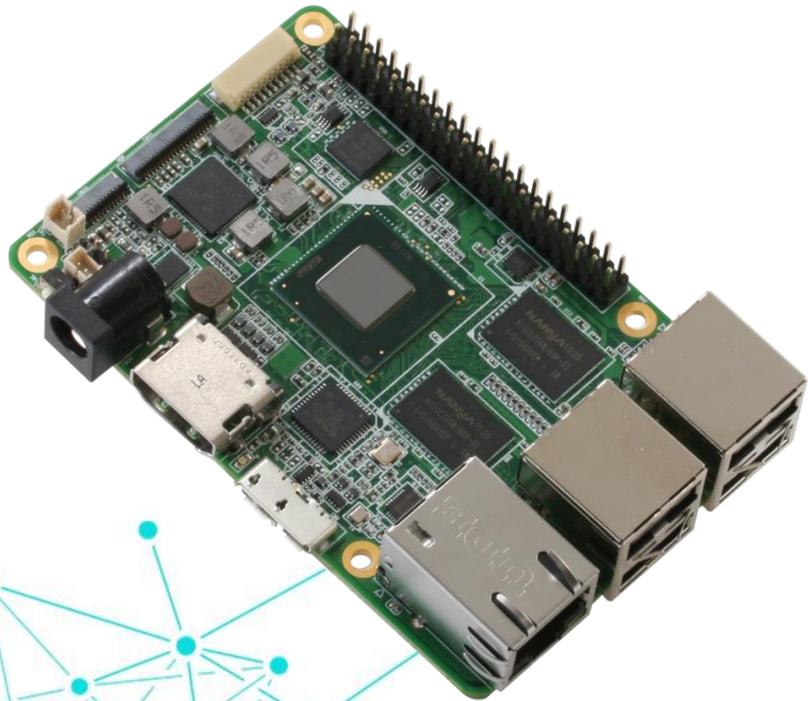


# Intel Movidius NCS / NCS2



# AAEON UpBoard 系列

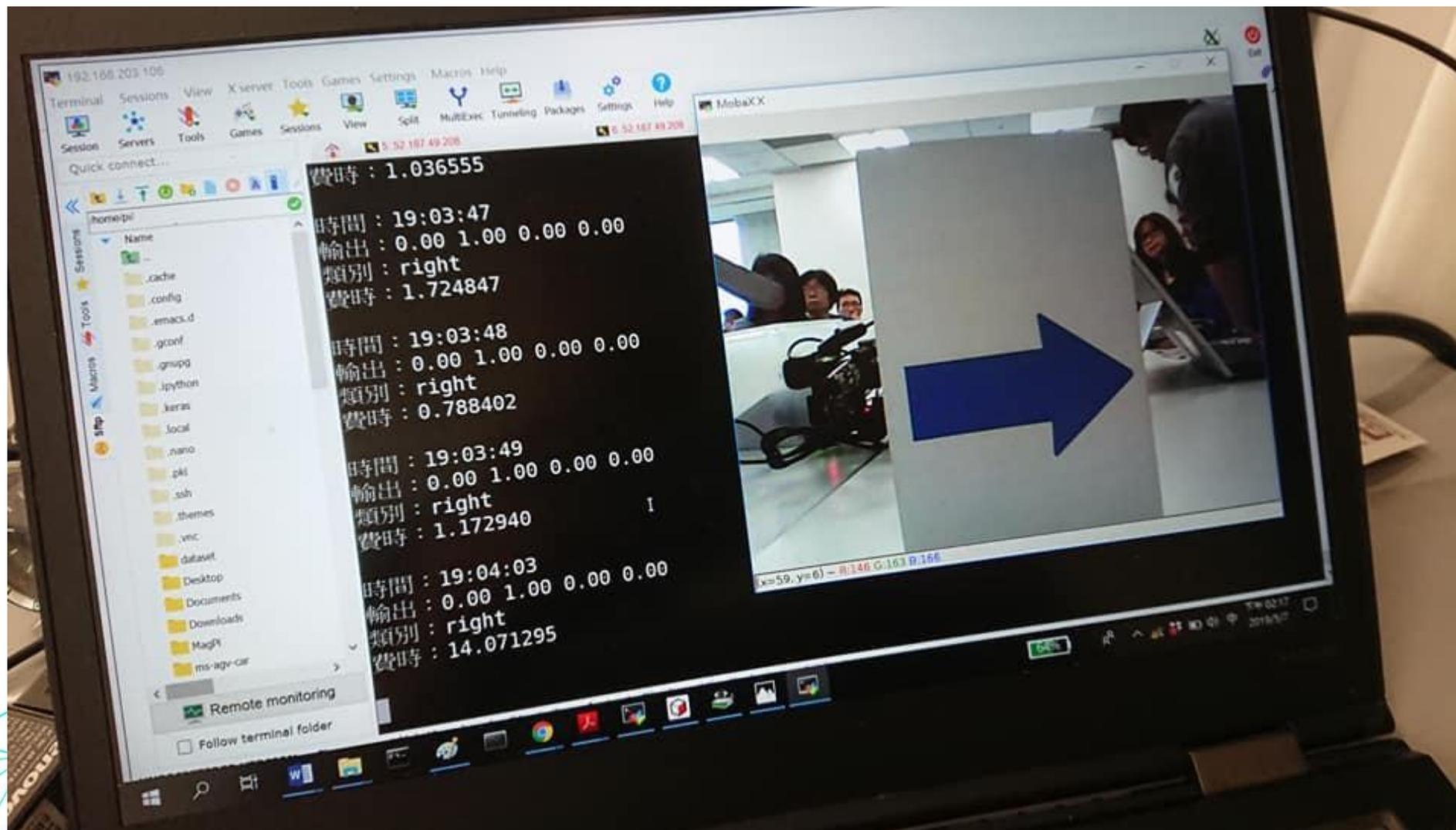
UP board / UP squared /UP AI core (Intel NCS)



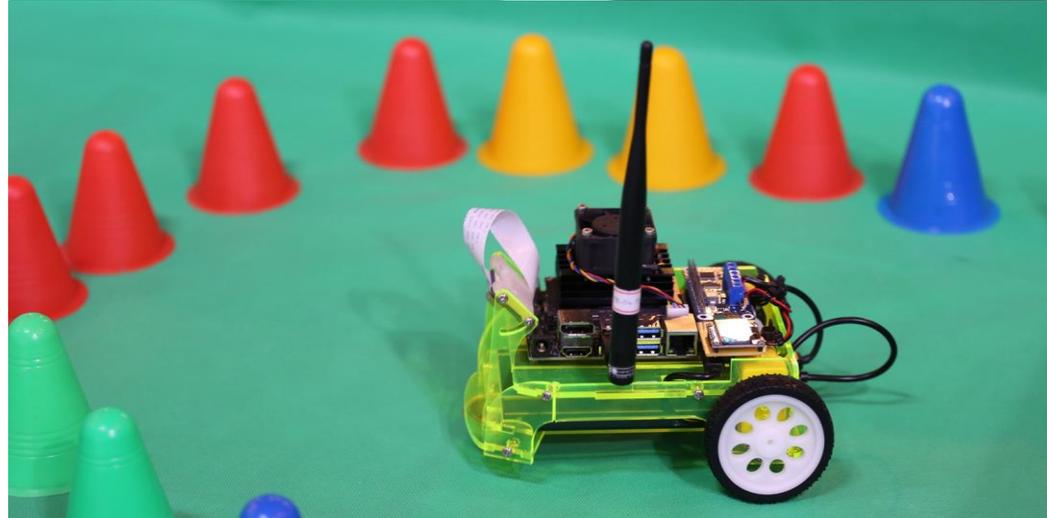
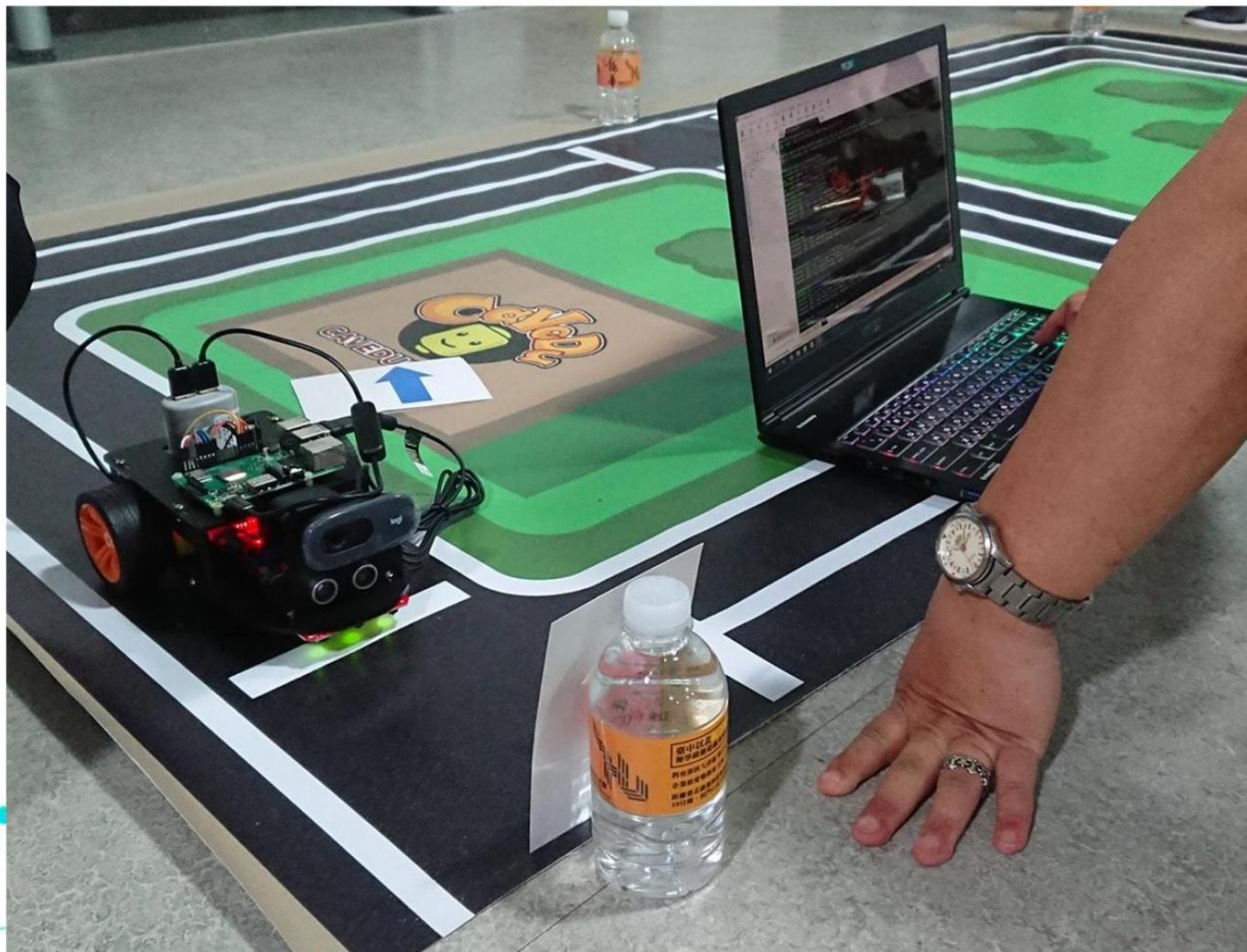
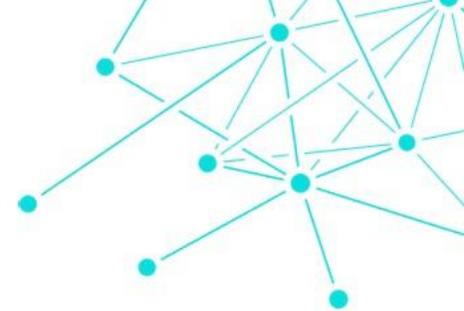
# M5StackV



# 理解影像中的“涵義”



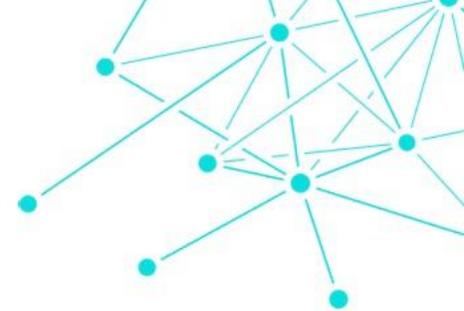
# 以自駕車情境為例





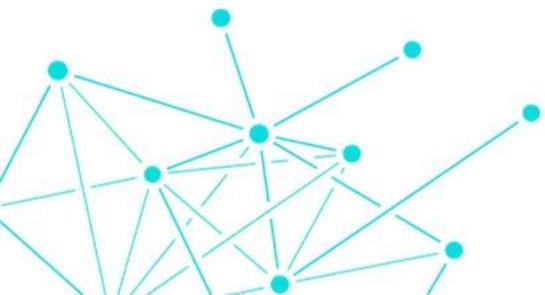


# TinyML

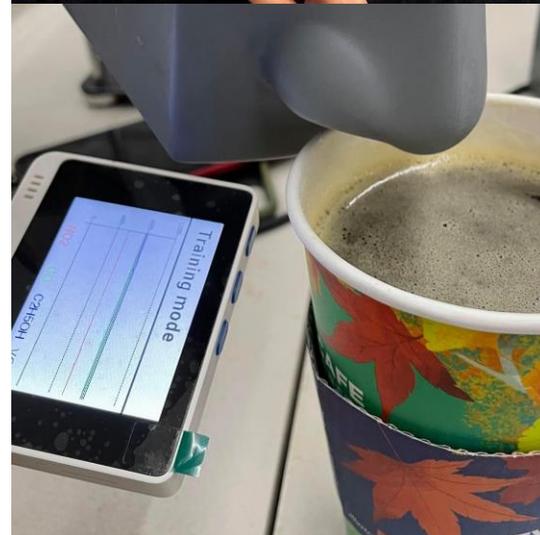


TinyML 的 **tiny** 代表 ML 模型已針對低功耗的微型裝置進行最佳化，例如 Arduino 為首的各種 MCU，各種應用紛紛出籠，但依然受限於 MCU 的算力。

常見應用：聲音場景、熱詞偵測、影像辨識、氣味分析



# tinyML 這個主題真的很酷



**Make:** MOTORIZED SELF SOLVING RUBIK'S CUBE

**MACHINE LEARNING**

Swear Bear... Trash Sorter... Easy AI Trainers  
Teach your project to think for itself

**BENJAMIN CABÉ'S "NOSE" KNOWS!**  
Build this smell-identifying AI sniffer

**23 PROJECTS!**

- Raspberry Pi Meteor Camera
- Digital String Art Portraits
- Animated LED Skirt
- Arduino Borealis Lights

**SKILL BUILDERS**

- Digital Mobile Radio
- Hack a Knitting Machine

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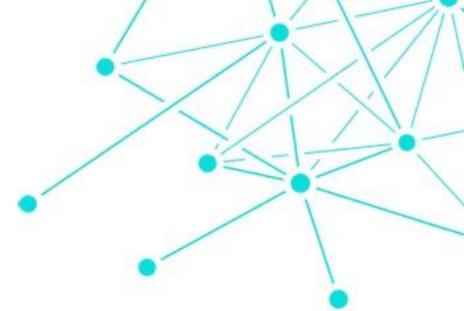
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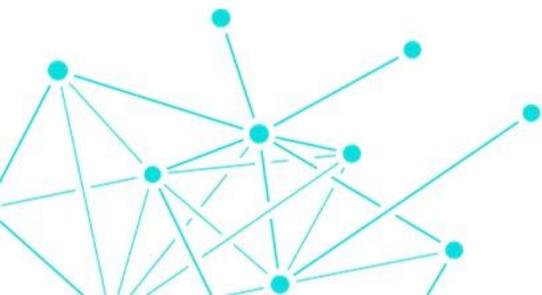
# 為何要在本地端執行ML？

- **降低延遲**：資料在雲端伺服器之間來回傳送需要時間，無法做到即時，也無法滿足必須在指定時間內回應的應用。
- **降低功耗**：資料在雲端伺服器之間來回傳送，耗能效應必定較低，即便使用藍牙這類低功耗通訊協定也一樣。
- **保護隱私**：本地端ML代表可保護使用者隱私，並避免分享敏感資訊。

# 我們怎麼由教育觀點看tinyML



- TinyML 是一系列機器學習技術與嵌入式系統，可在低功耗裝置上執行各類智能應用。
- 一般而言，這類裝置的規格有限，但它們可透過各類感測器來感知實體環境，並可根據ML演算法的結果來做出各種決策。
- **為傳統感測器賦予新意義**



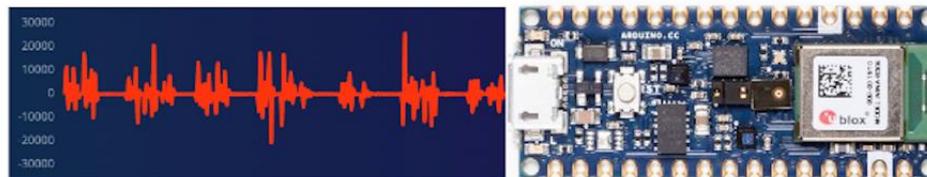
# 機會與挑戰

- TinyML 適用情境在於無法從外部環境取得電力，且相關應用必須能以電池來供電愈久愈好。
- 我們身邊已經充滿了各種電池供電，並可運用ML算法的裝置了。例如智慧手錶或健身帶這類穿戴式裝置就可以分辨人體活動來追蹤健康目標，或偵測跌倒等危險。
- TinyML 應用已全面見於各種情境與目的，因為它們都可由電池供電，也需要離線執行ML算法來賦予感測器資料更多意義。

# 如何把 ML 概念帶入K12教學現場

硬體：Wio Terminal (包括但不限於)

軟體：Arduino IDE + Edge Impulse

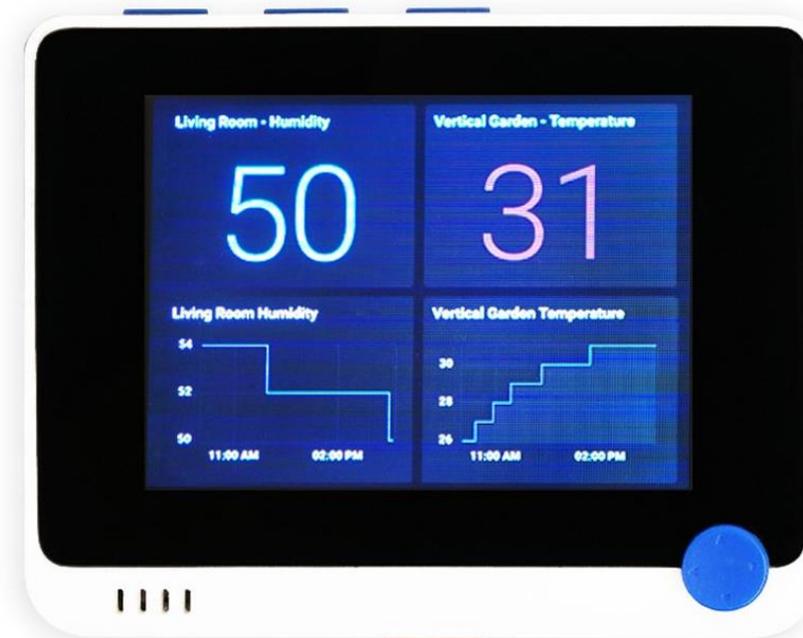


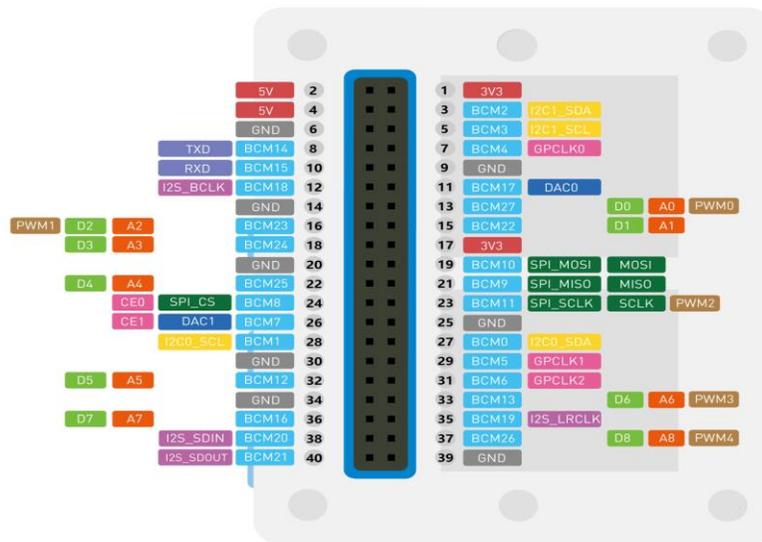
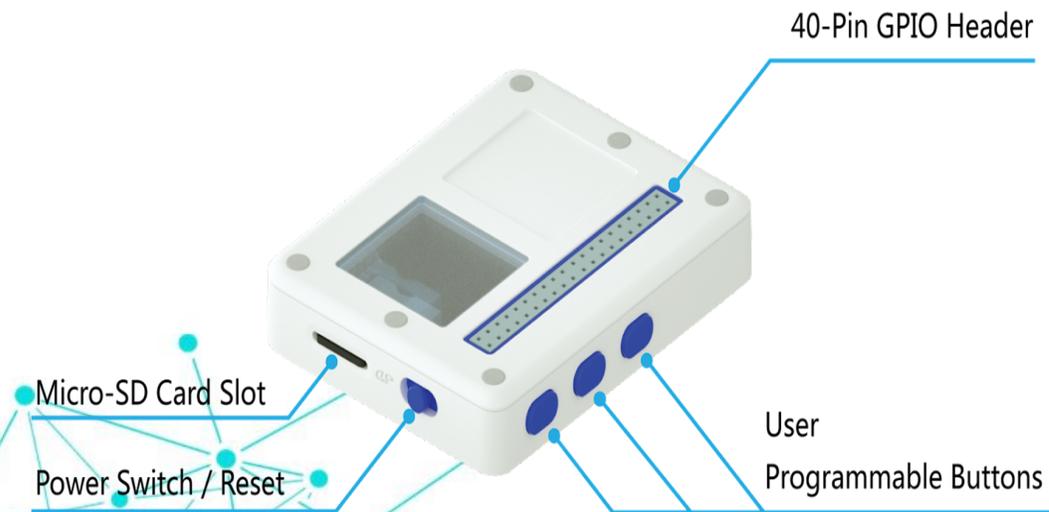
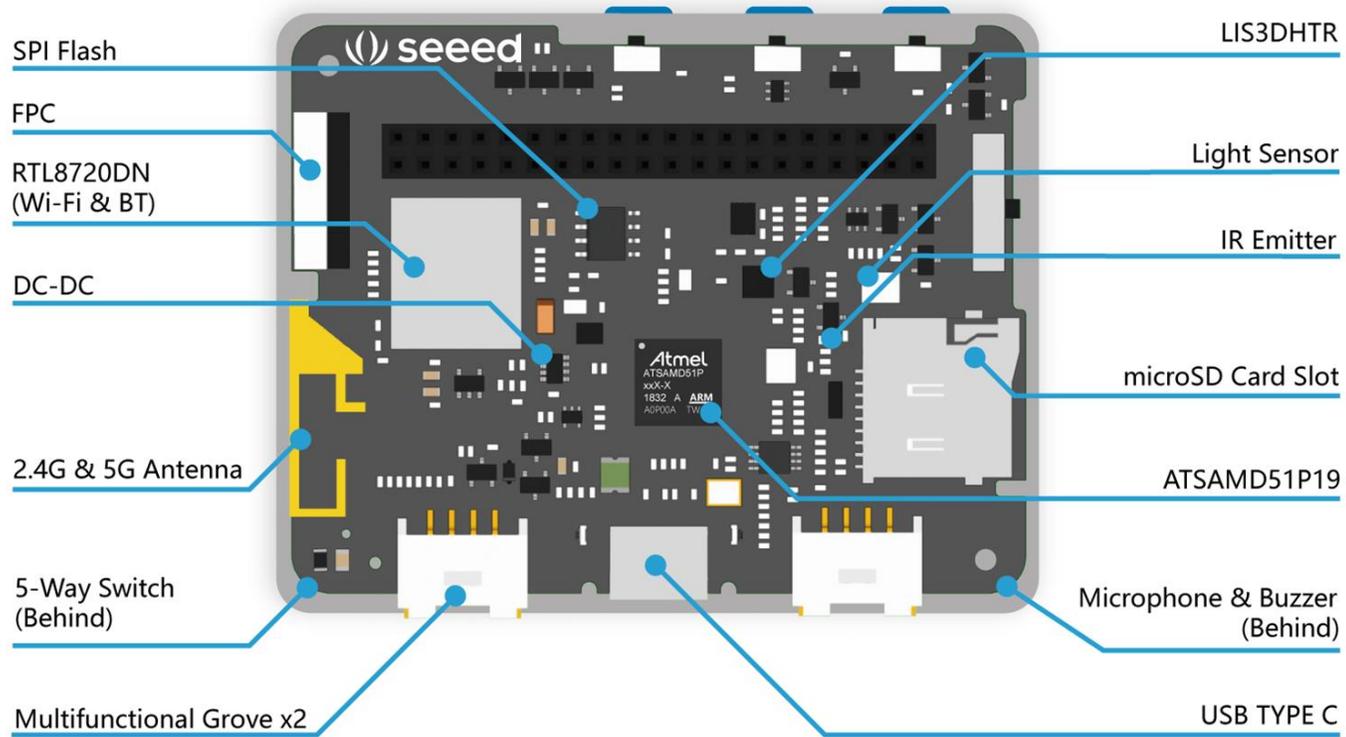
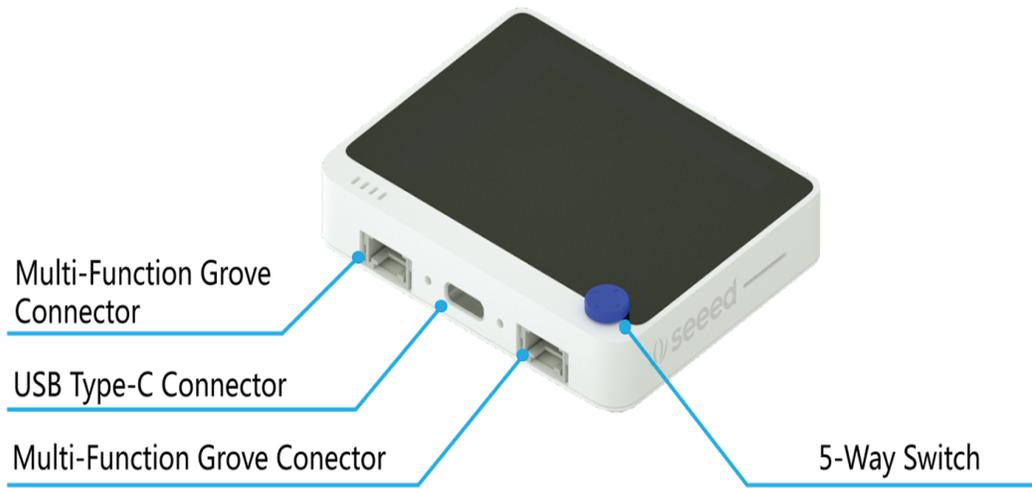
# Wio Terminal

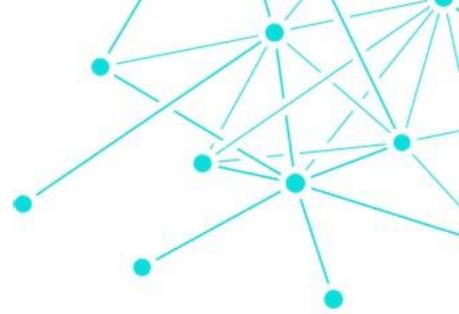
Wio Terminal 是一款專門用於 IoT 與 TinyML 的多功能開發板 – 包含了 ATSAM51P19 晶片並以 ARM Cortex-M4F 為核心 (20MHz)，支援多種針對微控制器的 ML 推論框架。

本開發板已包含：

- Wi-Fi / BLE 連線能力
- 光感測器(類比)
- 麥克風
- 可自訂按鈕 x 3
- 4 英吋彩色LCD
- 加速度感測器
- Grove 接頭 x 2，可連接多達300種 Grove 感測器

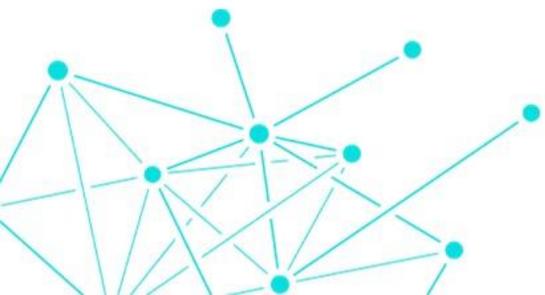






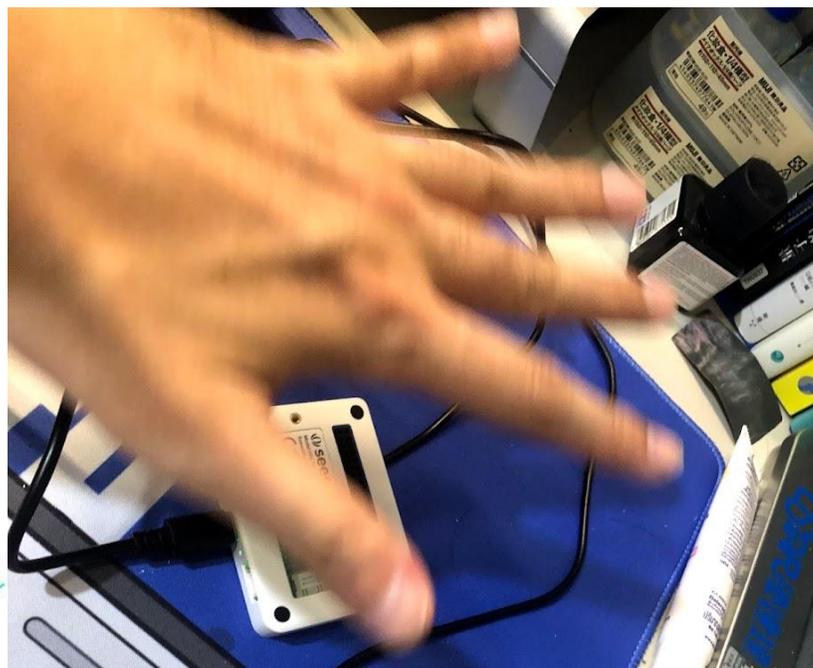
賦予傳統感測器全新意義

New insights with legacy sensors

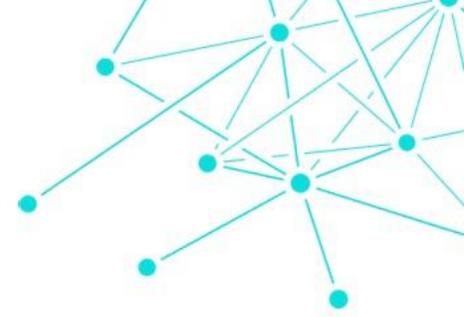


# 使用光感測器來偵測手勢 – 舉例

- 根據剪刀、石頭、布的光線遮斷樣式不同來區分
- 但：不同光線狀況，資料結果大不同
- if else 很難成功，**需要 ML 方案**來找出資料中的隱含關係與資訊



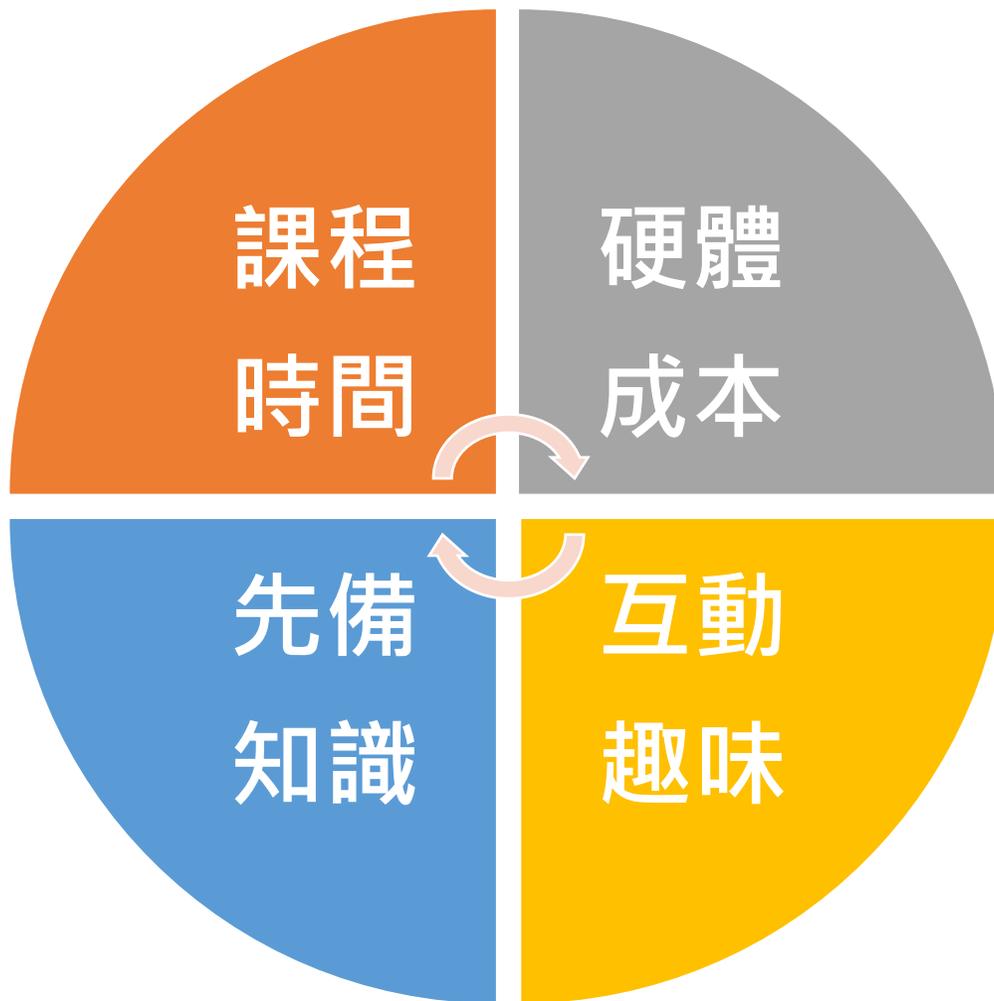
# 傳統的 if /else 到 ML maker 到小小資料分析師？



感測器	傳統 maker 課程	導入 ML 概念
光感測器	小夜燈	手勢辨識
聲音感測器	拍手開門	室內室外偵測
加速度	傾斜警告裝置	運動姿態分析
氣體濃度感測器	瓦斯警報器	分辨不同種類的酒
溫溼度感測器	物聯網空調	智慧植栽



# 考量



# 設計課程理念

- 發揮設備套件最佳效益
- 發想出更多有趣題目與前期測試
- 回頭詢問學生 問卷訪談
- 對於感測器操作、物理量意涵，熟悉度都顯著上升





# Edge Impulse

ML pipeline

EI支援硬體 / tflite model 轉 C array

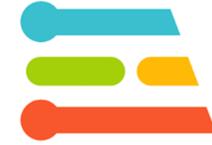


# 操作步驟

## 開發板



## Edge Impulse



1. Wio terminal 上傳單筆資料到 Edge Impulse

2. 把資料整理到不同類別，反覆操作
3. 設計 Impulse：資料處理、定義模型
4. **測試神經網路效能、修改、重複**
5. 匯出神經網路檔案

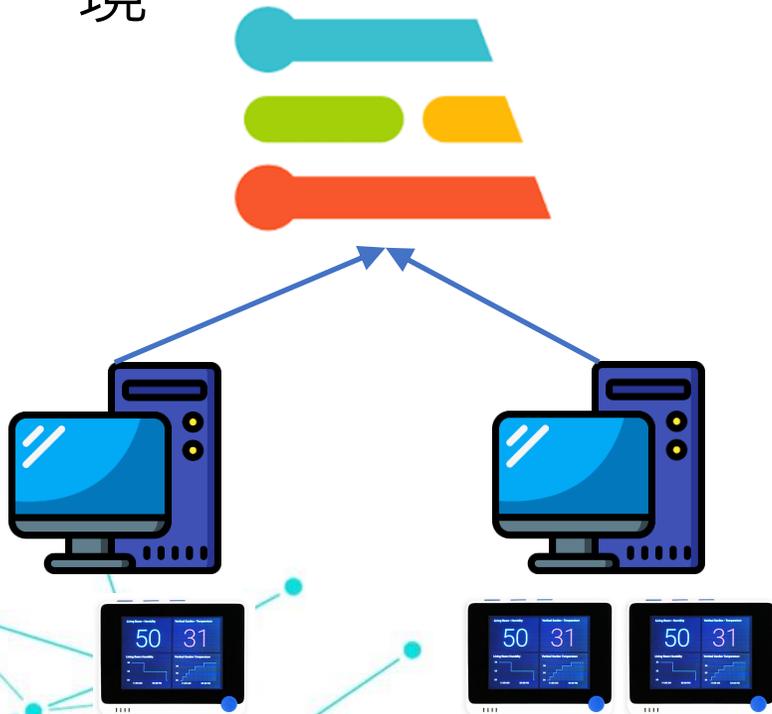
6. 透過 Arduino IDE 燒錄至 Wio

7. Wio 執行離線推論，完成！

# 1. Wio terminal 上傳單筆資料到 Edge Impulse

## Wio – PC – Edge Impulse

Edge Impulse 可接收來自多片不同板子的資料 --- 符合物聯網情境



```
(testA1) C:\Users\nissi>edge-impulse-data-forwarder
Edge Impulse data forwarder v1.13.15
? What is your user name or e-mail address (edgeimpulse.com)? nissin@cavedu.com
? What is your password? [hidden]
Endpoints:
  Websocket: wss://remote-mgmt.edgeimpulse.com
  API:       https://studio.edgeimpulse.com/v1
  Ingestion: https://ingestion.edgeimpulse.com

? Which device do you want to connect to? COM4 (Microsoft)
[SER] Connecting to COM4
[SER] Serial is connected (01:DF:FE:43:53:36:46:4E:4D:20:20:20:FF:19:22:4A)
[WS ] Connecting to wss://remote-mgmt.edgeimpulse.com
[WS ] Connected to wss://remote-mgmt.edgeimpulse.com

[SER] Detecting data frequency...
[SER] Detected data frequency: 39Hz
? 1 sensor axes detected (example values: [137]). What do you want to call them? Separate the names with ',': light
```

# 2. 管理資料與定義類別

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
  - Create impulse
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

GETTING STARTED

- Documentation
- Forums

DATA COLLECTED  
11s



TRAIN / TEST SPLIT  
100% / 0%



Collected data

SAMPLE NAME	LABEL	ADDED	LENGTH
paper.json.2h2bk17e	paper	Today, 21:13:07	1s
rock.json.2h2bjn46	rock	Today, 21:12:57	1s
rock.json.2h2bjahj	rock	Today, 21:12:44	1s
rock.json.2h2bj3tk	rock	Today, 21:12:37	1s
rock.json.2h2biu4t	rock	Today, 21:12:31	1s
rock.json.2h2bin6s	rock	Today, 21:12:24	1s
rock.json.2h2biej1	rock	Today, 21:12:15	1s
rock.json.2h2bhu7r	rock	Today, 21:11:59	1s
rock.json.2h2bhkct	rock	Today, 21:11:49	1s
rock.json.2h2bh1u0	rock	Today, 21:11:30	1s
rock.json.2h2beu20	rock	Today, 21:10:20	1s

Record new data

Connect using WebUSB

Device

wio\_cavedu

Label

paper

Sample length (ms.)

1000

Sensor

Sensor with 1 axes (light)

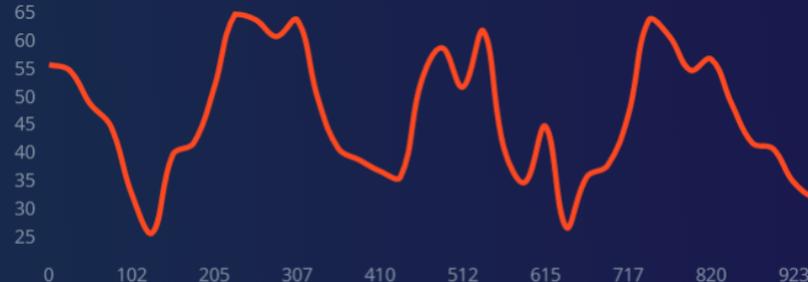
Frequency

39Hz

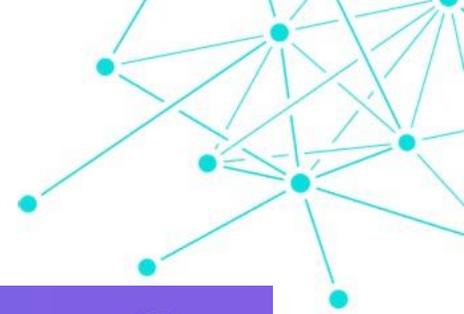
Start sampling

RAW DATA

paper.json.2h2bk17e



# 3. 設計Impulse – ML運算方式



CREATE IMPULSE (NISSIN-PROJECT-1)

nissin

An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

原始資料

Time series data



Axes  
light

Window size



1000 ms.

Window increase



1000 ms.

Frequency (Hz)

39

Zero-pad data



Add a processing block



Add a learning block

Output features

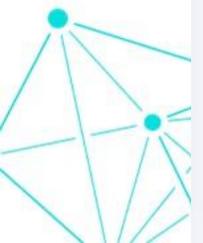


輸出特徵

Save Impulse

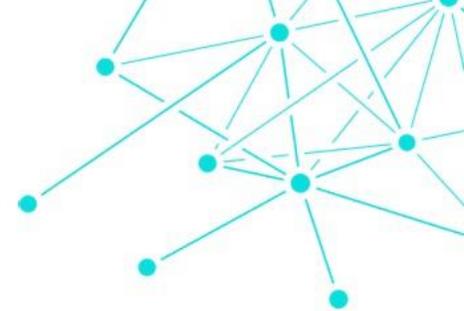
資料處理

機器學習



# 已內建許多資料處理 / 機器學習指令

## Rich built-in blocks



### ⚡ Add a processing block

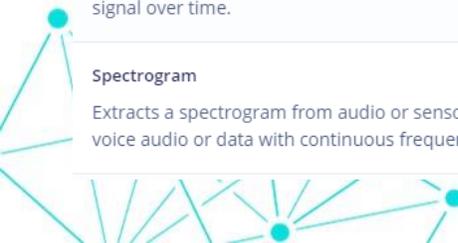
DESCRIPTION	AUTHOR	RECOMMENDED
<b>Flatten</b> Flatten an axis into a single value, useful for slow-moving averages like temperature data, in combination with other blocks.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Image</b> Preprocess and normalize image data, and optionally reduce the color depth.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Audio (MFCC)</b> Extracts features from audio signals using Mel Frequency Cepstral Coefficients, great for human voice.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Audio (MFE)</b> Extracts a spectrogram from audio signals using Mel-filterbank energy features, great for non-voice audio.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Spectral Analysis</b> Great for analyzing repetitive motion, such as data from accelerometers. Extracts the frequency and power characteristics of a signal over time.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Spectrogram</b> Extracts a spectrogram from audio or sensor data, great for non-voice audio or data with continuous frequencies.	EdgeImpulse Inc.	<a href="#">Add</a>

### 🧪 Add a learning block

Some learning blocks have been hidden based on the data in your project.

DESCRIPTION	AUTHOR	RECOMMENDED
<b>Classification (Keras)</b> Learns patterns from data, and can apply these to new data. Great for categorizing movement or recognizing audio.	EdgeImpulse Inc.	★ <a href="#">Add</a>
<b>Regression (Keras)</b> Learns patterns from data, and can apply these to new data. Great for predicting numeric continuous values.	EdgeImpulse Inc.	<a href="#">Add</a>
<b>Anomaly Detection (K-means)</b> Find outliers in new data. Good for recognizing unknown states, and to complement classifiers.	EdgeImpulse Inc.	<a href="#">Add</a>

[Cancel](#)



# 範例 Impulse / Example impulse

CREATE IMPULSE (NISSIN-PROJECT-1) nissin

 An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.

### Time series data

Axes  
light

Window size ?  
1000 ms.

Window increase ?  
1000 ms.

Frequency (Hz) ?  
39 

Zero-pad data ?

### Raw Data

Name  
Raw data

Input axes  
 light



  
Add a processing block

### Classification (Keras)

Name  
NN Classifier

Input features  
 Raw data

Output features  
2 (paper, rock)



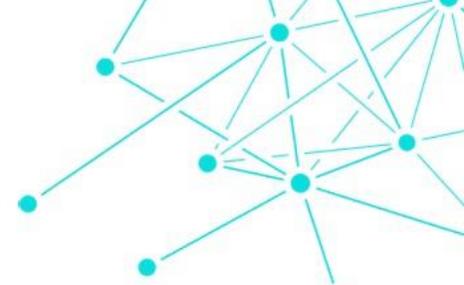
  
Add a learning block

### Output features

2 (paper, rock)

Save Impulse

# 方便好用的神經網路設定



### Neural Network settings

Training settings

Number of training cycles

Learning rate

### Neural network architecture

Input layer (39 features)

Dense layer (20 neurons)

Dense layer (10 neurons)

Add an extra layer

Output layer (2 features)

**Start training**

### Training output

Model Model version:

Last training performance (validation set)

**ACCURACY 75.0%** **LOSS 0.65**

Confusion matrix (validation set)

	PAPER	ROCK
PAPER	66.7%	33.3%
ROCK	0%	100%
F1 SCORE	0.80	0.67

Feature explorer (full training set)

- paper - correct
- rock - correct
- paper - incorrect

一鍵訓練！



# 4. 不斷修改讓模型更好！

The screenshot displays the 'NN CLASSIFIER (NISSIN-PROJECT-1)' interface. On the left, the 'Neural Network settings' panel includes 'Training settings' (500 cycles, 0.0001 learning rate) and 'Neural network architecture' (Input layer: 39 features, Dense layer: 20 neurons, Dense layer: 10 neurons, Output layer: 2 features). A 'Start training' button is at the bottom. The right panel, 'Training output', shows 'Model version: Quantized (int8)', 'Last training performance' (100.0% Accuracy, 0.62 Loss), a 'Confusion matrix' table, a 'Feature explorer' 3D plot, and 'On-device performance' (1 ms inference time, 1.7K peak RAM usage, 18.0K flash usage).

	PAPER	ROCK
PAPER	100%	0%
ROCK	0%	100%
F1 SCORE	1.00	1.00

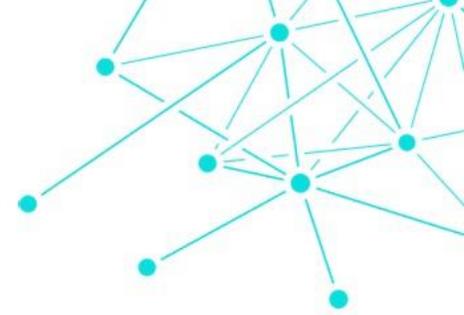
Metric	Value
INFERENCE TIME	1 ms.
PEAK RAM USAGE	1.7K
FLASH USAGE	18.0K

更多資料

調整NN架構

重新訓練！

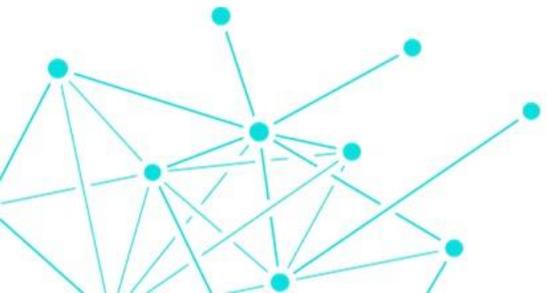




# Edge Impulse

讓課堂中**多次修改/重新訓練/測試**成為可能

Edge Impulse makes it possible to **repeatedly modify / retrain and test** your solution

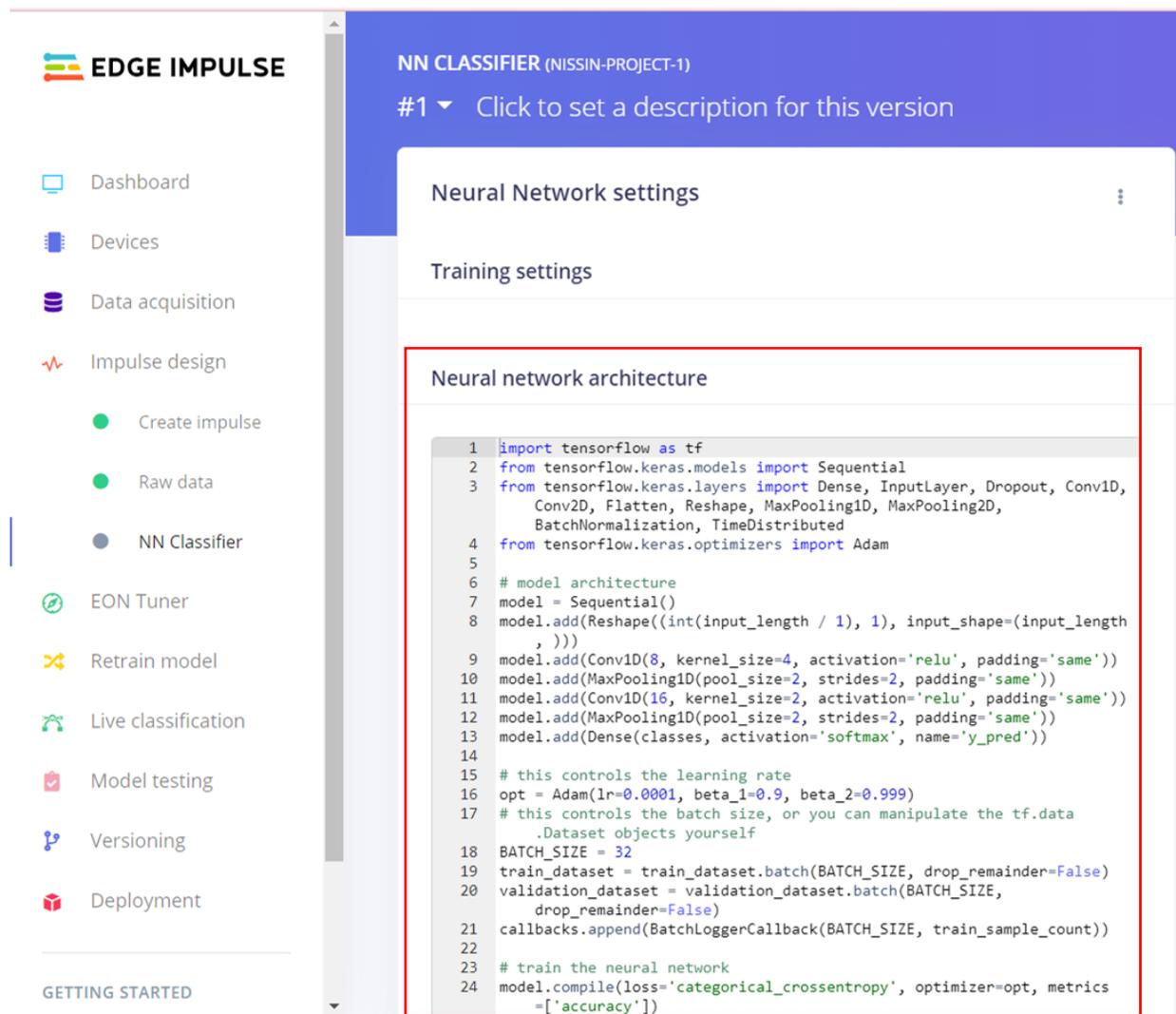


# 4a 進階使用者可以直接改程式碼

## Neural Network settings

點選 [...] 切換到

就可以直接編輯程式碼  
(tf.keras)



EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
  - Create impulse
  - Raw data
  - NN Classifier
- EON Tuner
- Retrain model
- Live classification
- Model testing
- Versioning
- Deployment

GETTING STARTED

NN CLASSIFIER (NISSIN-PROJECT-1)  
#1 Click to set a description for this version

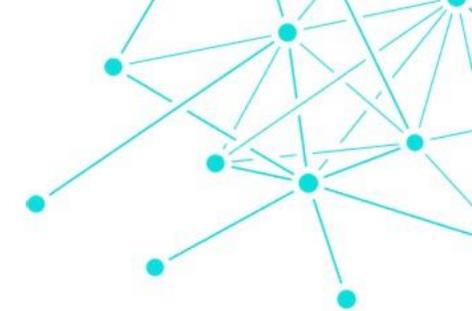
Neural Network settings

Training settings

Neural network architecture

```
1 import tensorflow as tf
2 from tensorflow.keras.models import Sequential
3 from tensorflow.keras.layers import Dense, InputLayer, Dropout, Conv1D,
   Conv2D, Flatten, Reshape, MaxPooling1D, MaxPooling2D,
   BatchNormalization, TimeDistributed
4 from tensorflow.keras.optimizers import Adam
5
6 # model architecture
7 model = Sequential()
8 model.add(Reshape((int(input_length / 1), 1), input_shape=(input_length
   , )))
9 model.add(Conv1D(8, kernel_size=4, activation='relu', padding='same'))
10 model.add(MaxPooling1D(pool_size=2, strides=2, padding='same'))
11 model.add(Conv1D(16, kernel_size=2, activation='relu', padding='same'))
12 model.add(MaxPooling1D(pool_size=2, strides=2, padding='same'))
13 model.add(Dense(classes, activation='softmax', name='y_pred'))
14
15 # this controls the learning rate
16 opt = Adam(lr=0.0001, beta_1=0.9, beta_2=0.999)
17 # this controls the batch size, or you can manipulate the tf.data
   .Dataset objects yourself
18 BATCH_SIZE = 32
19 train_dataset = train_dataset.batch(BATCH_SIZE, drop_remainder=False)
20 validation_dataset = validation_dataset.batch(BATCH_SIZE,
   drop_remainder=False)
21 callbacks.append(BatchLoggerCallback(BATCH_SIZE, train_sample_count))
22
23 # train the neural network
24 model.compile(loss='categorical_crossentropy', optimizer=opt, metrics
   =['accuracy'])
```

# 4b 檢視NN訓練結果



模型效能

特徵探索

Training output

Model

Model version: Quantized (int8)

Last training performance (validation set)

**75.0%** ACCURACY

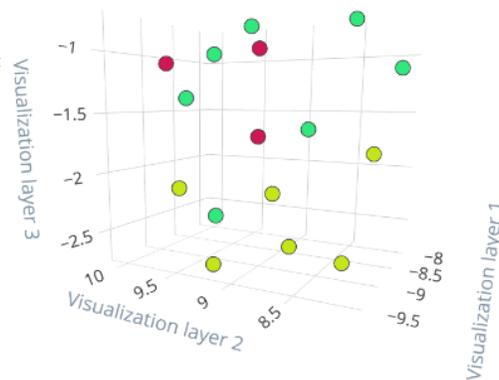
**0.65** LOSS

Confusion matrix (validation set)

	PAPER	ROCK
PAPER	66.7%	33.3%
ROCK	0%	100%
F1 SCORE	0.80	0.67

Feature explorer (full training set)

- paper - correct
- rock - correct
- paper - incorrect



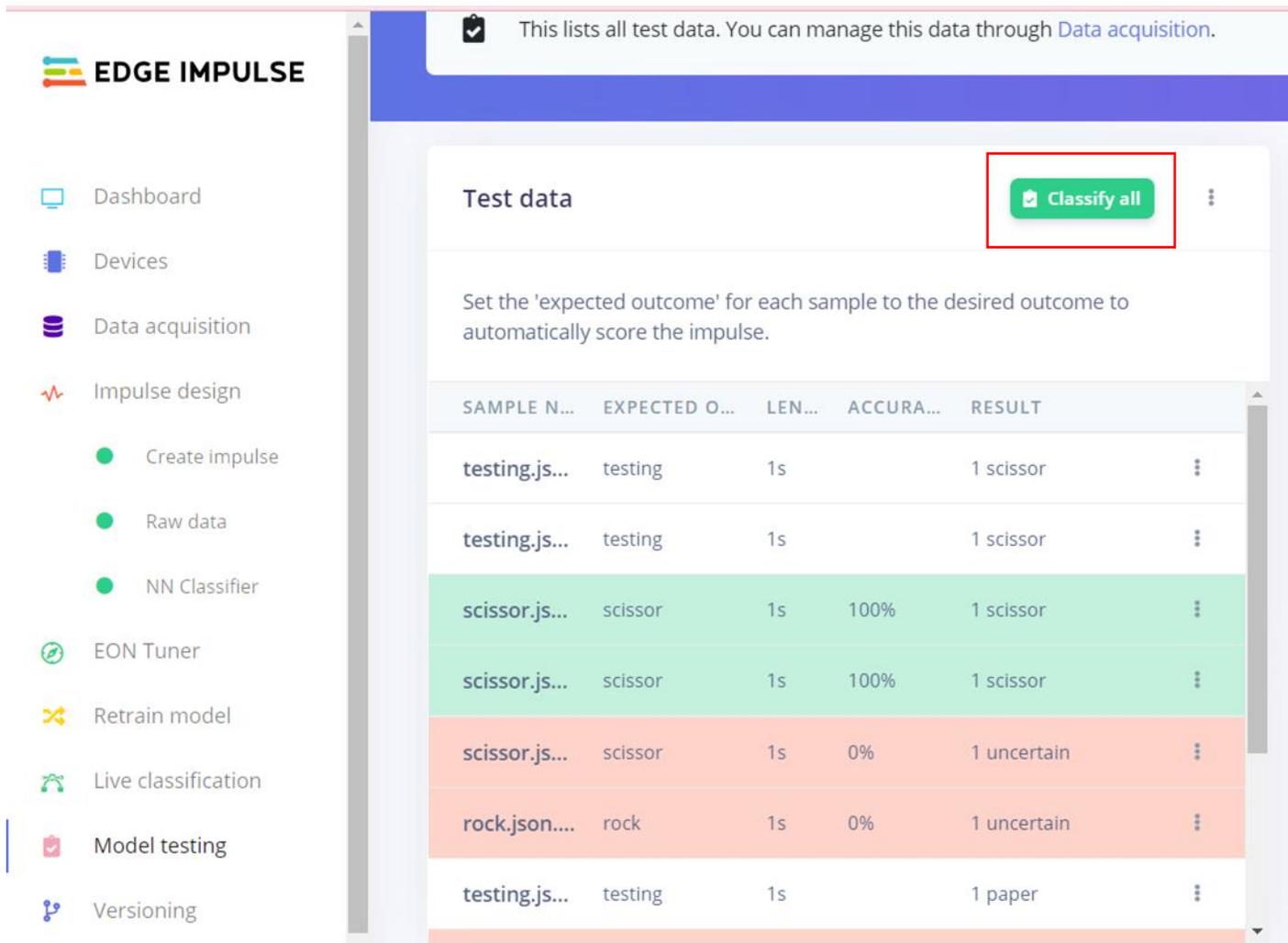
混淆矩陣



# 4c 在 Model testing 檢視模型成效

test data 的每一筆結果

可以搬到 train dataset  
再次重新訓練



EDGE IMPULSE

Dashboard  
Devices  
Data acquisition  
Impulse design  
Create impulse  
Raw data  
NN Classifier  
EON Tuner  
Retrain model  
Live classification  
Model testing  
Versioning

This lists all test data. You can manage this data through [Data acquisition](#).

Test data Classify all

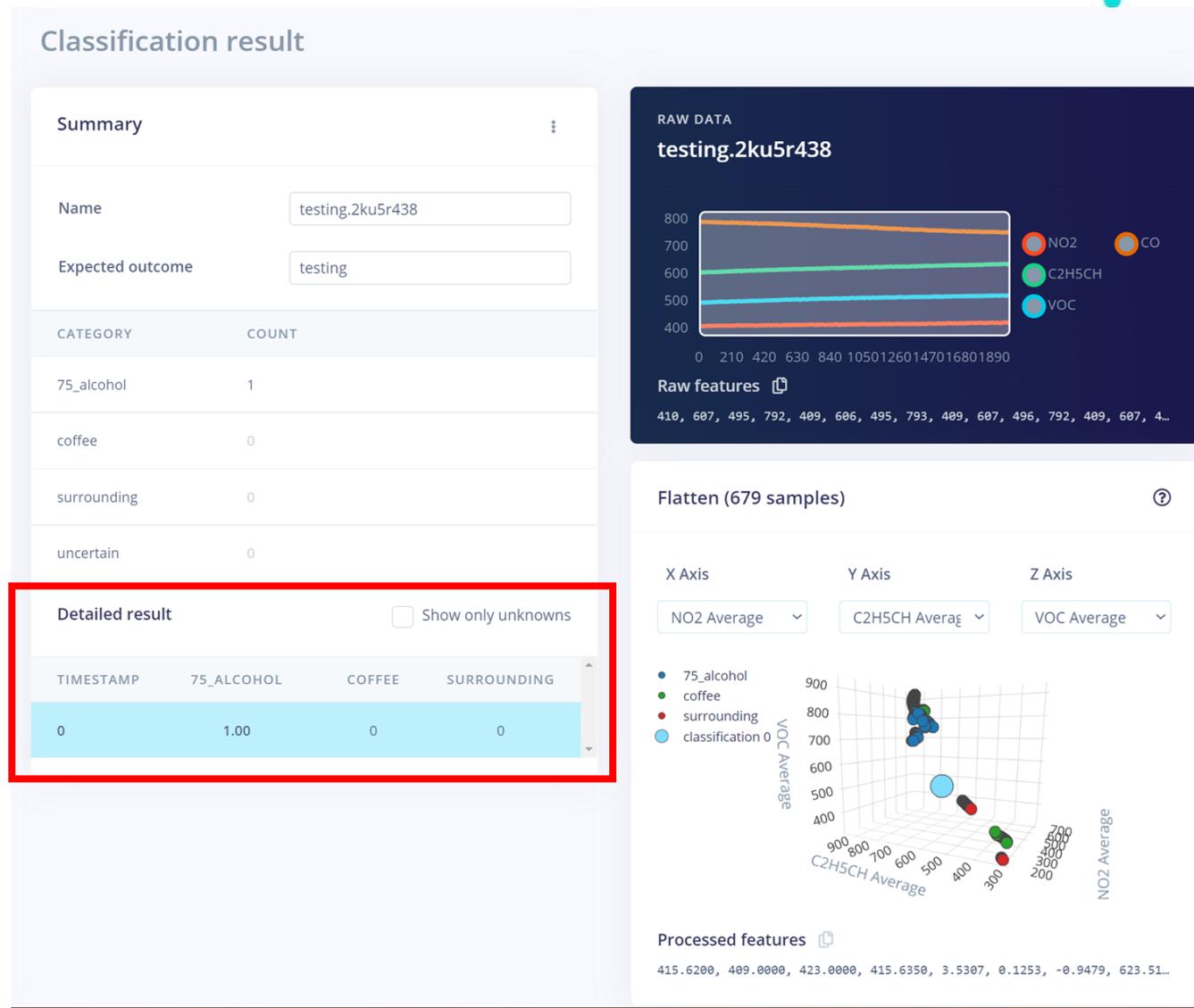
Set the 'expected outcome' for each sample to the desired outcome to automatically score the impulse.

SAMPLE N...	EXPECTED O...	LEN...	ACCURA...	RESULT
testing.js...	testing	1s		1 scissor
testing.js...	testing	1s		1 scissor
scissor.js...	scissor	1s	100%	1 scissor
scissor.js...	scissor	1s	100%	1 scissor
scissor.js...	scissor	1s	0%	1 uncertain
rock.json....	rock	1s	0%	1 uncertain
testing.js...	testing	1s		1 paper

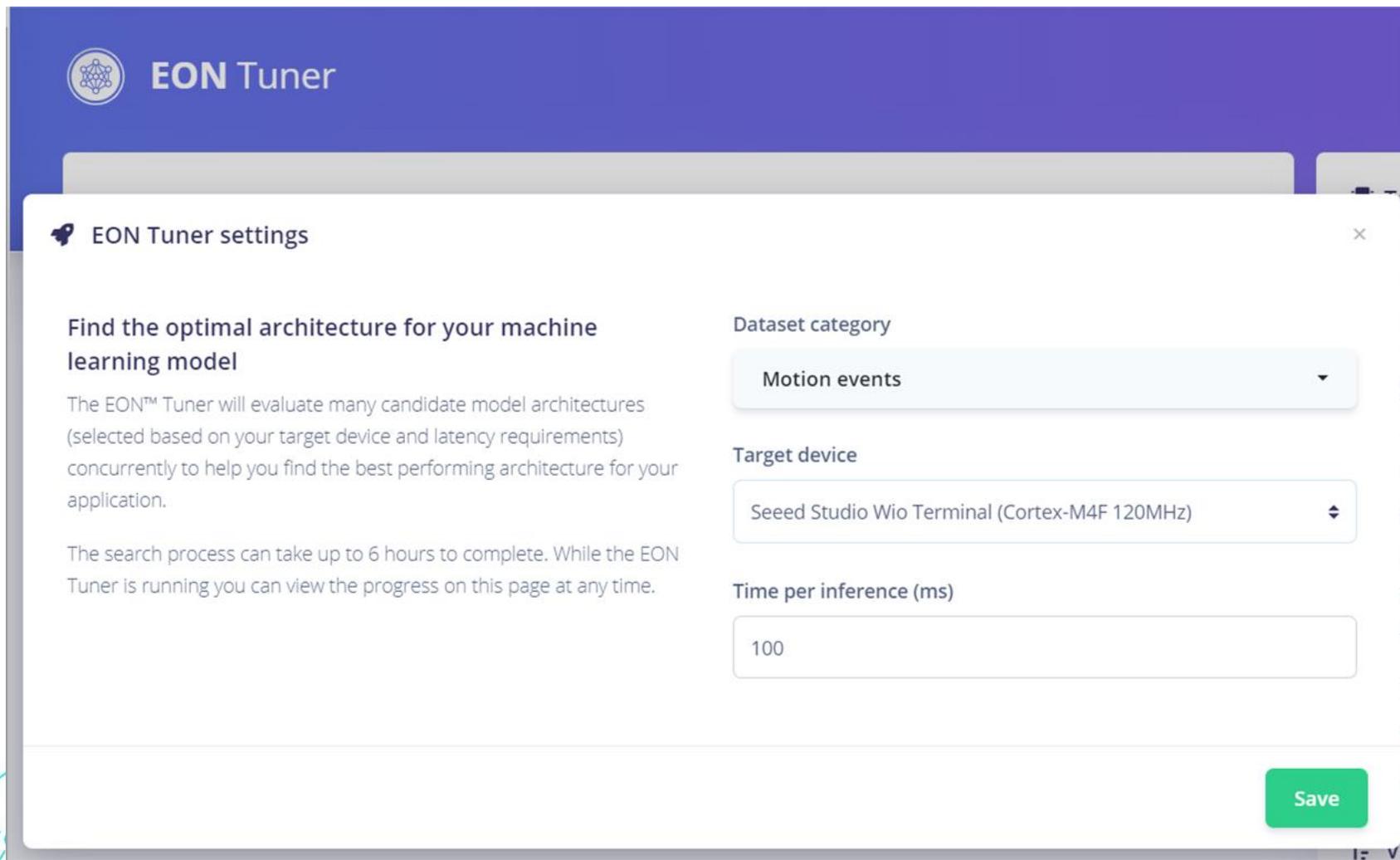
# 4e 即時測試

上傳感測器資料來即時測試

測試資料也可納入訓練資料集  
來重新訓練



# 4f EON tuner - 針對開發板最佳化 Performance optimizer for your dev board



**EON Tuner**

### EON Tuner settings

**Find the optimal architecture for your machine learning model**

The EON™ Tuner will evaluate many candidate model architectures (selected based on your target device and latency requirements) concurrently to help you find the best performing architecture for your application.

The search process can take up to 6 hours to complete. While the EON Tuner is running you can view the progress on this page at any time.

**Dataset category**  
Motion events

**Target device**  
Seeed Studio Wio Terminal (Cortex-M4F 120MHz)

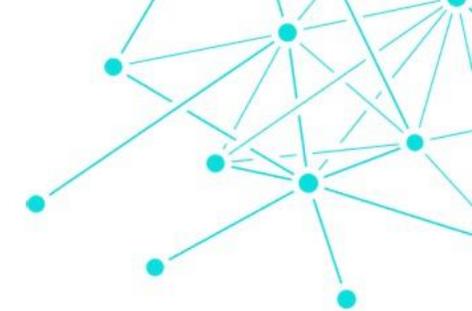
**Time per inference (ms)**  
100

**Save**



# 5. 根據硬體平台匯出神經網路模型

# 5. Export NN model for various HW platforms



### Deploy your impulse

You can deploy your impulse to any device. This makes the model run without an internet connection, minimizes latency, and runs with minimal power consumption. [Read more.](#)

### Create library

Turn your impulse into optimized source code that you can run on any device.



C++ library



Arduino library



Cube.MX CMSIS-PACK



WebAssembly



TensorRT library

### Build firmware

Or get a ready-to-go binary for your development board that includes your impulse.



Linux boards

### Select optimizations (optional)

Model optimizations can increase on-device performance but may reduce accuracy. Click below to analyze optimizations and see the recommended choices for your target. Or, just click Build to use the currently selected options.

 **Enable EON™ Compiler**  Same accuracy, up to 50% less memory. Open source.

### Available optimizations for NN Classifier

	RAM USAGE	LATENCY	FLASH USAGE	ACCURACY
<b>Quantized (int8)</b> <input checked="" type="button" value="Currently selected"/>	1.7K	1 ms	18.0K	-
<b>Unoptimized (float32)</b> <input type="button" value="Click to select"/>	1.8K	1 ms	20.6K	-

Estimate for Cortex-M4F 80MHz

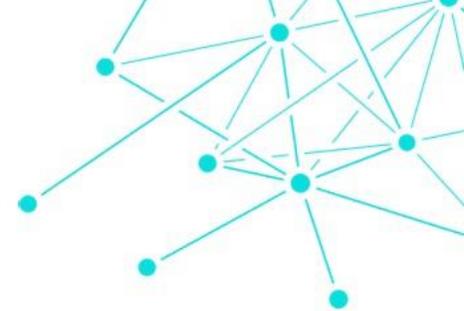
### Build output

```
Creating job... OK (ID: 1380447)
Writing templates...
Writing templates OK
Job started
Copying Edge Impulse SDK...
Copying Edge Impulse SDK OK
Compiling EON model...
Compiling EON model OK
Removing clutter and updating headers...
Removing clutter and updating headers OK
Creating archive...
Creating archive OK
Job completed
```

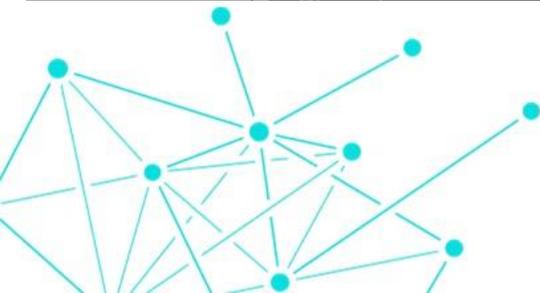
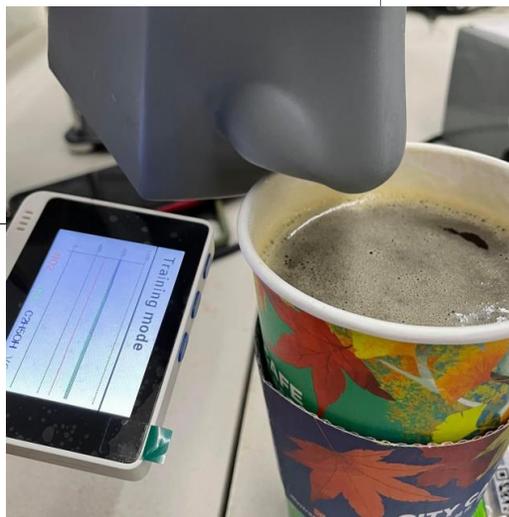


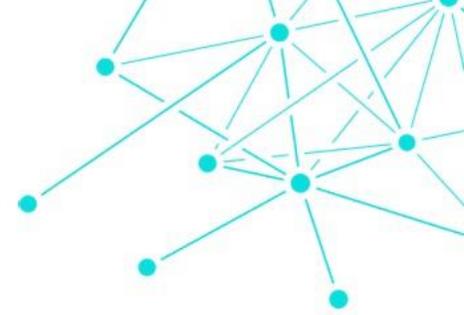
# 6. 透過 Arduino IDE 上傳至開發板

# 7. 離線執行ML應用！



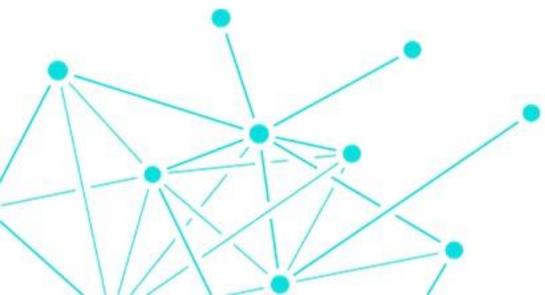
```
static_buffer | Arduino IDE 2.0.0-beta.12
File Edit Sketch Tools Help
Seeeduino Wio Terminal at C...
static_buffer.ino
static_buffer.ino
1 /* Edge Impulse Arduino examples
2 * Copyright (c) 2021 EdgeImpulse Inc.
3 *
4 * Permission is hereby granted, free of charge, to any person obtaining a copy
5 * of this software and associated documentation files (the "Software"), to deal
6 * in the Software without restriction, including without limitation the rights
7 * to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
8 * copies of the Software, and to permit persons to whom the Software is
9 * furnished to do so, subject to the following conditions:
10 *
11 * The above copyright notice and this permission notice shall be included in
Serial Monitor X
Message (Ctrl+Enter to send message to 'Seeeduino Wio Terminal' on 'COM6')
New Line 9600 baud
paper: 0.47656
rock: 0.52344
Edge Impulse standalone inferencing (Arduino)
run_classifier returned: 0
Predictions (DSP: 0 ms., Classification: 0 ms., Anomaly: 0 ms.):
[0.47656, 0.52344]
paper: 0.47656
rock: 0.52344
```





# 針對教學現場所設計之tinyML課表與套件包

tinyML education kit



# 智慧植栽套件包 / Smart plant kit

螺絲與線材們



20公分PVC管



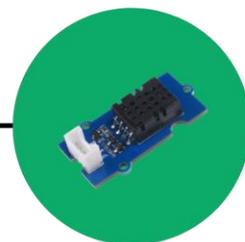
Wio Terminal 開發板



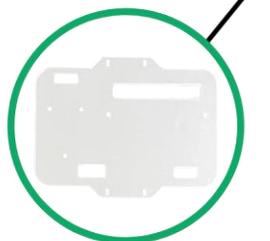
Gravity類比式防水電容式土壤濕度感測器



50公分矽膠管



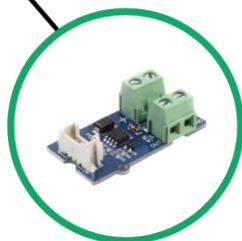
Grove - 溫溼度感測器  
(DHT20)



雷射切割壓克力背板



直流沉水式抽水馬達



Grove - MOSFET模組

# RK Wio Terminal Education Kit – 20 projects!



- Wio Terminal開發板
- Grove -多通道氣體感測器 V2
- Grove – MOSFET模組
- Grove -氣壓感測器(BME280)
- Grove -超音波測距模組
- Gravity: 類比式防水電容式土壤濕度感測器
- 直流沉水式抽水馬達
- 含收納與配件

洞洞參教學材料包



# RK Wio Terminal Education Kit



Multi-Function Grove Connector

(多功能Grove連接埠)

USB Type-C Connector

(USB Type-C 連接埠)

Multi-Function Grove Connector

(多功能Grove連接埠)



5-Way Switch

(五向式開關)



(Micro SD記憶卡插槽)  
Micro SD Card Slot

Power Switch / Reset

(電源開關/重置)

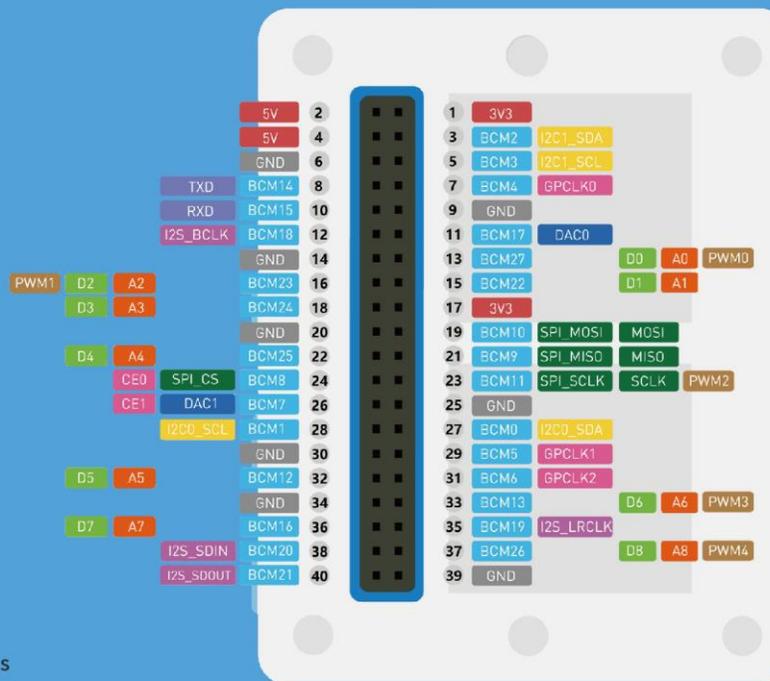


40-Pin GPIO Header

(40-Pin GPIO 接頭)

User programmable Buttons

(使用者可程式定義按鈕)

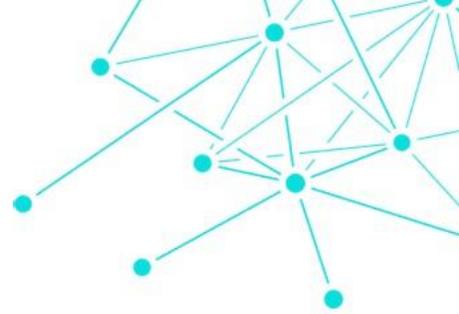


機器人王國 [www.robotkingdom.com.tw](http://www.robotkingdom.com.tw)

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EMAIL | [service@robotkingdom.com.tw](mailto:service@robotkingdom.com.tw)





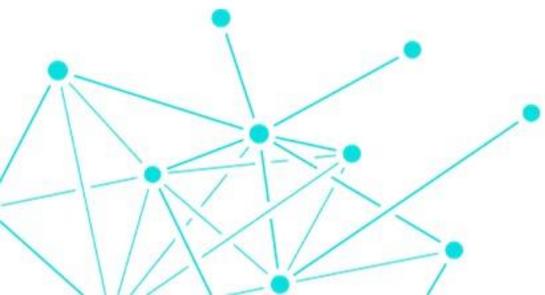
Any question is welcomed!

Or contact me:

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Facebook: 曾吉弘

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Sony Semiconductor Solutions Corporation

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\* as of March 28, 2022; several more under final reviews

