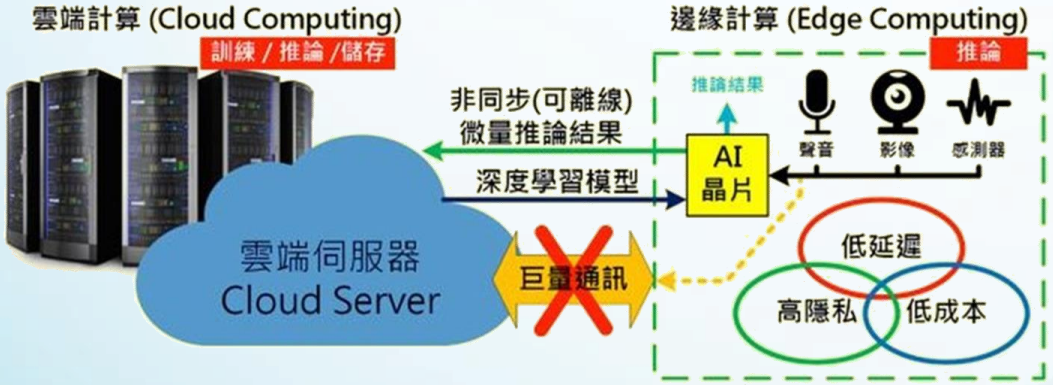
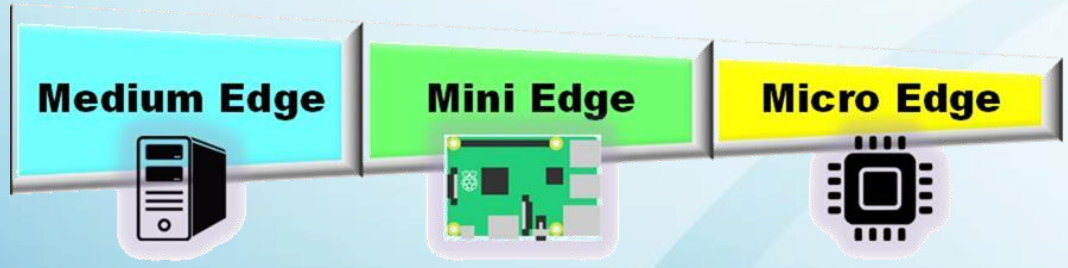
OmniXRI's Edge AI & TinyML 小學堂





【第14講】
實作案例 – 異常偵測

歐尼克斯實境互動工作室 (OmniXRI Studio)
許哲豪 (Jack Hsu)

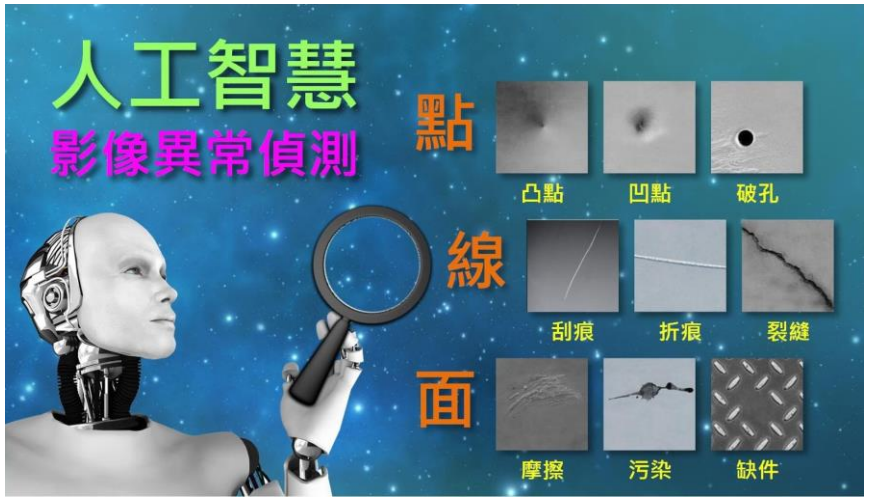
簡報大綱

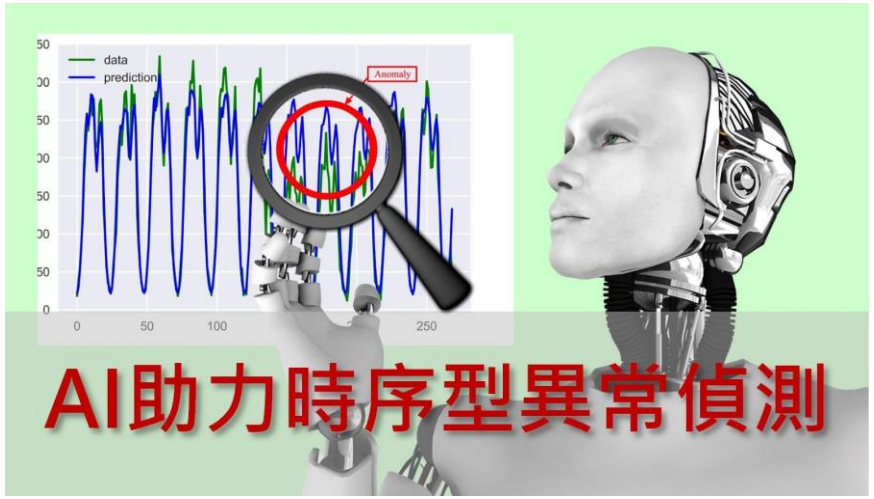
- 14.1. 異常偵測技術簡介
- 14.2. 異常偵測開源資源
- 14.3. 常見MCU AI視覺模組
- 14.4. 異常影像偵測案例

本課程完全免費，請勿移作商業用途！
歡迎留言、訂閱、點讚、轉發，讓更多需要的朋友也能一起學習。

完整課程大綱： https://omnixri.blogspot.com/2024/02/omnixris-edge-ai-tinyml-0.html
課程直播清單： https://www.youtube.com/@omnixri1784/streams

何謂異常偵測（離群偵測）

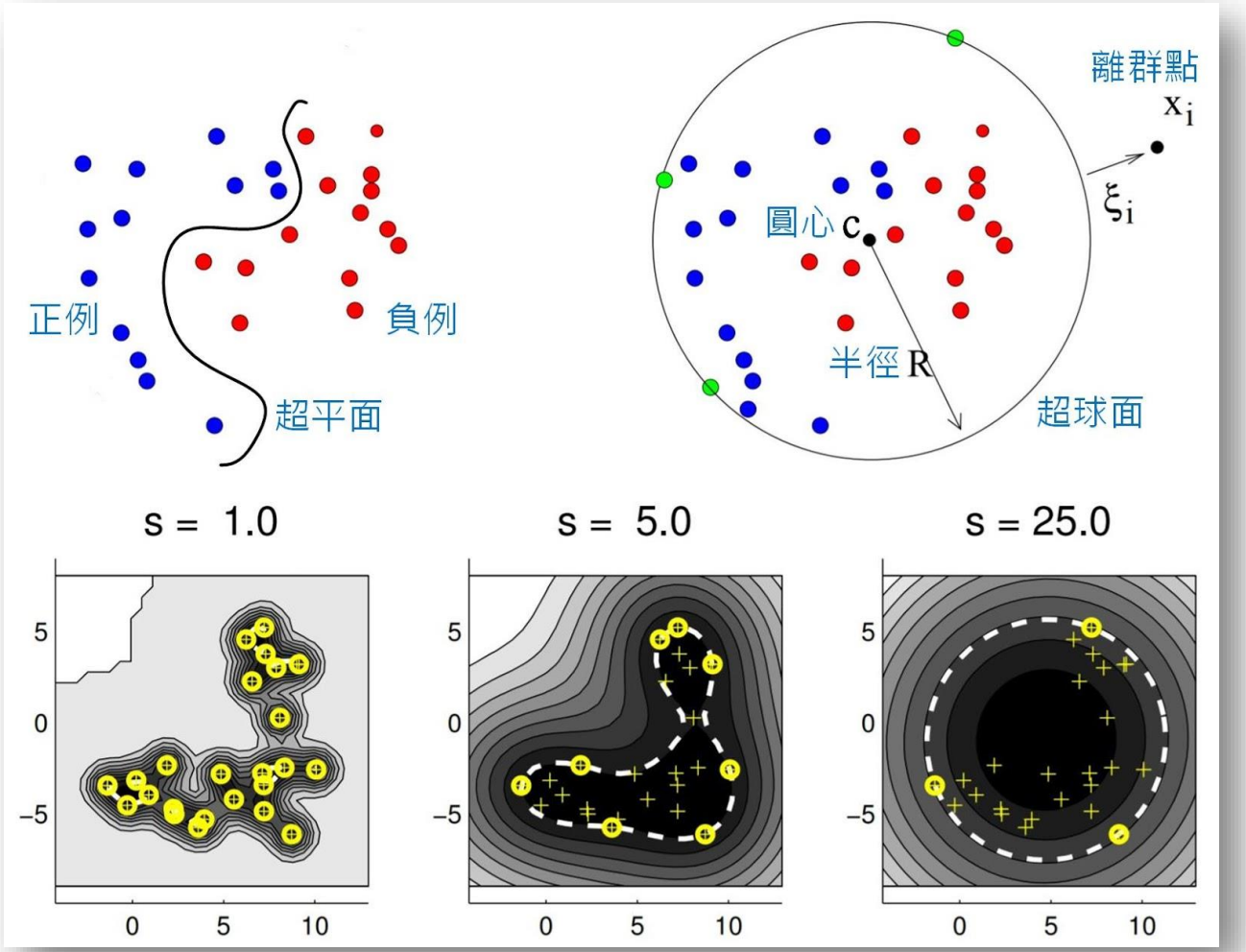




常見異常偵測作法

- 一元異常偵測
- 時序異常偵測
- 影像異常偵測（瑕疵檢測）
  - 分類、物件、分割

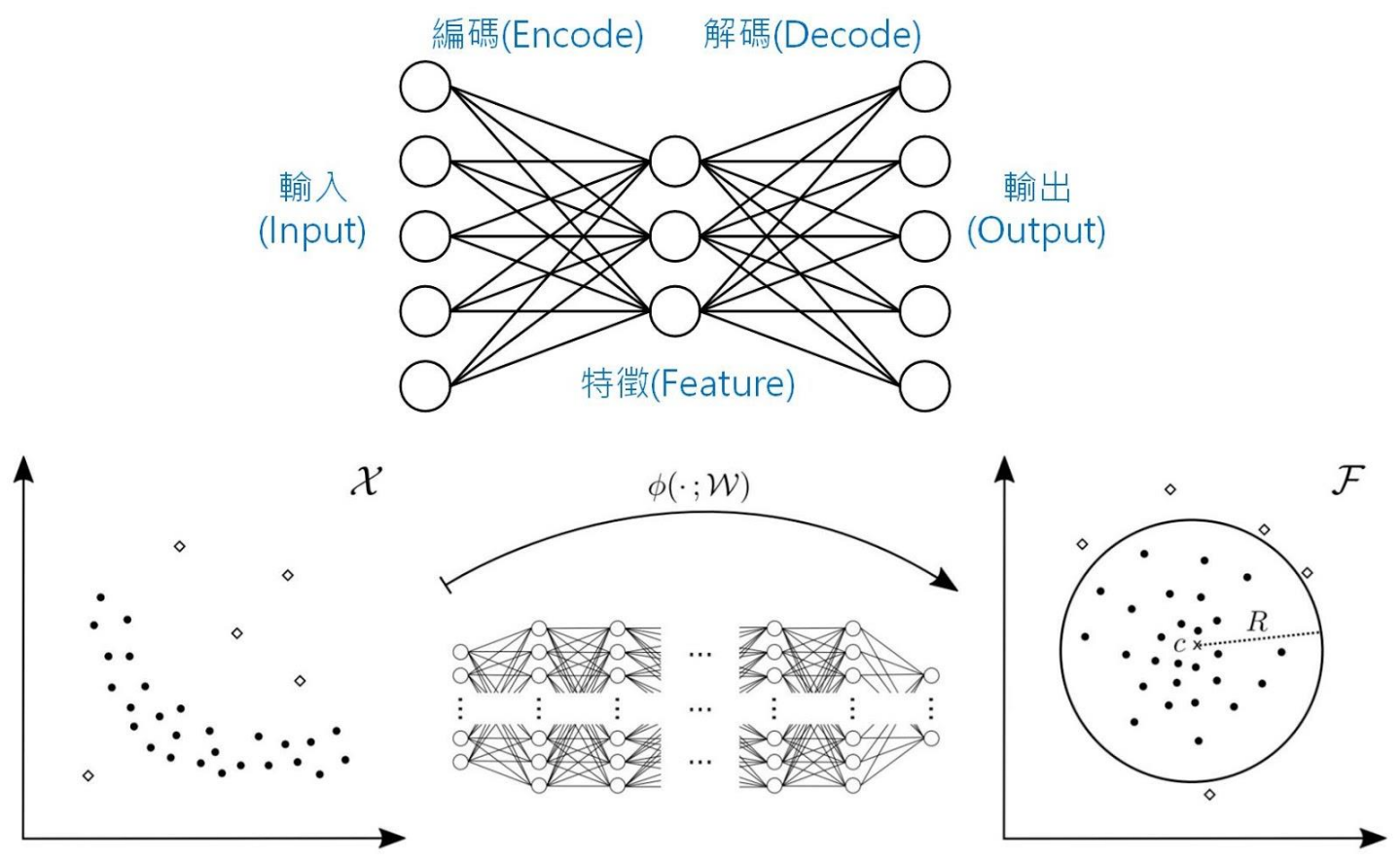
常見一元異常偵測 – 基於支持向量機式



傳統機器學習領域的支持向量機(Support Vector Machine, SVM)常用於二分類，主要概念是找出資料中一個（多維）超平面(Hyper Plane)能完美分割二組（正例、負例）數據（如左上圖）。借鑑這條思路，可延伸變成找出一個（多維）超球體的中心c及半徑r來包圍所有已知數據（只有正常一類），而這種方法稱為支持向量數據描述(Support Vector Data Description, SVDD)（如右上圖）。

資料來源：https://omnixri.blogspot.com/2020/06/ai-hubai.html

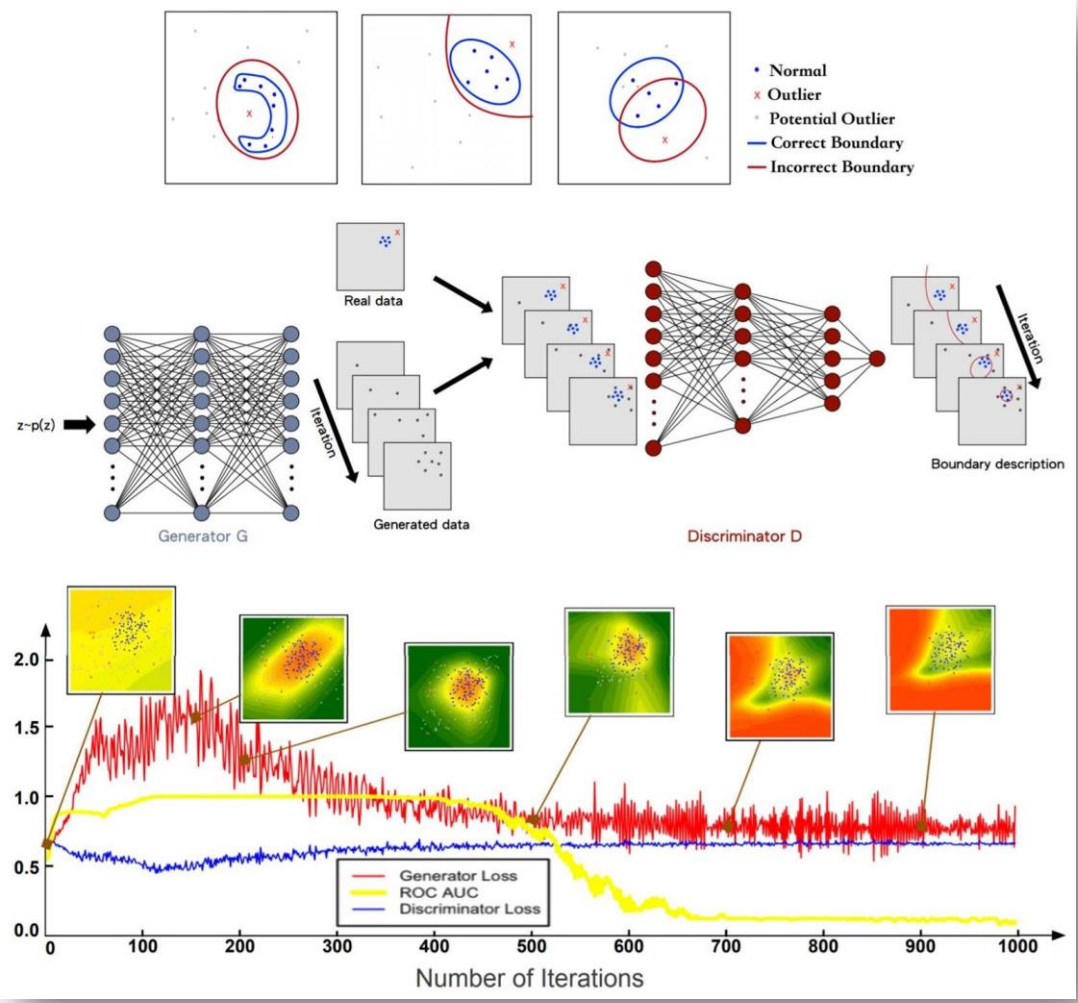
常見一元異常偵測 – 基於自動編碼器式



在深度學習中有一種非監督學習技術，稱為自動編碼器**(Auto Encoder, AE)**（如上圖所示）。當資料分佈不均勻或維度過高時，利用SVDD常會找不到合適的超球面圓心及半徑，此時若先將資料使用深度自動編碼器(Deep Auto Encoder, DAE)方式提取出特徵（或稱降維），將資料分佈轉成低維度資料，如此就較容易使用SVDD找到新的超球面圓心、半徑，正確找出離群點，如下圖所示。

資料來源：https://omnixri.blogspot.com/2020/06/ai-hubai.html

常見一元異常偵測 – 基於生成對抗網路式

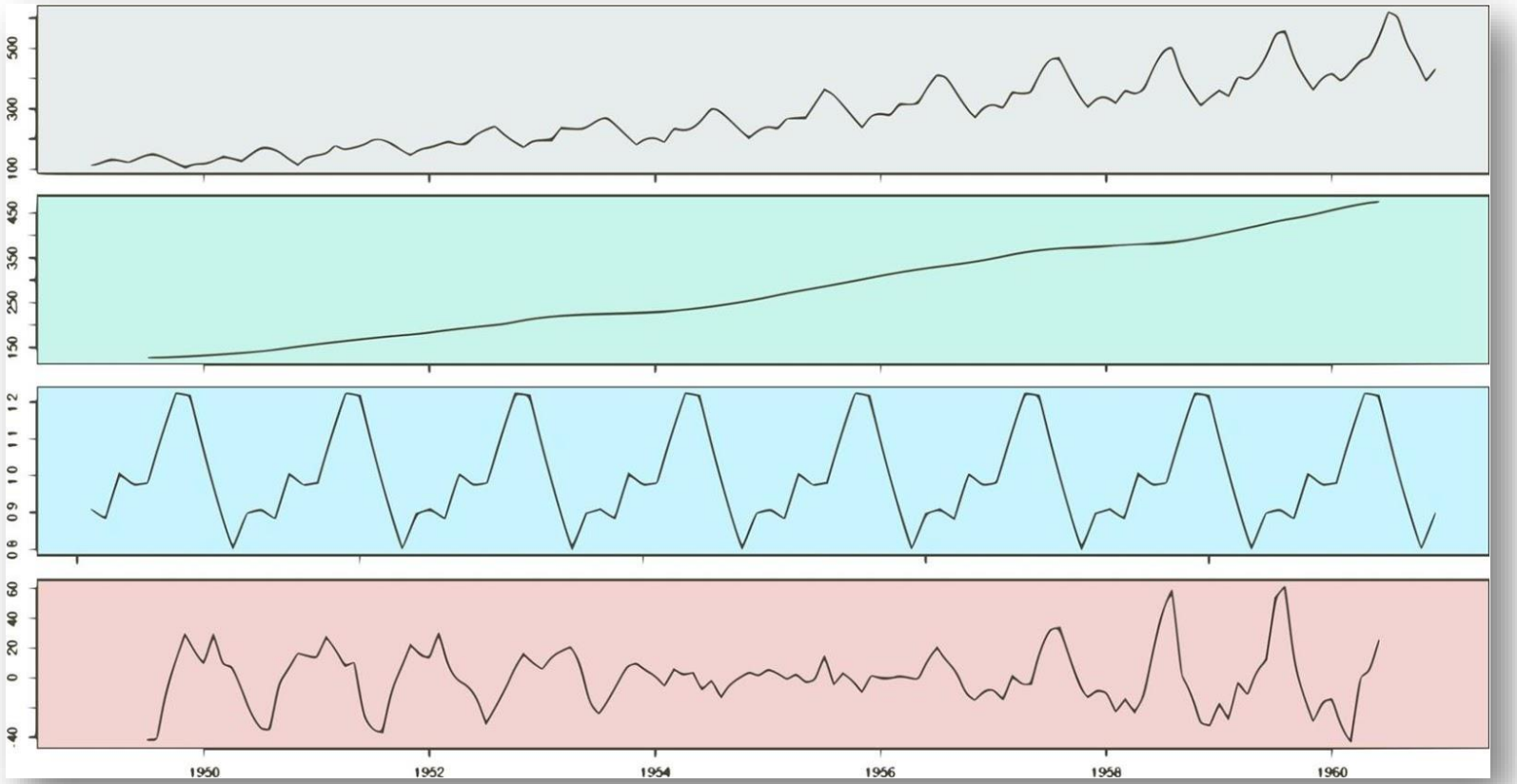


資料來源：https://omnixri.blogspot.com/2020/06/ai-hubai.html

生成對抗網路 (Generative Adversarial Network, GAN)常用來產生一些看似真實但其實不存在的資料，以滿足資料集不足或分佈不平均的問題。其主要思路有兩大元素生成網路(Generative Network)和判別網路(Discriminative Network)，生成網路負責產生虛假資料讓判別網路學習真偽，如此反覆訓練即可得到真偽難辨的資料集。這項技術可以從現有資料集中學習到資料集分佈特性，因此很適合用來協助找出非（高維）超球形分佈的資料集的邊界。

時序型資料分解

時間序列分解工具(Time Series Decomposition Tools)
STL分解法(Seasonal and Trend decomposition using Loess)



原始資料(Original)

趨勢(Trend)

季節性(Seasonality)

殘差(Residual)

資料來源：https://omnixri.blogspot.com/2020/06/ai-hub.html

常見時序異常偵測 – 傳統統計型

(a)自迴歸模型 (AR)

$$X_t = c + \sum_{i=1}^{p} \varphi_i X_{t-i} + \varepsilon_t$$

(b)向量自迴歸模型 (VAR)

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + e_t$$

(c)移動平均模型 (MA)

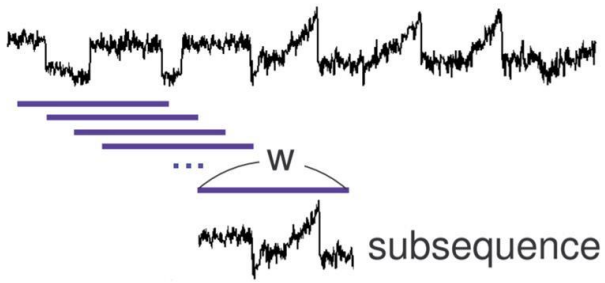
$$x_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - -\theta_q \varepsilon_{t-q}$$

(d)AR/MA混合模型 (ARIMA)

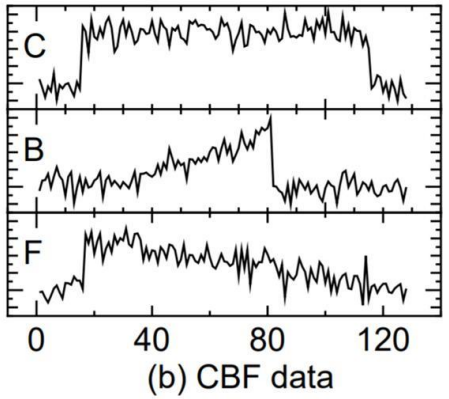
$$\left(1 - \sum_{i=1}^{p} \phi_i L^i\right) (1 - L)^d X_t = \left(1 + \sum_{i=1}^{q} \theta_i L^i\right) \varepsilon_t$$

資料來源：https://omnixri.blogspot.com/2020/06/ai-hub.html

常見時序異常偵測 – 機器學習型

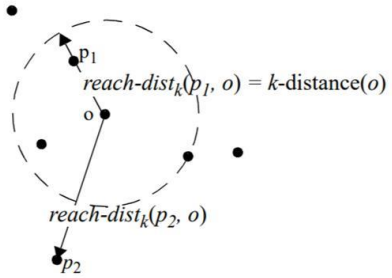


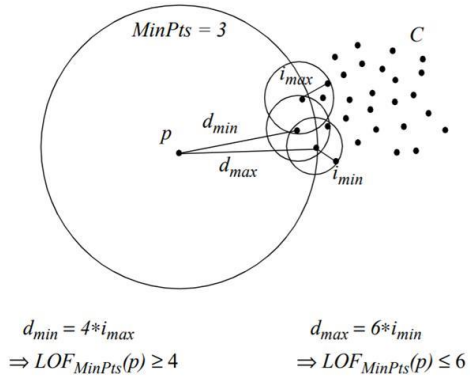
(a) sliding window technique



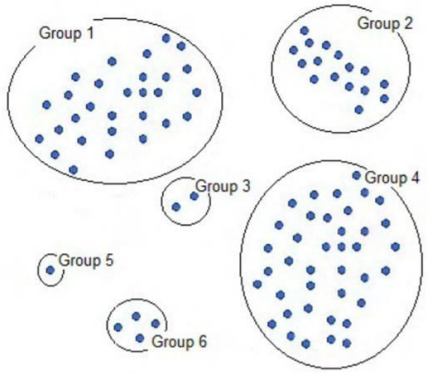
(b) CBF data

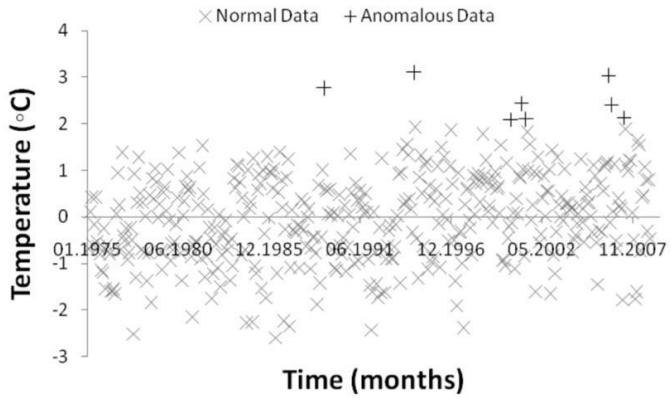
(a) K-Mean



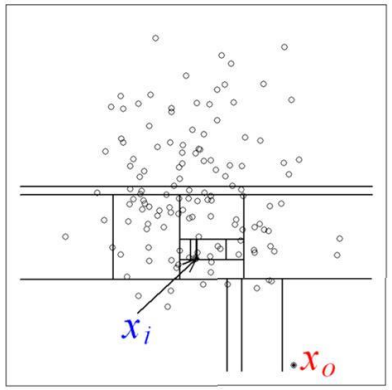


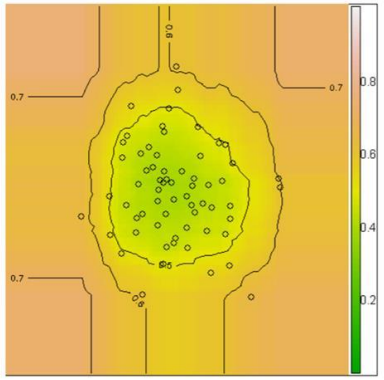
(c) LOF





(b) DBSCAN

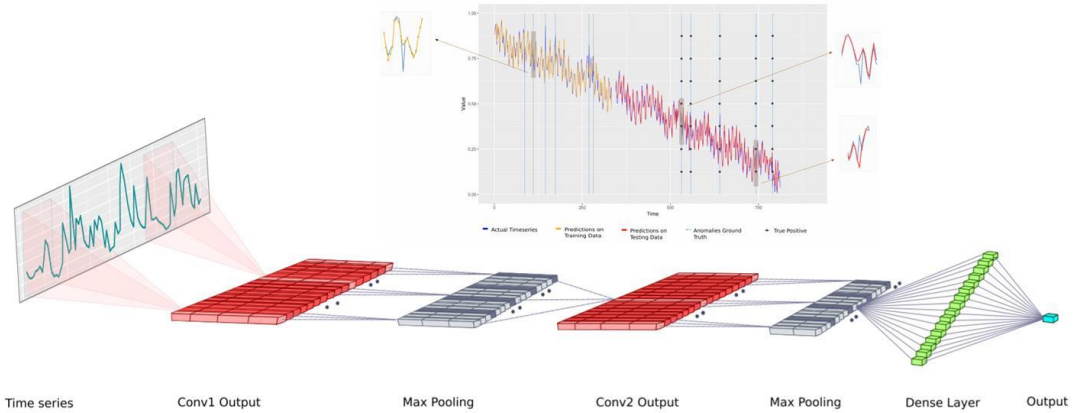




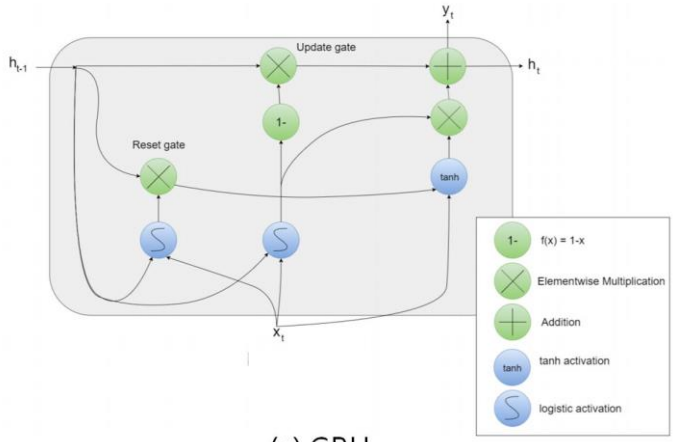
(d) IF

資料來源：https://omnixri.blogspot.com/2020/06/ai-hub.html

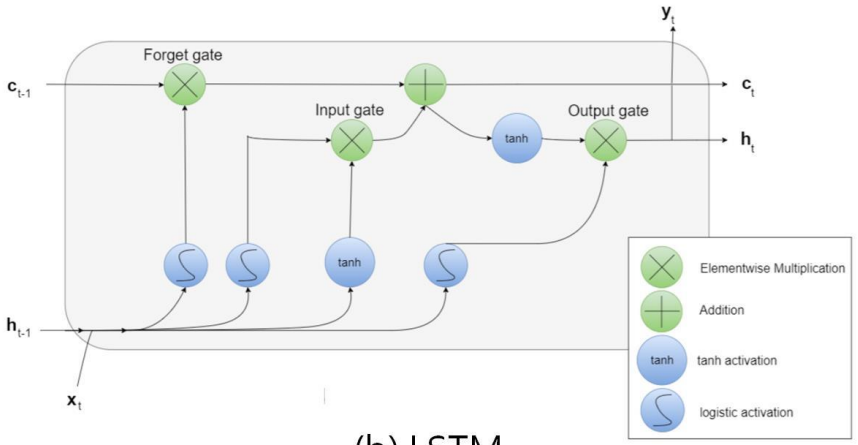
常見時序異常偵測－深度學習型



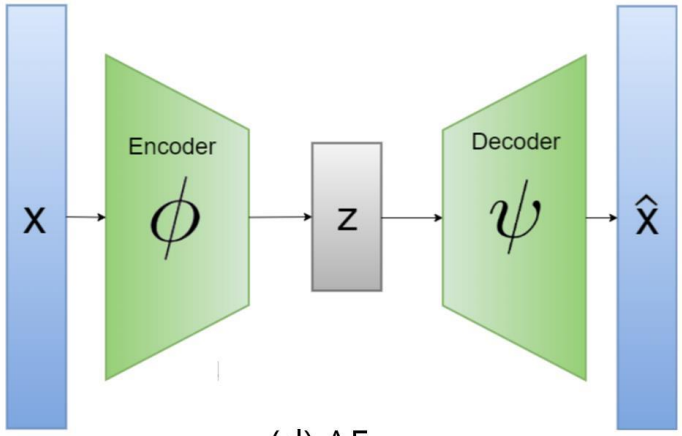
(a) CNN



(c) GRU



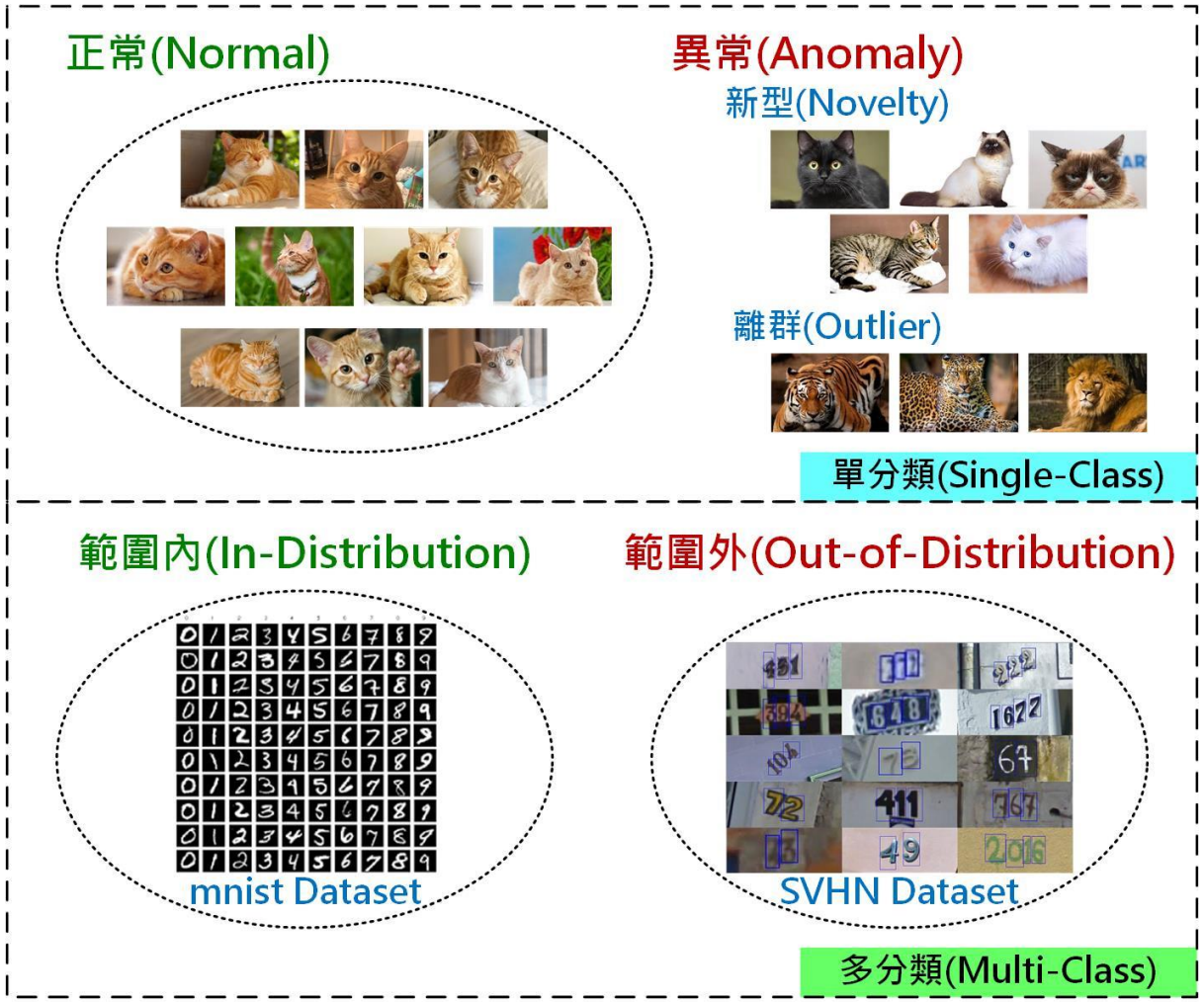
(b) LSTM

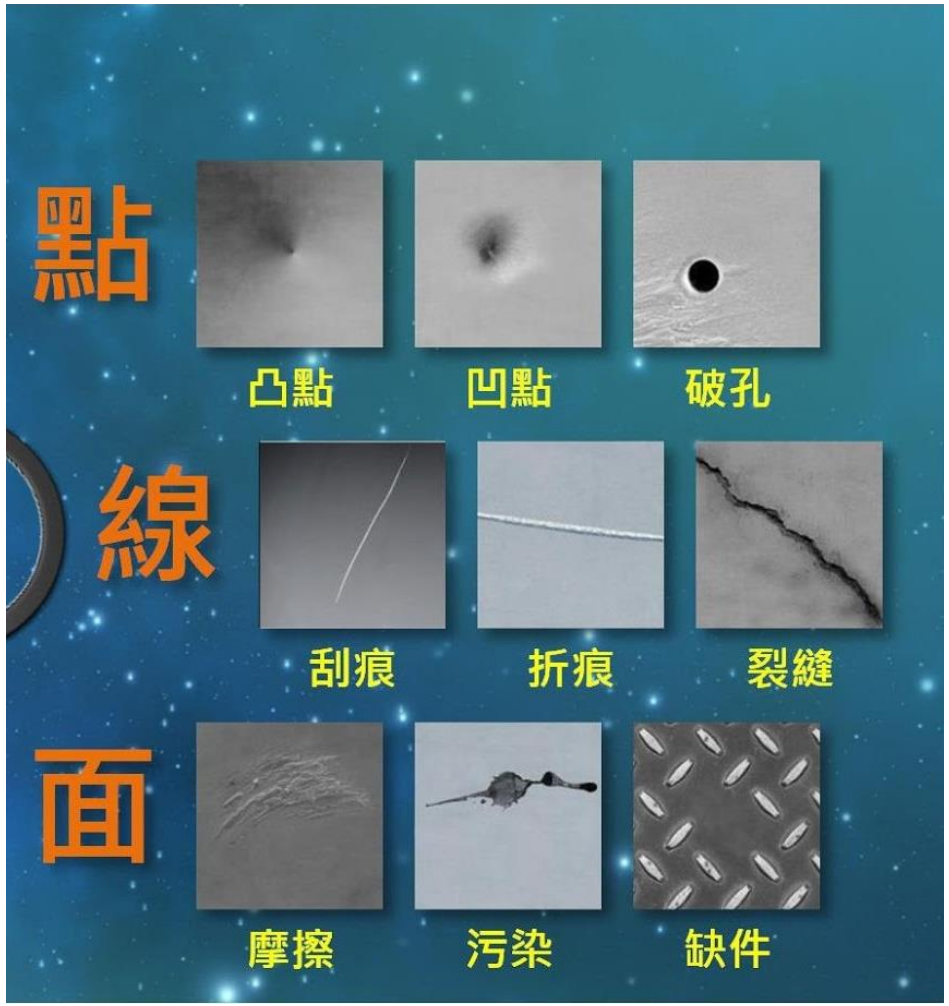


(d) AE

資料來源：https://omnixri.blogspot.com/2020/06/ai-hub.html

影像異常偵測（瑕疵檢測）

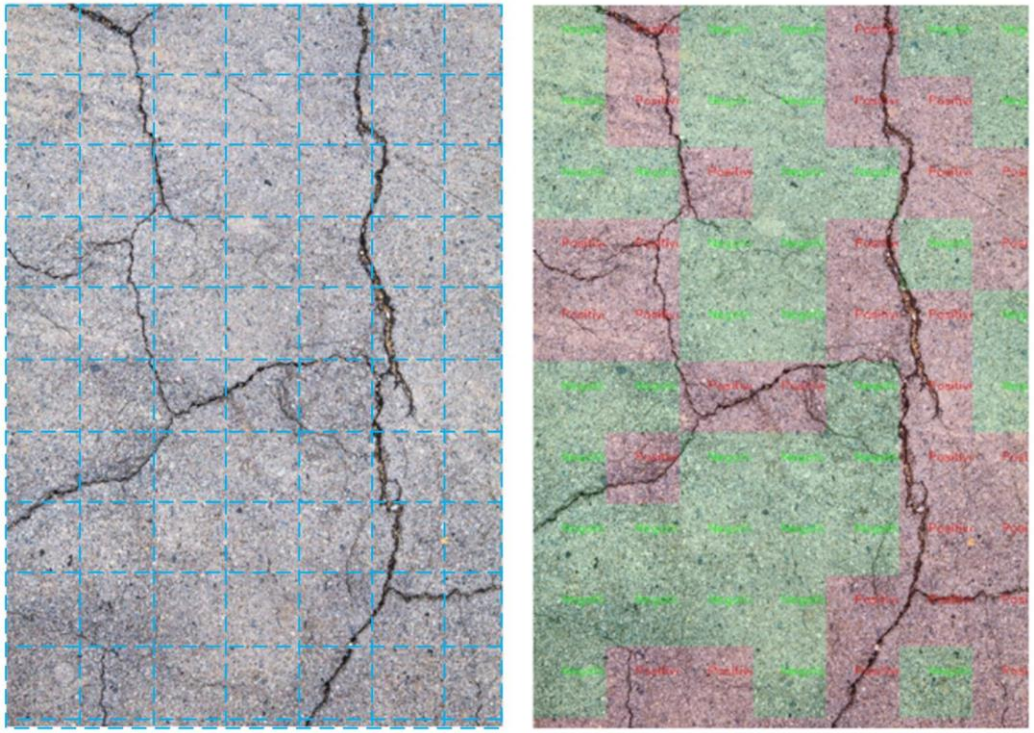




資料來源：https://omnixri.blogspot.com/2020/07/ai-hubai.html

影像異常偵測 – 深度學習式

影像分類（局部）



(a)　(b)

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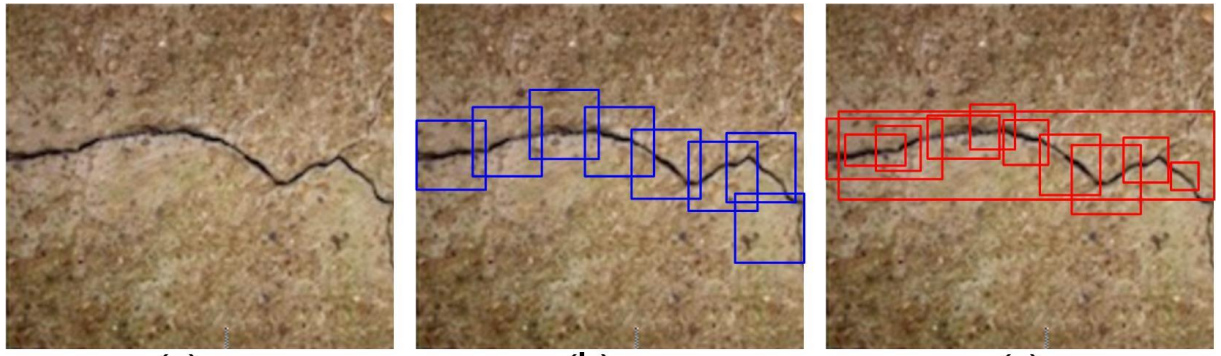
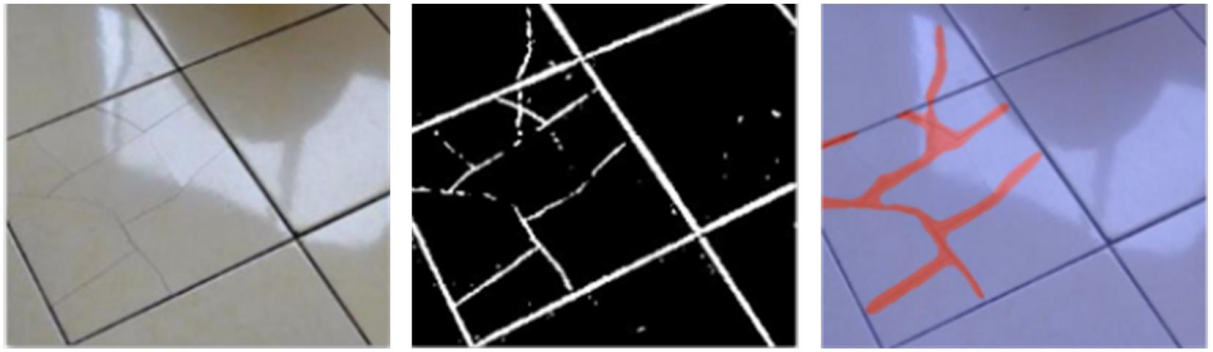
物件偵測



(a)　(b)　(c)

OmniXRI Nov. 2020整理製作

影像分割（語義分割）



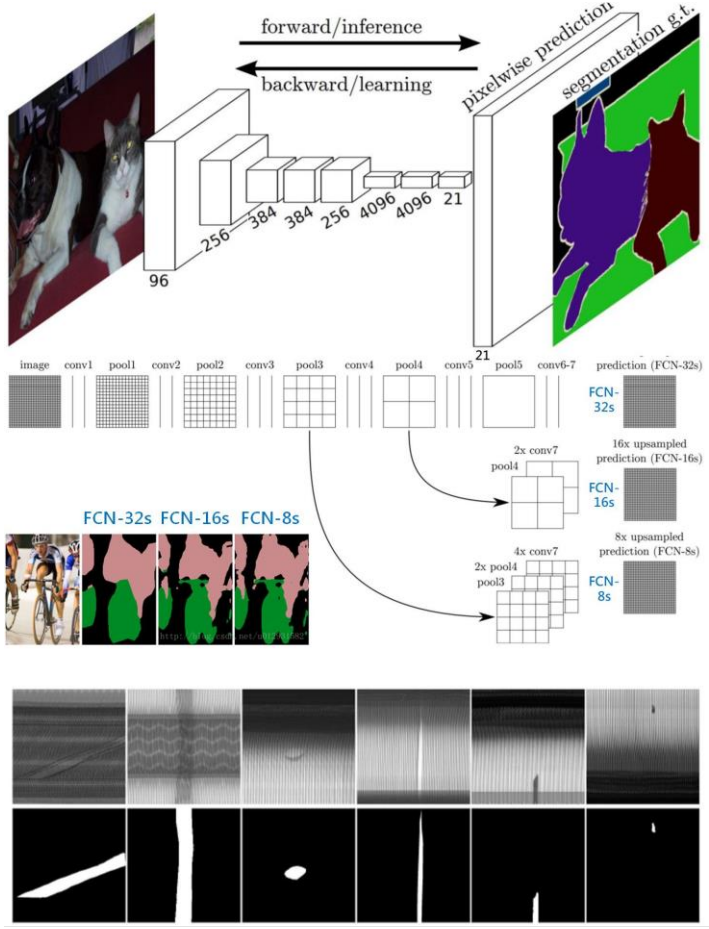
(a)　(b)　(c)

OmniXRI Nov. 2020整理製作

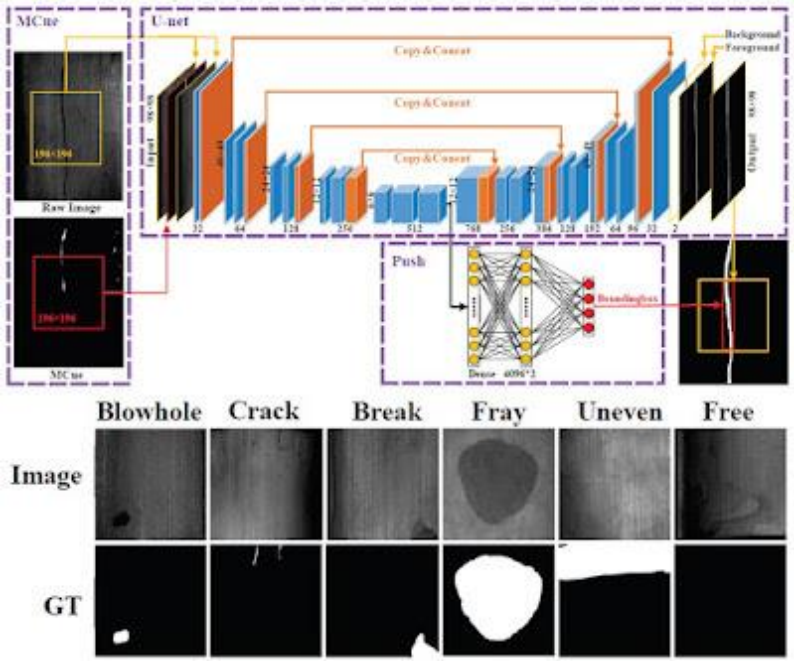
資料來源：https://omnixri.blogspot.com/2020/11/ai-hub_23.html

常見影像異常偵測 – 基於語義分割式

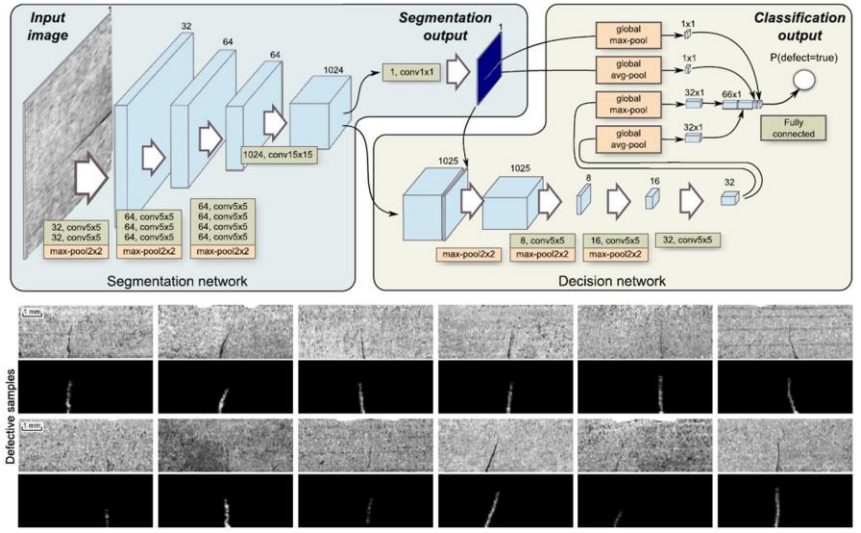
完全卷積網路



編碼/解碼網路

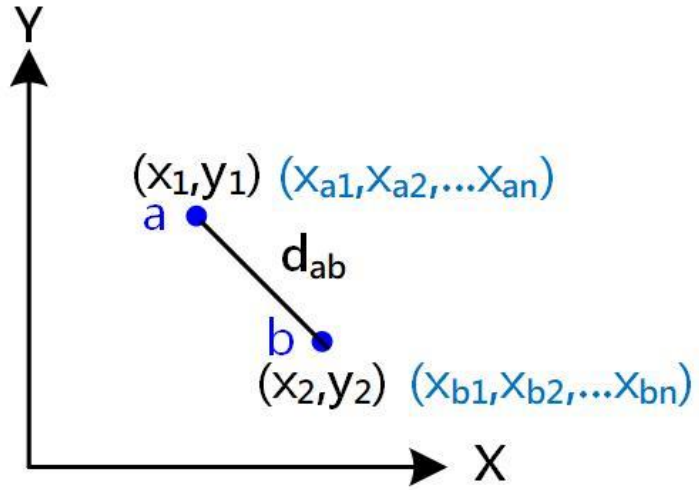


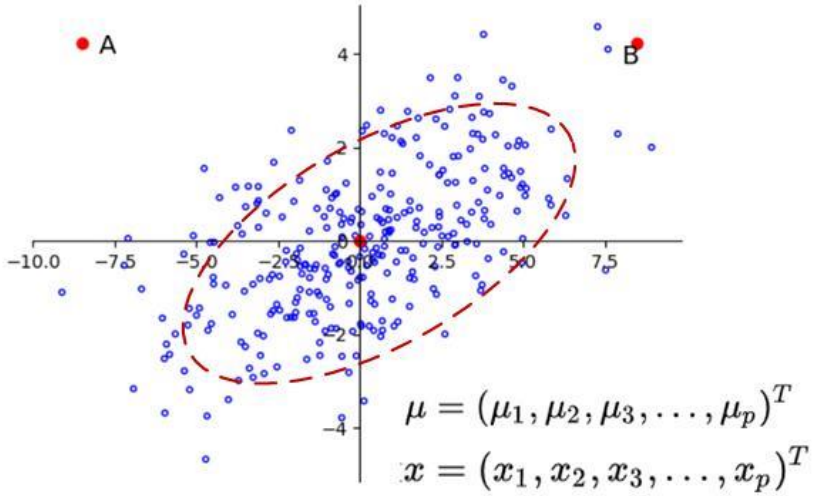
分割/決策網路

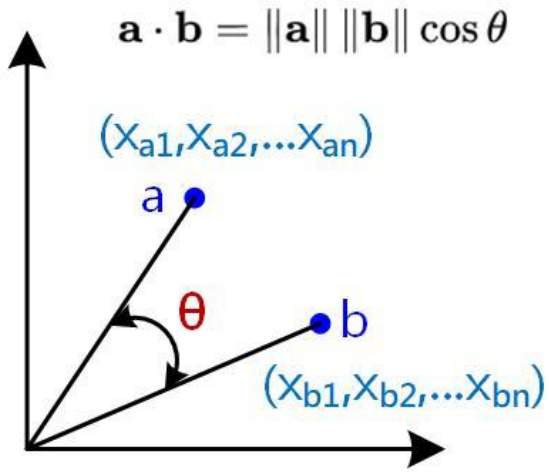


資料來源：https://omnixri.blogspot.com/2020/07/ai-hubai.html

常見資料距離量測







2維距離： $d_{ab} = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2}$

n維距離： $d_{ab} = \sqrt{\sum_{k=1}^{n}(x_{ak} - x_{bk})^2}$

單點距離： $D_M(x) = \sqrt{(x-\mu)^T \Sigma^{-1} (x-\mu)}$

兩點距離： $d(\vec{x}, \vec{y}) = \sqrt{(\vec{x}-\vec{y})^T \Sigma^{-1} (\vec{x}-\vec{y})}$

$$\cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|} = \frac{\sum_{i=1}^{n} A_i \times B_i}{\sqrt{\sum_{i=1}^{n}(A_i)^2} \times \sqrt{\sum_{i=1}^{n}(B_i)^2}}$$

歐幾里德距離
(Euclidean Distance)

馬哈拉諾比斯距離
(Mahalanobis Distance)

餘弦距離
(Cosine Distance)

資料來源：https://omnixri.blogspot.com/2020/12/ai-hub.html

MLCommons Tiny - Anomaly Detection

ML Commons

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Server	queries to the SUT according to a Poisson distribution	270,336 queries and 60 seconds	1	Benchmark specific	99%	throughput parameter supported
Offline	LoadGen sends all queries to the SUT at start	1 query and 60 seconds	At least 24,576	None	N/A	Measured throughput

Benchmarks

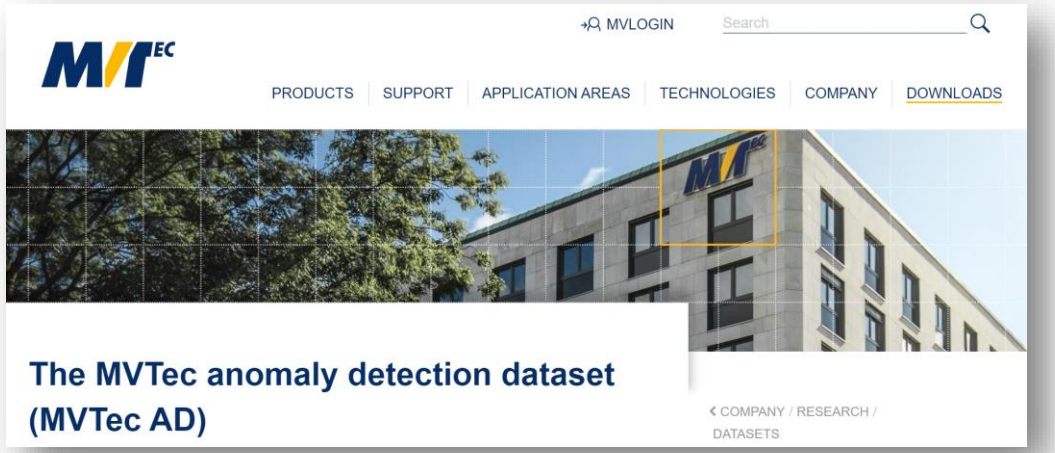
Each benchmark is defined by a Dataset and Quality Target. The following table summarizes the benchmarks in this version of the suite (the rules remain the official source of truth):

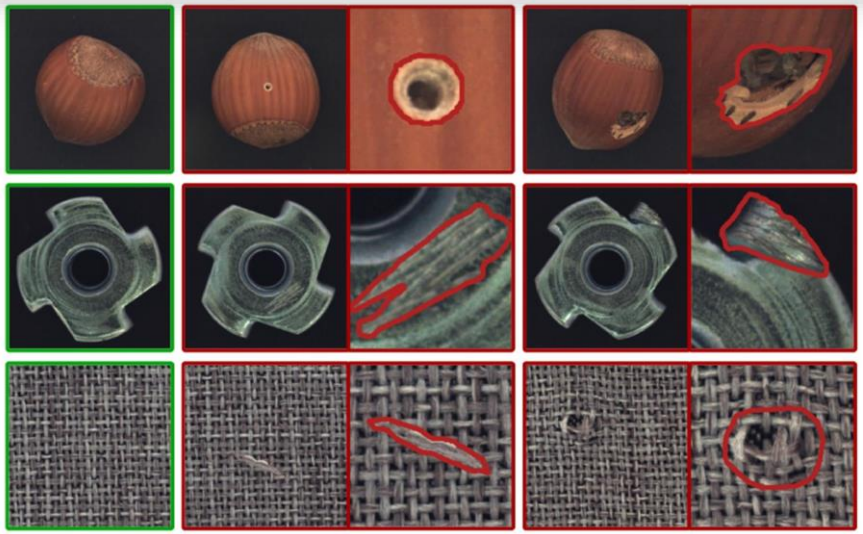
All MLPerf Tiny benchmarks are single

Task	Dataset	Model	Mode	Quality	Latest Version Available
Keyword Spotting	Google Speech Commands	DS-CNN	Single-stream, Offline	90% (Top 1)	v1.1
Visual Wake Words	Visual Wake Words Dataset	MobileNetV1 0.25x	Single-stream	80% (Top 1)	v1.1
Image classification	CIFAR10	ResNet-8	Single-stream	85% (Top 1)	v1.1
Anomaly Detection	ToyADMOS	Deep AutoEncoder	Single-stream	0.85 (AUC)	v1.1

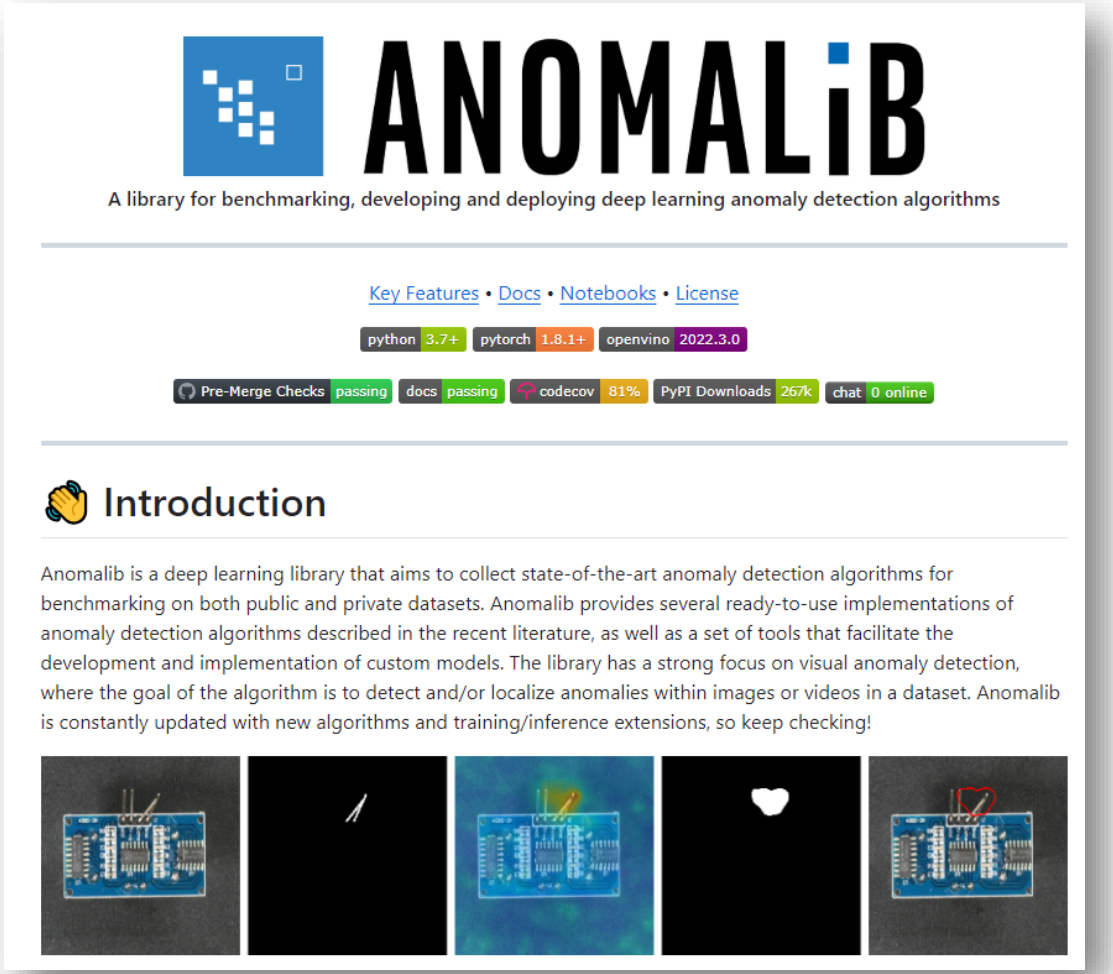
資料來源：https://mlcommons.org/benchmarks/inference-tiny/

異常偵測開源資源





https://www.mvtec.com/company/research/datasets/mvtec-ad/



https://github.com/openvinotoolkit/anomalib

Edge Impulse 異常偵測開源案例

Optimize a cloud-based Visual Anomaly Detection Model for Edge Deployments

Advanced ML workflow with available Jupyter Notebook us
computer vision, AWS SageMaker and MLFlow to benchmar
industry visual anomaly models.

Created By: Mathieu Lescaudron

Public Project Link: https://studio.edgeimpulse.com/public/376268

GitHub Repo: https://github.com/emergy-official/anomaly.parf.ai

https://docs.edgeimpulse.com/experts/featured-machine-learning-projects/fomo-ad-in-aws

Brushless DC Motor Anomaly Detection

Sample data from a BLDC motor controller and apply machine learning to receive predictive maintenance alerts.

Created By: Avi Brown

Public Project Link: https://studio.edgeimpulse.com/public/102584/latest

https://docs.edgeimpulse.com/experts/predictive-maintenance-and-fault-classification/brushless-dc-motor-anomaly-detection

Continuous Gait Monitor (Anomaly Detection) - Nordic Thingy:53

A wearable for continuous gait analysis, aiming to detect gait abnorma
potential medical conditions.

Created By: Samuel Alexander

Public Project Link: https://studio.edgeimpulse.com/public/366723/live

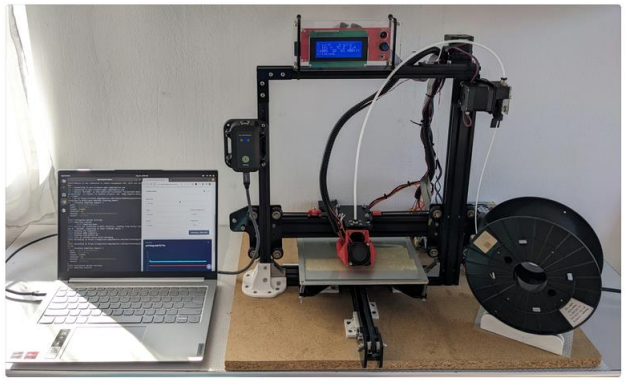
https://docs.edgeimpulse.com/experts/accelerometer-and-activity-projects/continuous-gait-monitor-nordic-thingy53

BrickML Demo Project - 3D Printer Anomaly Detection

Use machine learning classification to monitor the operation of a 3D printer and look for anomalies in movement, with the Reloc / Edge Impulse BrickML device.

Created By: Attila Tokes

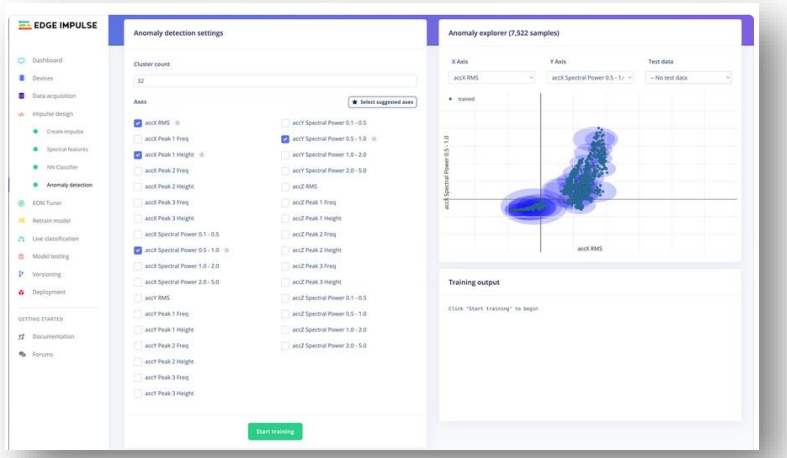
Public Project Link: https://studio.edgeimpulse.com/public/283049/latest



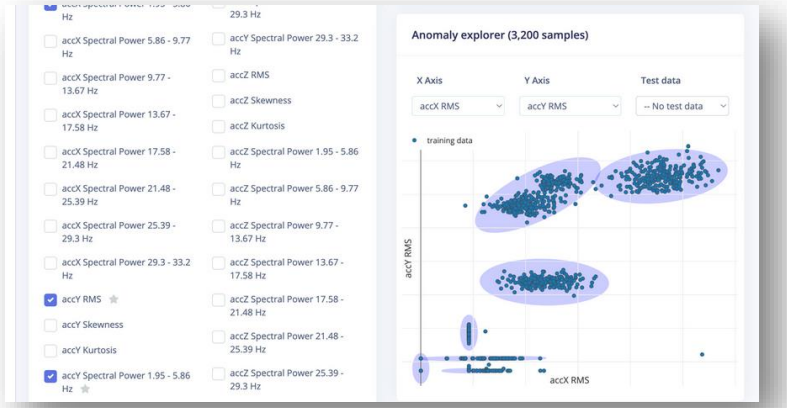
https://docs.edgeimpulse.com/experts/predictive-maintenance-and-fault-classification/brickml-3d-printer-anomaly-detection

Edge Impulse Document – Experts Network Projects – Predictive Maintenance & Fault Classification

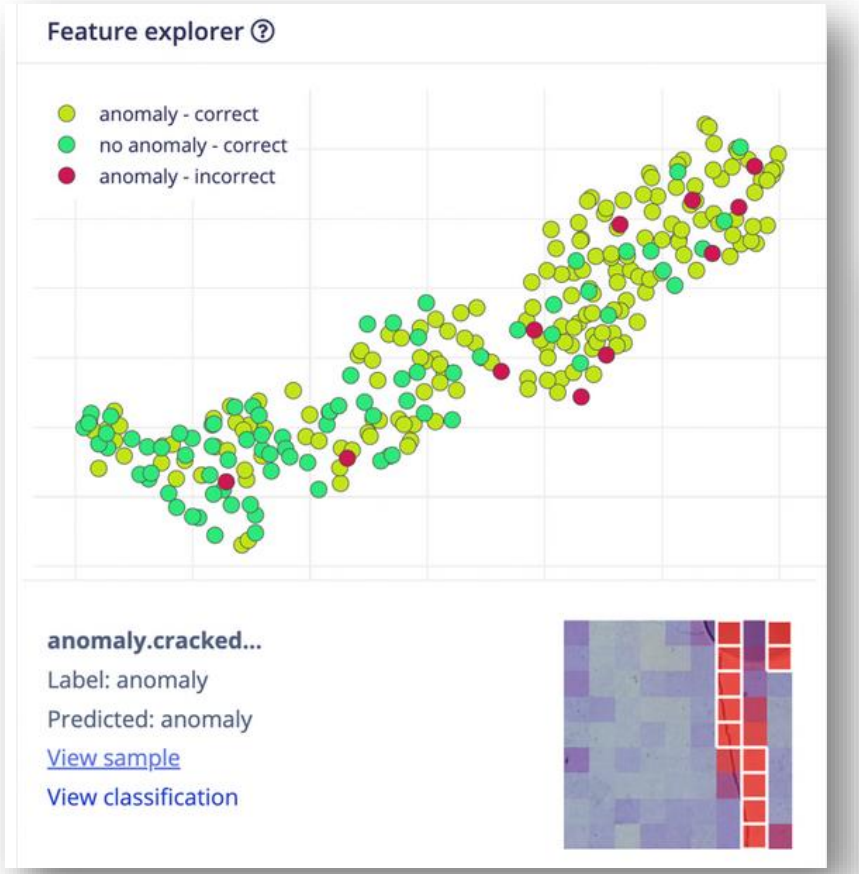
Edge Impulse Anomaly Detection Block



Anomaly Detection (K-means)



Anomaly Detection (GMM)



Visal Anomaly Detection (FOMO-AD with GMM)

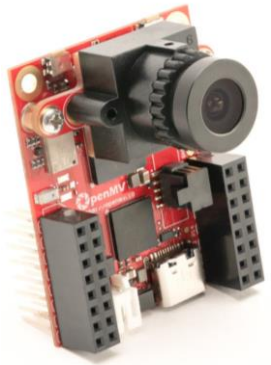
資料來源：https://docs.edgeimpulse.com/docs/edge-impulse-studio/learning-blocks

常見MCU AI視覺模組（2022）

資料來源：https://omnixri.blogspot.com/2022/12/tinymlmcu.html

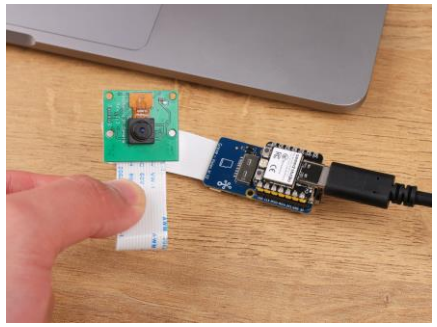
常見MCU AI視覺模組（2024）

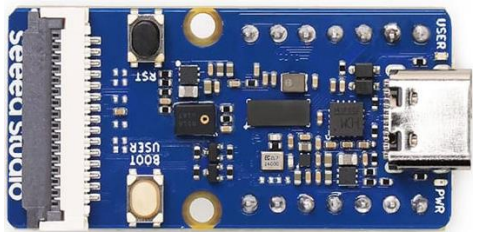
Telit & ALIF Vision AppKit
(ALIF E3, Arm Cortex-M55 *2 + Ethos-U55 *2)



OpenMV Cam RT1062
(NXP i.MX RT1062, Arm Cortex-M7)

STM32N6
(Arm Cortex ?? + NPU ??)





Seeed Grove Vision AI Module v2
(Himax HX6538, Arm Cortex-M55 *2 + Ethos-U55)

Seeed Xiao ESP32 Sense
(Xtensa DSP LX7 *2)

Renesas EK-RA8D1
(Arm Cortex-M85)

常見MCU AI視覺模組(2024) 性能比較

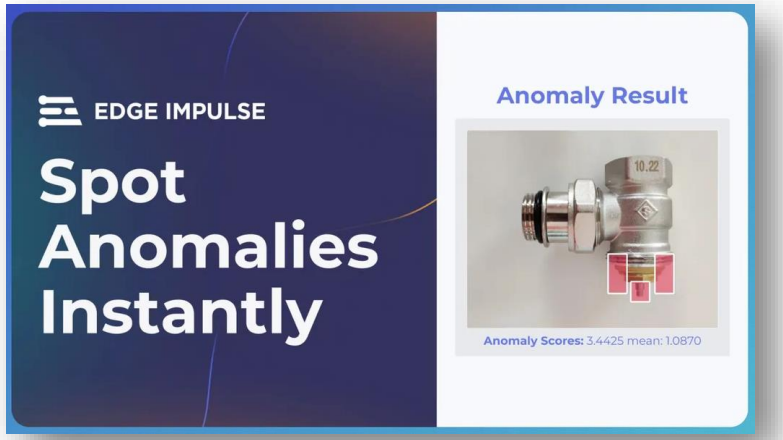
資料來源：https://www.hackster.io/limengdu0117/2024-mcu-ai-vision-boards-performance-comparison-998505

14.4.
異常影像偵測案例

- Edge Impulse FOMO-AD 水五金異常偵測案例
- Seeed Vision AI Module V2 + Seeed SenseCraft 應用例

Edge Impulse FOMO-AD 範例資源

水五金異常偵測案例



FOMO + GMM
= FOMO-AD

學習模組─Visual anomaly detection (FOMO-AD)：

https://docs.edgeimpulse.com/docs/edge-impulse-studio/learning-blocks/visual-anomaly-detection

說明文章：

https://www.edgeimpulse.com/blog/announcing-visual-anomaly-detection/

公開範例：

https://studio.edgeimpulse.com/public/377568/live

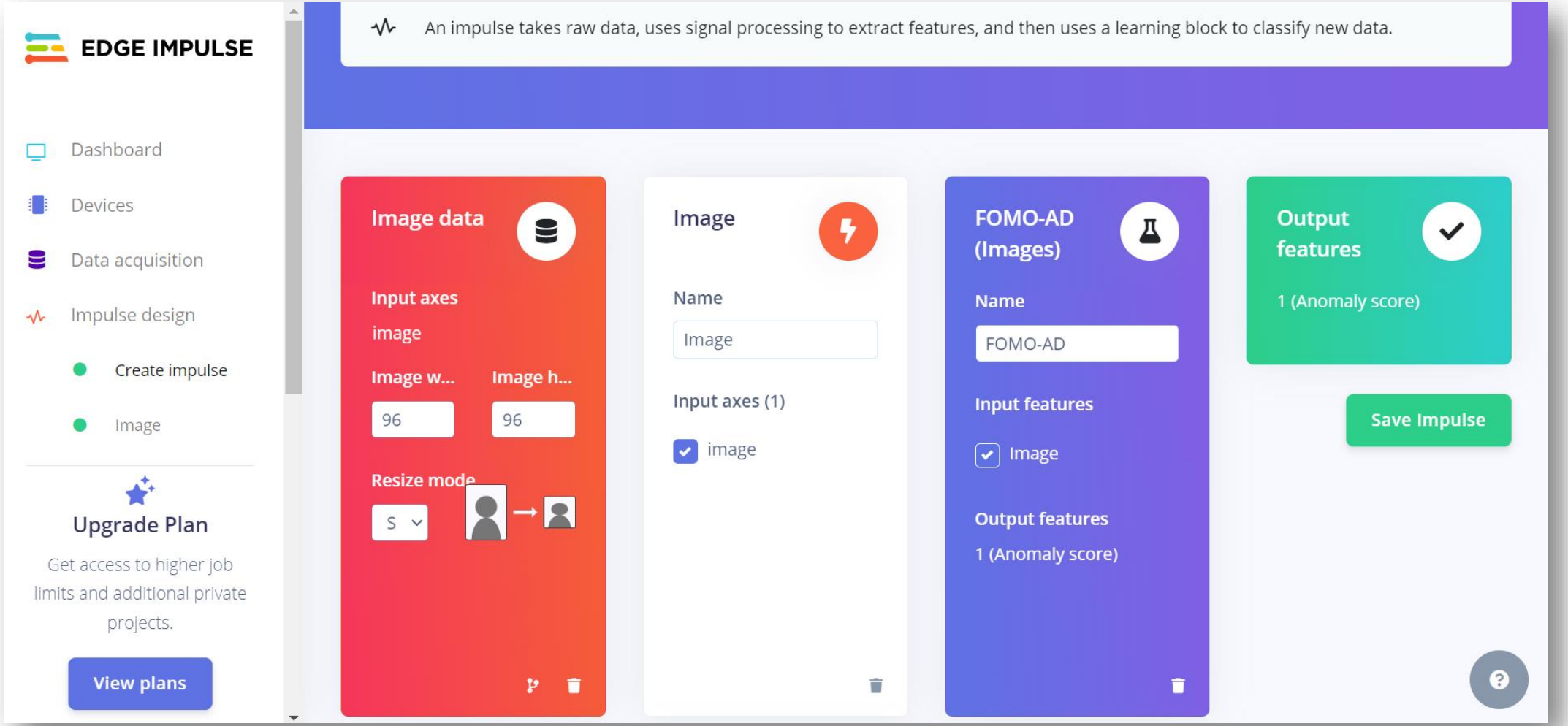
將案例複製到個人帳號中再執行

Edge Impulse FOMO-AD – Data Acquisition

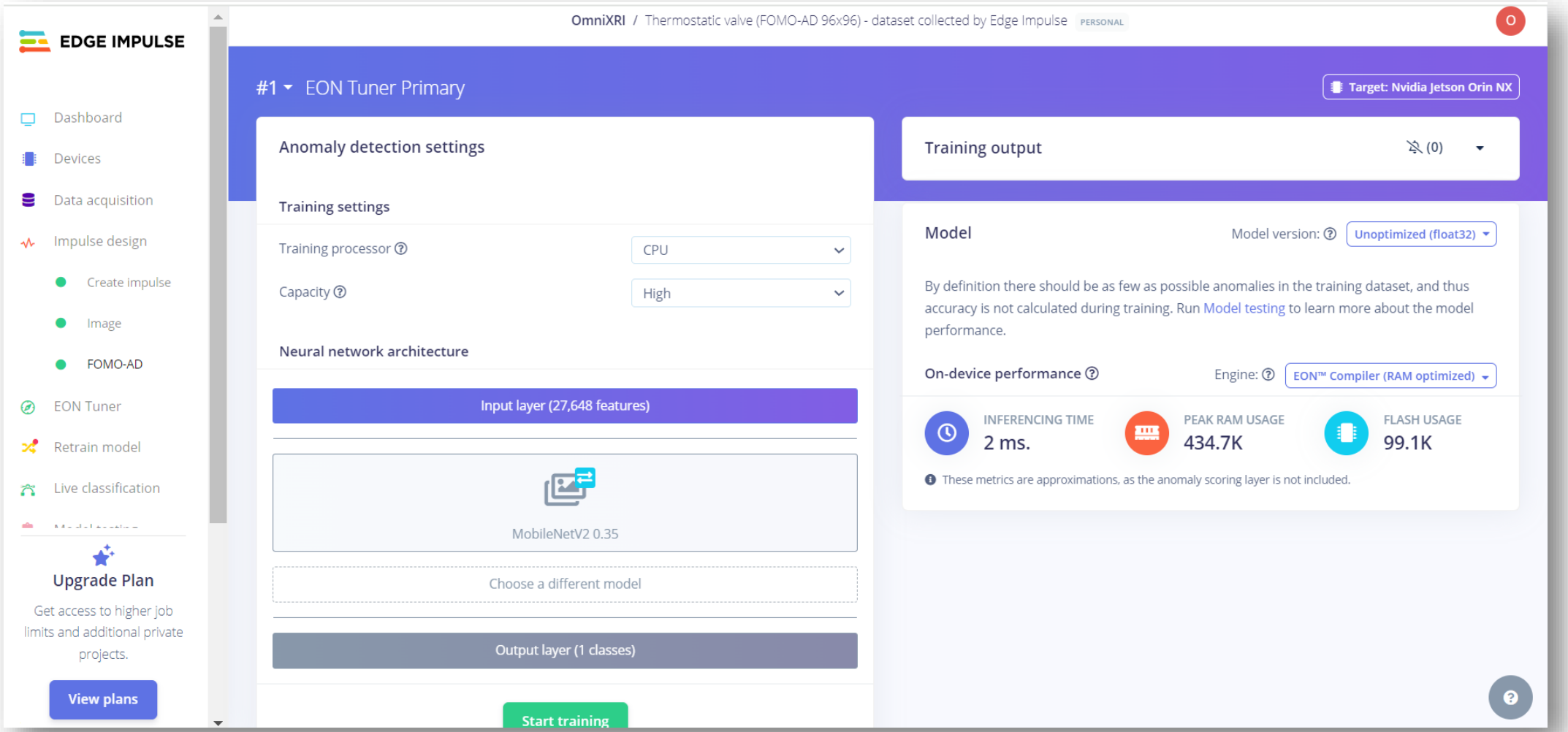
no anomaly

anomaly

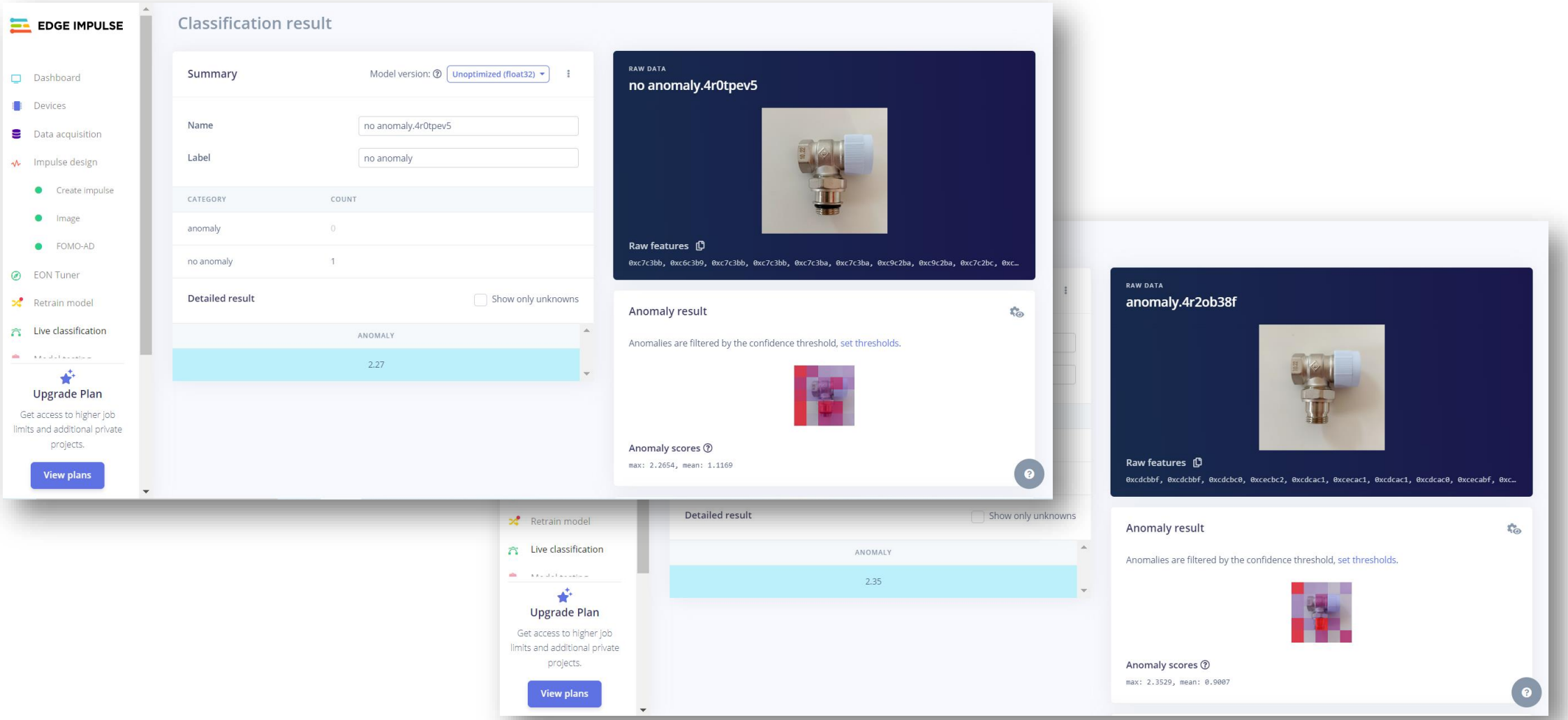
Edge Impulse FOMO-AD – Impulse Design



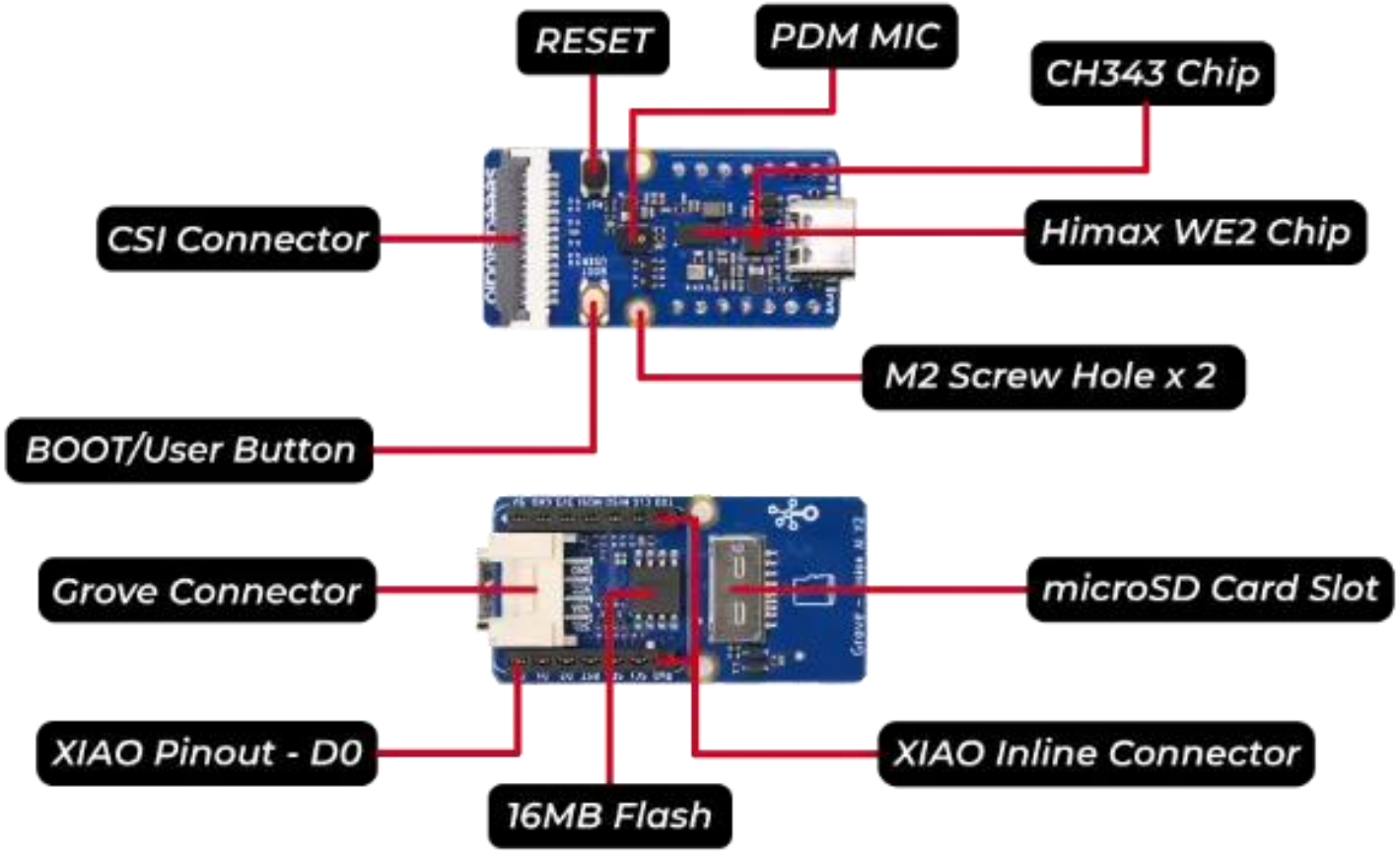
Edge Impulse FOMO-AD – Model Training



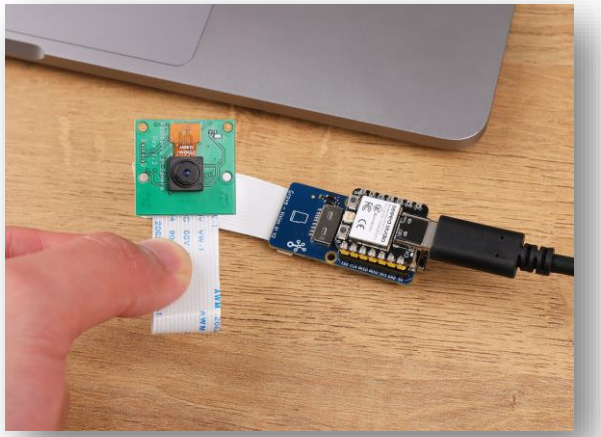
Edge Impulse FOMO-AD - Live Test



實驗器材 – Seeed Vision AI Module V2



資料來源：https://wiki.seeedstudio.com/grove_vision_ai_v2/
https://www.himax.com.tw/products/wiseeye-ai-sensing/wiseeye2-ai-processor/



Himax（奇景）WiseEye2
(Arm Cortex-M55 *2 @400MHz / 160MHz + Micro NPU Ethos-U55 400MHz)
SRAM: 2432KB
Boot ROM: 64KB
Sensor: PDM
SD Card Slot
Camera: **Pi OV5647-62** (Option)

安裝序列埠驅動程式

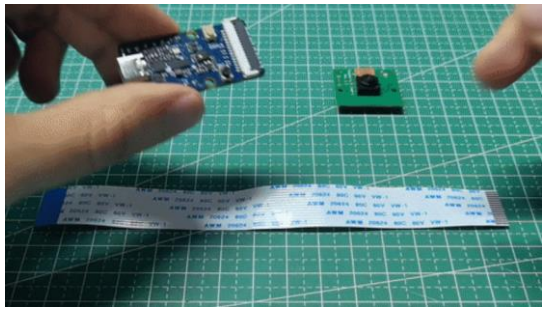
Driver

If you find that the Grove Vision AI V2 is not recognised after connecting it to your computer. Then you may need to install the CH343 driver on your computer. Here are some links to download and install the CH343 driver.

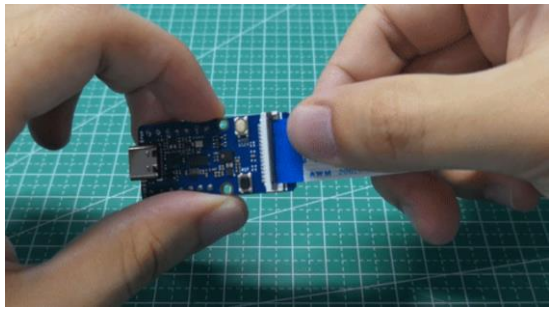
- Windows Vendor VCP Driver One-Click Installer: CH343SER.EXE
- Windows Vendor VCP Driver: CH343SER.ZIP
- Windows CDC driver one-click installer: CH343CDC.EXE
- Windows CDC driver: CH343CDC.ZIP
- macOS Vendor VCP Driver: CH34xSER_MAC.ZIP

選擇對應作業系統驅動程式並安裝

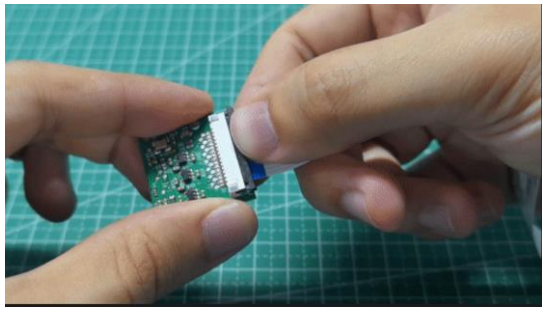
檢查裝置管理員連接埠（COM）



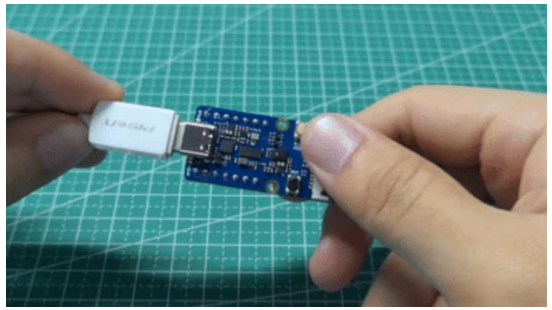
開發板、攝影機、軟排線



軟排插入開發板



軟排插入攝影機

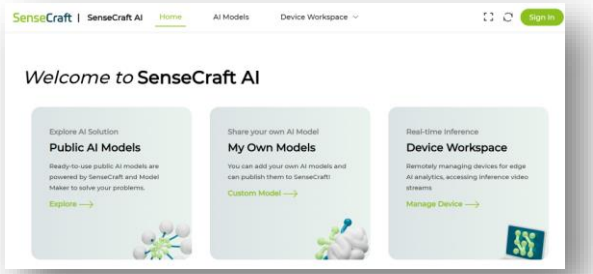


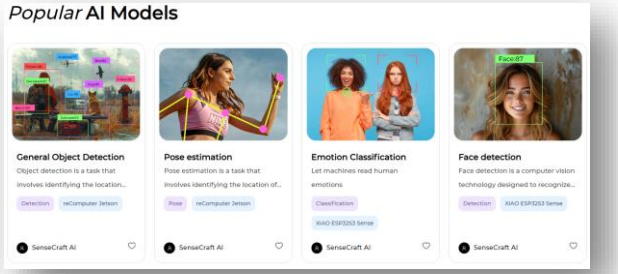
USB插入開發板後
USB另一端插入電腦

資料來源：https://wiki.seeedstudio.com/grove_vision_ai_v2/

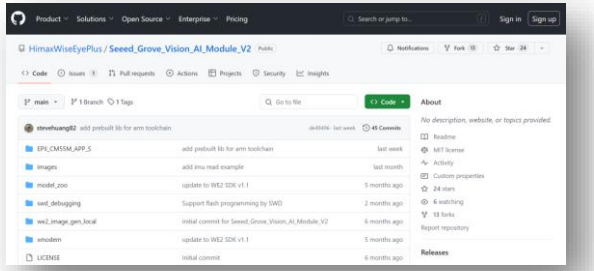
Seeed Vision AI Module V2 開發資源

矽遞科技 WIKI 文檔平台 ─ Grove – Vision AI V2 模塊人工智能
(英文版) https://wiki.seeedstudio.com/grove_vision_ai_v2/
(簡中版) https://wiki.seeedstudio.com/cn/grove_vision_ai_v2/



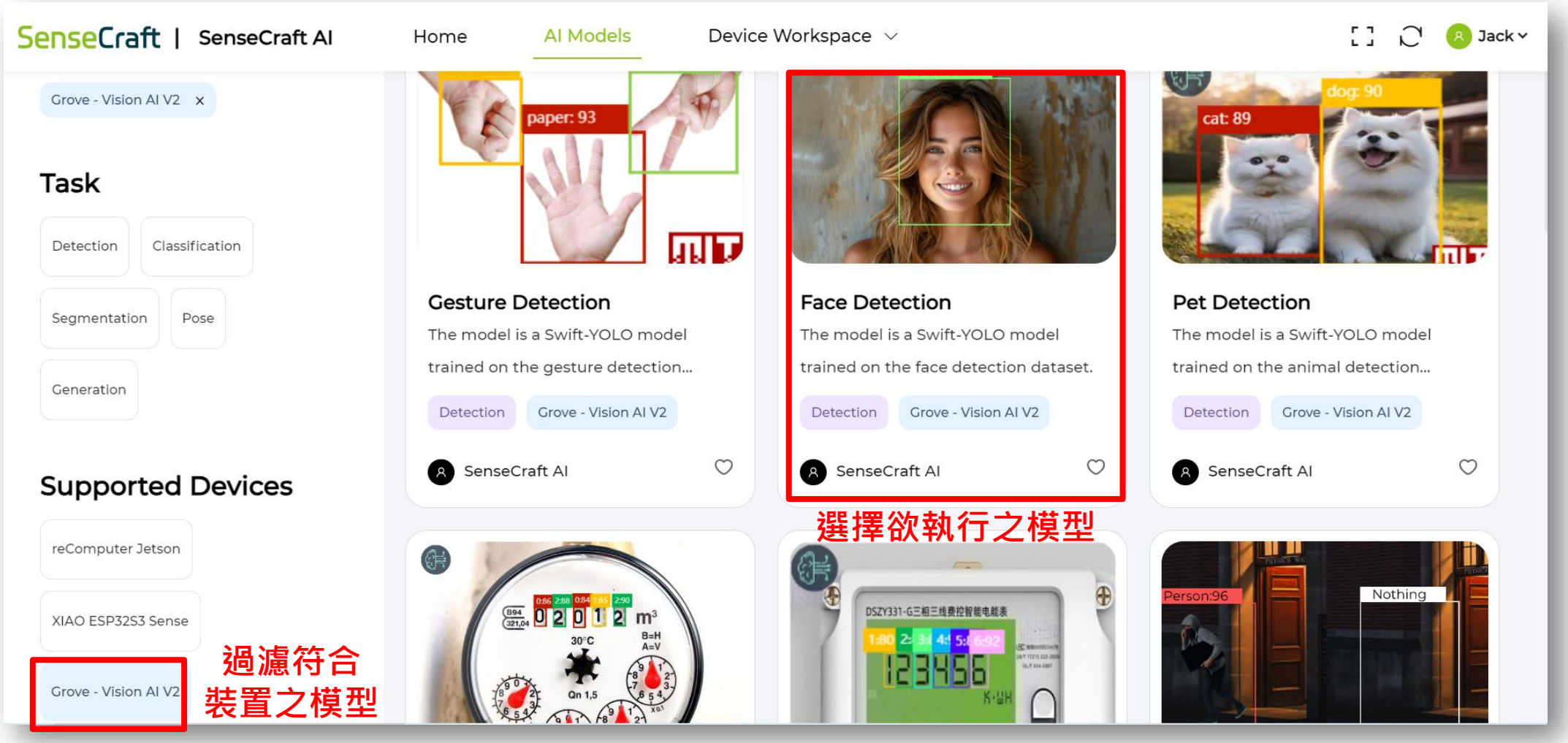


Seeed - SenseCraft AI
https://sensecraft.seeed.cc/ai/#/home



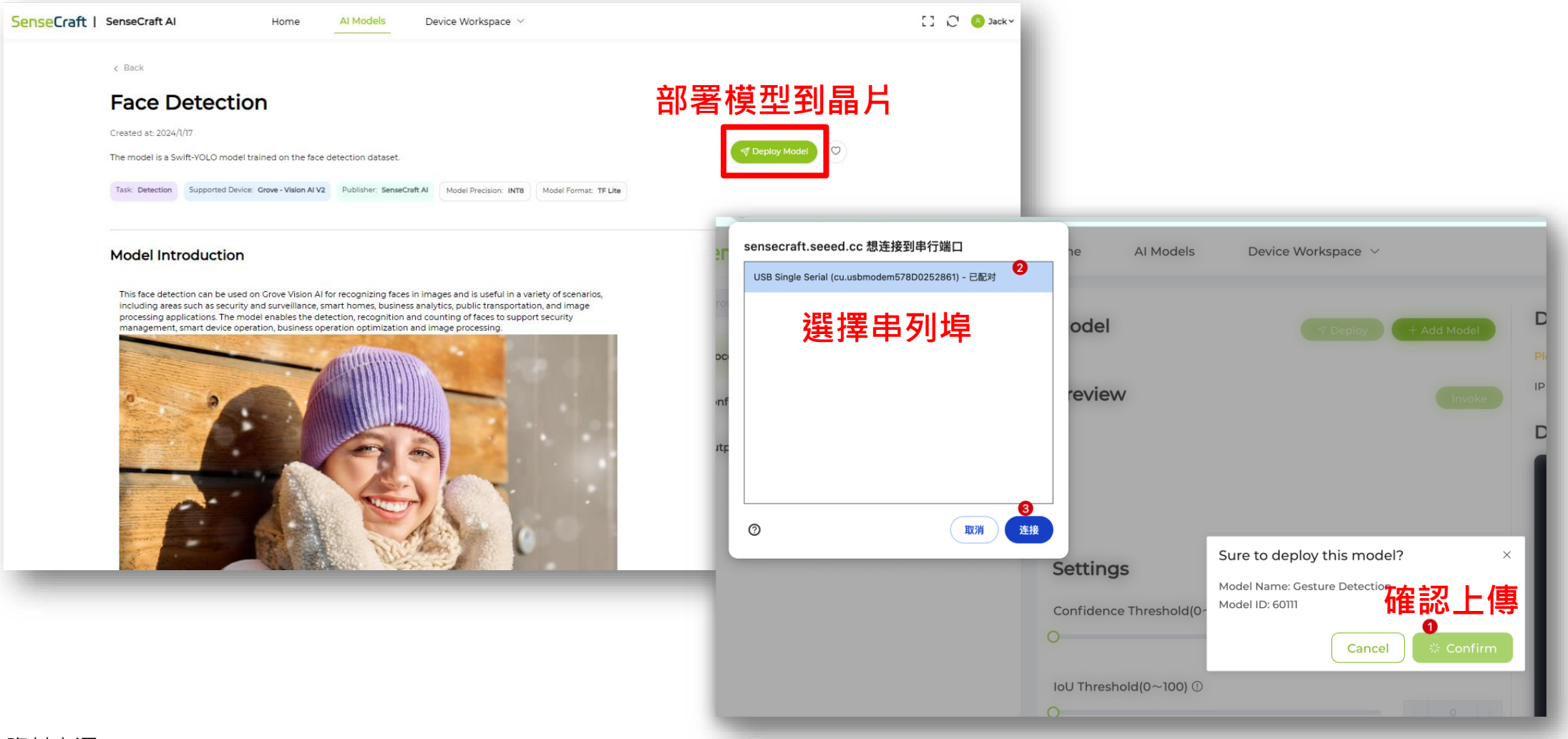
Github, Himax WiseEye Plus – Seeed_Grove_Vision_AI_Module_V2
https://github.com/HimaxWiseEyePlus/Seeed_Grove_Vision_AI_Module_V2

Seeed SenseCraft AI 選擇裝置及模型



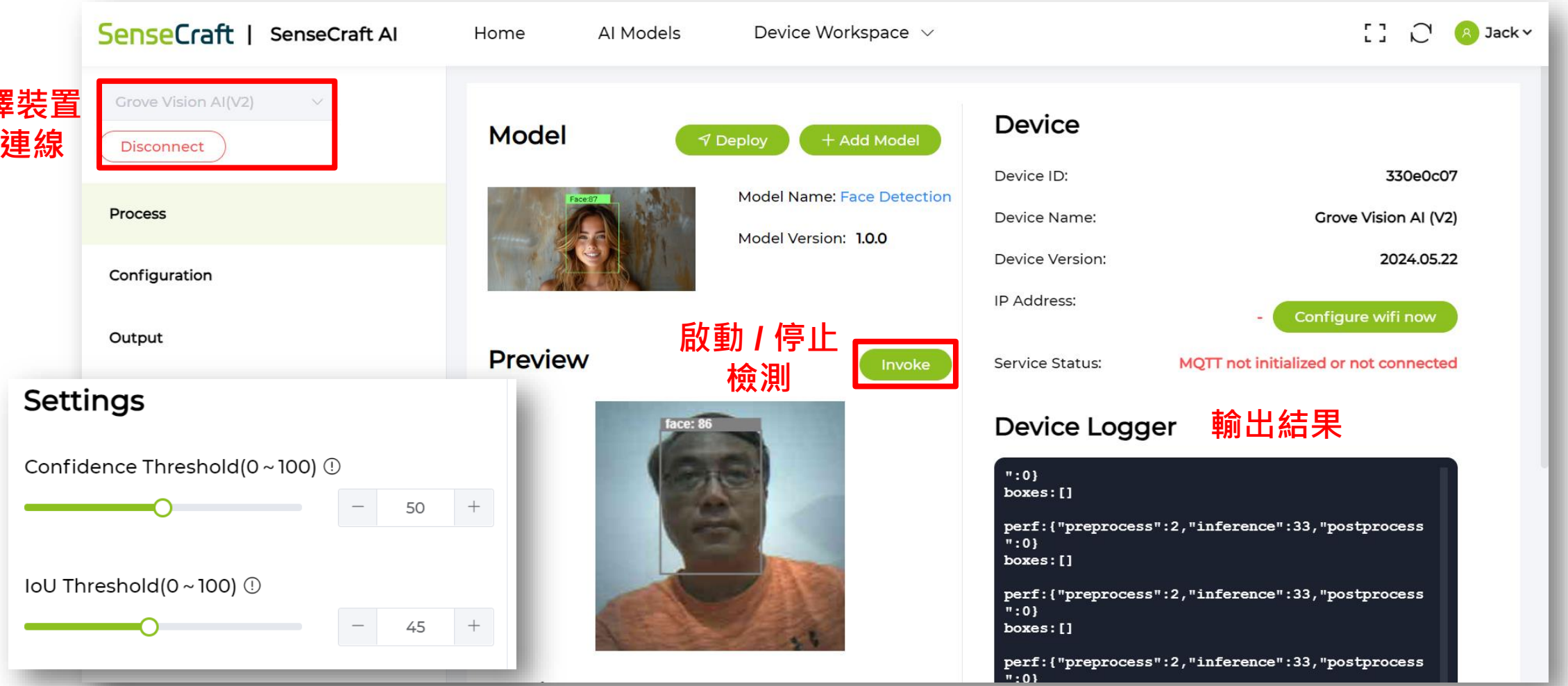
資料來源：https://sensecraft.seeed.cc/ai/#/model

Seeed SenseCraft AI 模型部署



資料來源：https://sensecraft.seeed.cc/ai/#/model

Seeed SenseCraft AI 連接、上傳、測試



資料來源：https://sensecraft.seeed.cc/ai/#/model

參考文獻

- 許哲豪，臺灣科技大學資訊工程系「人工智慧與邊緣運算實務」（2021~2023）

https://omnixri.blogspot.com/p/ntust-edge-ai.html

- 許哲豪，有了TinyML加持MCU也能開始玩電腦視覺了

https://omnixri.blogspot.com/2022/12/tinymlmcu.html

- Himax, WiseEye2 AI Processor (WE2) (HX6538)

https://www.himax.com.tw/products/wiseeye-ai-sensing/wiseeye2-ai-processor/

- Seeed, Grove - Vision AI V2模块人工智能

https://wiki.seeedstudio.com/cn/grove_vision_ai_v2/

- Seeed, SenseCraft AI

https://sensecraft.seeed.cc/ai/#/home

- Edge Impulse Document – Seeed Grove – Vision AI Module

https://docs.edgeimpulse.com/docs/edge-ai-hardware/mcu-+-ai-accelerators/seeed-grove-vision-ai

延伸閱讀

- 許哲豪，【AI HUB專欄】導入AI異常偵測技術讓傳產也能邁向智慧製造
https://omnixri.blogspot.com/2020/06/ai-hubai.html
- 許哲豪，【AI HUB專欄】如何利用時序型資料異常偵測提昇智慧製造成效
https://omnixri.blogspot.com/2020/06/ai-hub.html
- 許哲豪，【AI HUB專欄】導入AI表面瑕疵異常偵測提升智慧製造品質
https://omnixri.blogspot.com/2020/07/ai-hubai.html
- 許哲豪，【AI HUB專欄】生成對抗網路不只能變臉也能成為異常偵測好幫手
https://omnixri.blogspot.com/2020/08/ai-hub.html
- 許哲豪，【AI HUB專欄】利用深度學習技術讓裂縫無所遁形
https://omnixri.blogspot.com/2020/11/ai-hub_23.html
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https://omnixri.blogspot.com/2020/12/ai-hub.html

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開　源：https://github.com/OmniXRI

YOUTUBE 直播： https://www.youtube.com/@omnixri1784/streams