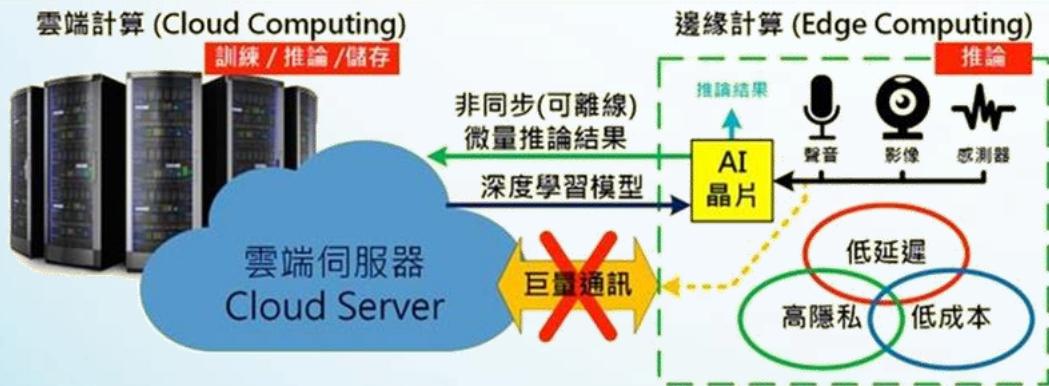


OmniXRI's Edge AI & TinyML 小學堂



歡迎加入
邊緣人俱樂部

【第13講】
實作案例 — 運動辨識



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

實驗器材簡介及開發平台安裝回顧

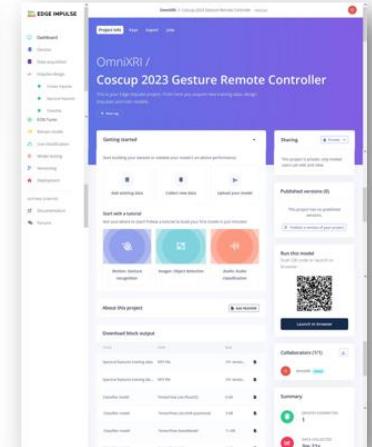
實驗器材及開發平台



Seeed Xiao nRF52840 Sense


USB Type C 繩線


Arduino IDE 2.x


Edge Impulse Studio


2024/05/09 慈濟醫資系_穿戴式人工智慧工作坊_利用TinyML技術快速搭建微型智慧應用_OmniXRI Jack 24

直播連結：<https://youtu.be/y5SOsljxEIA>

快速指令：https://github.com/OmniXRI/Edge_AI_TinyML_Course_2024/blob/main/Ch12_Keyword_Spoting/Ch12_KWS_Quick_Guide.md

本週課程假設已在個人電腦上安裝好開發環境。

若尚未安裝者請參考第**12**講課程。

簡報大綱

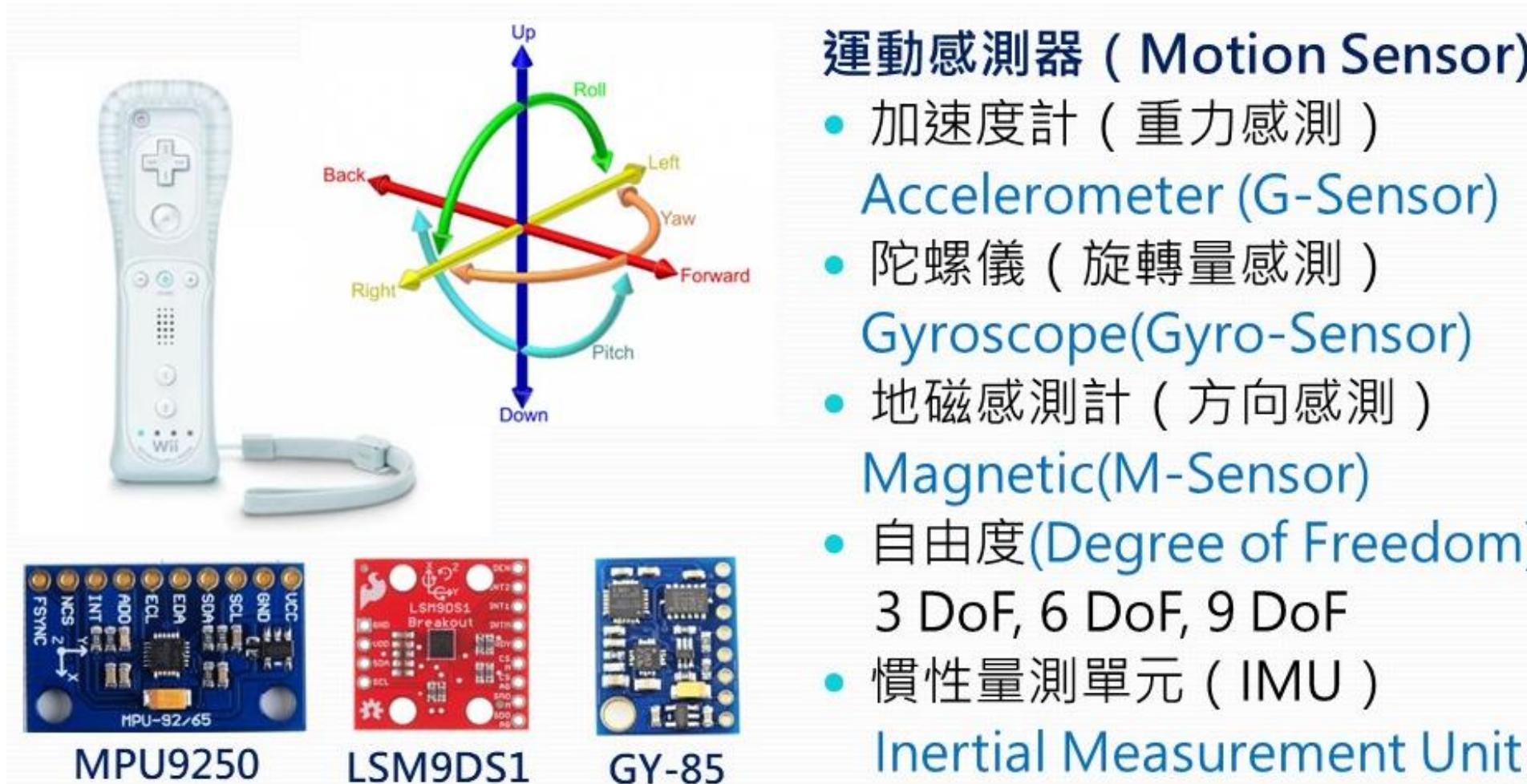


- 13.1. 運動感測技術簡介
- 13.2. 運動感測器取值與輸出
- 13.3. 手勢設計與資料上傳
- 13.4. Edge Impulse 手勢辨識案例

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/@omnixri1784streams>

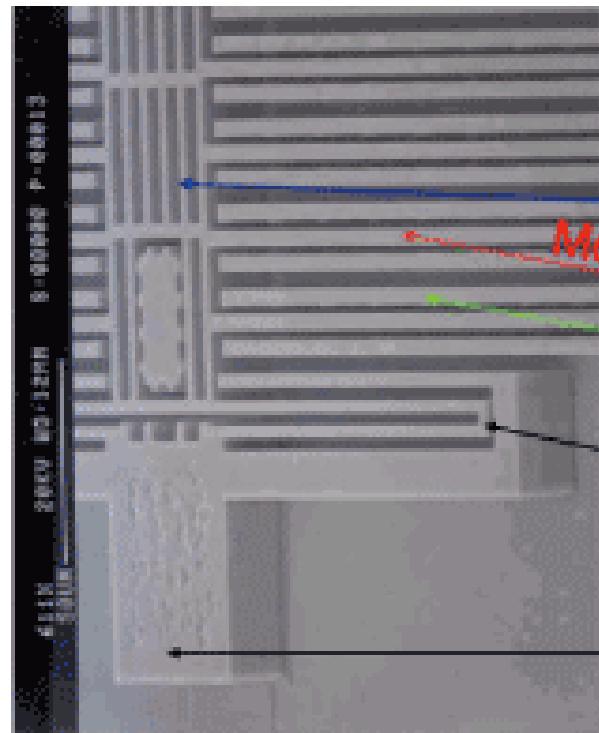
何謂運動感測器



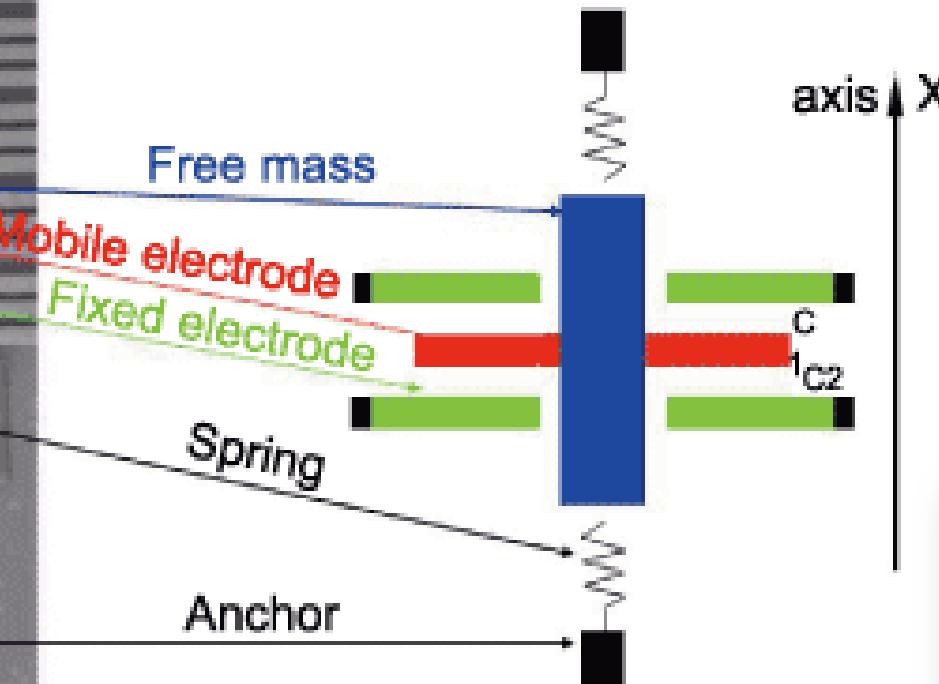
資料來源：<https://omnixri.blogspot.com/2022/04/20220408.html>

加速度計 (G Sensor)

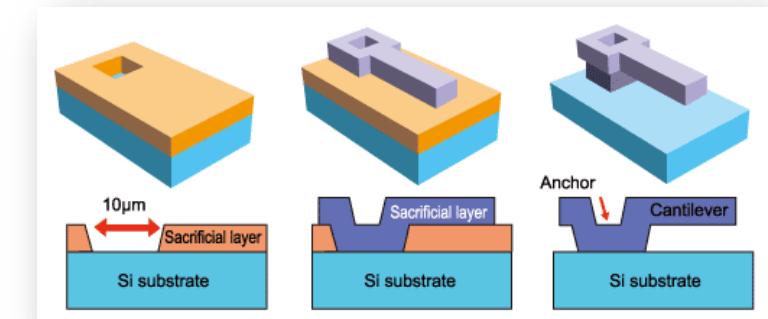
Silicon Mechanical Structure



MEMS Model

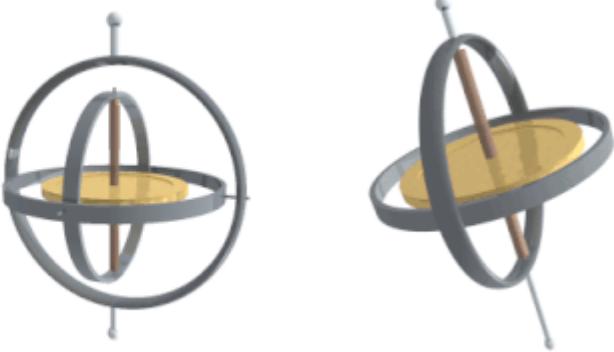


微機電MEMS
製程示意圖



資料來源：<https://www.ctimes.com.tw/DispArt/tw/%E7%BE%A9%E6%B3%95%E5%8D%8A%E5%B0%8E%E9%AB%94/MEMS/ST:%E5%8D%8A%E5%B0%8E%E9%AB%94/0711220000AW.shtml>

陀螺儀 (Gyro Sensor)

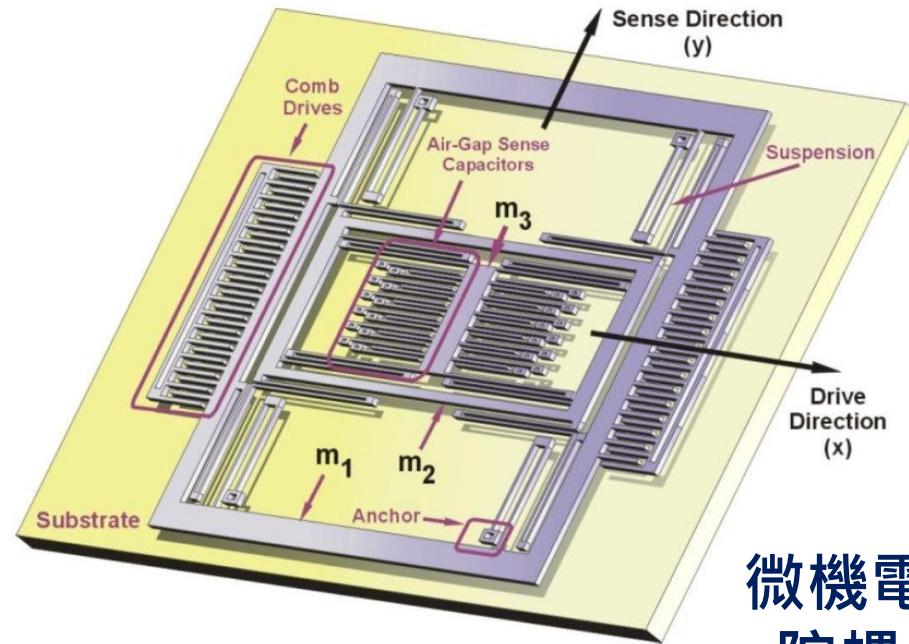
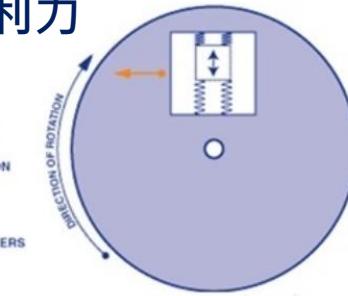
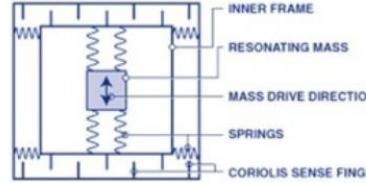


機械式陀螺儀



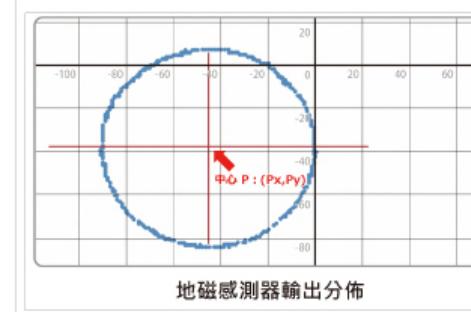
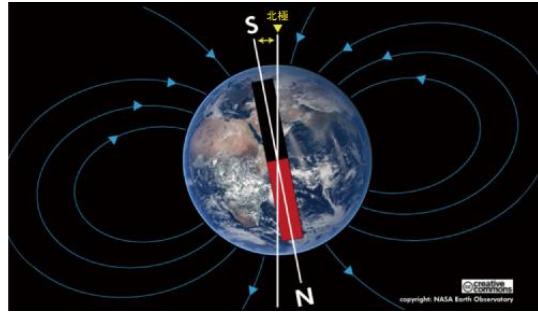
資料來源：<https://zh.wikipedia.org/wiki/%E9%99%80%E8%9E%BA%E5%84%80>

科里奧利力



微機電式
陀螺儀

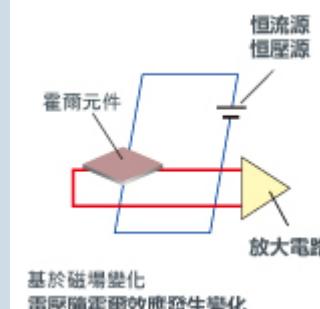
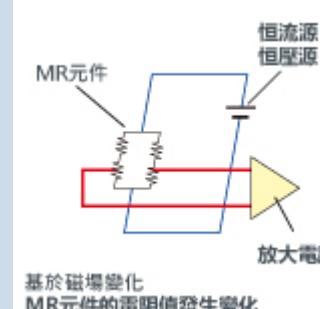
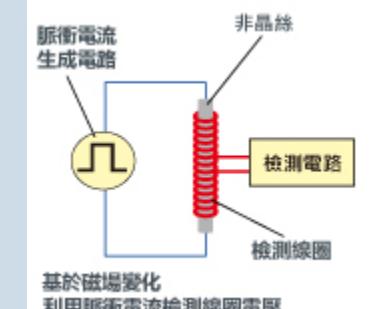
地磁感測器



X **Y**

$$\text{角度} = \tan^{-1} \frac{Y - Py}{X - Px}$$

磁北角的計算公式

檢測方法	霍爾(Hall)	磁阻(MR)	磁抗(MI)
構成	 <p>恒流源 恒壓源 霍爾元件 放大電路 基於磁場變化 電壓隨霍爾效應發生變化</p>	 <p>恒流源 恒壓源 MR元件 放大電路 基於磁場變化 MR元件的電阻值發生變化</p>	 <p>脈衝電流 生成電路 非晶絲 檢測線圈 基於磁場變化 利用脈衝電流檢測線圈電壓</p>
抗雜訊 (靈敏度)	X	△	◎
消耗電流	X	△	◎
回應速度	X	△	◎

資料來源：https://www.rohm.com.tw/electronics-basics/sensors/sensor_what2

運動感測常見應用



人機互動
(Wii / PS Move 搖桿)



慣性導航 / 室內定位
(GPS無法看見天空)



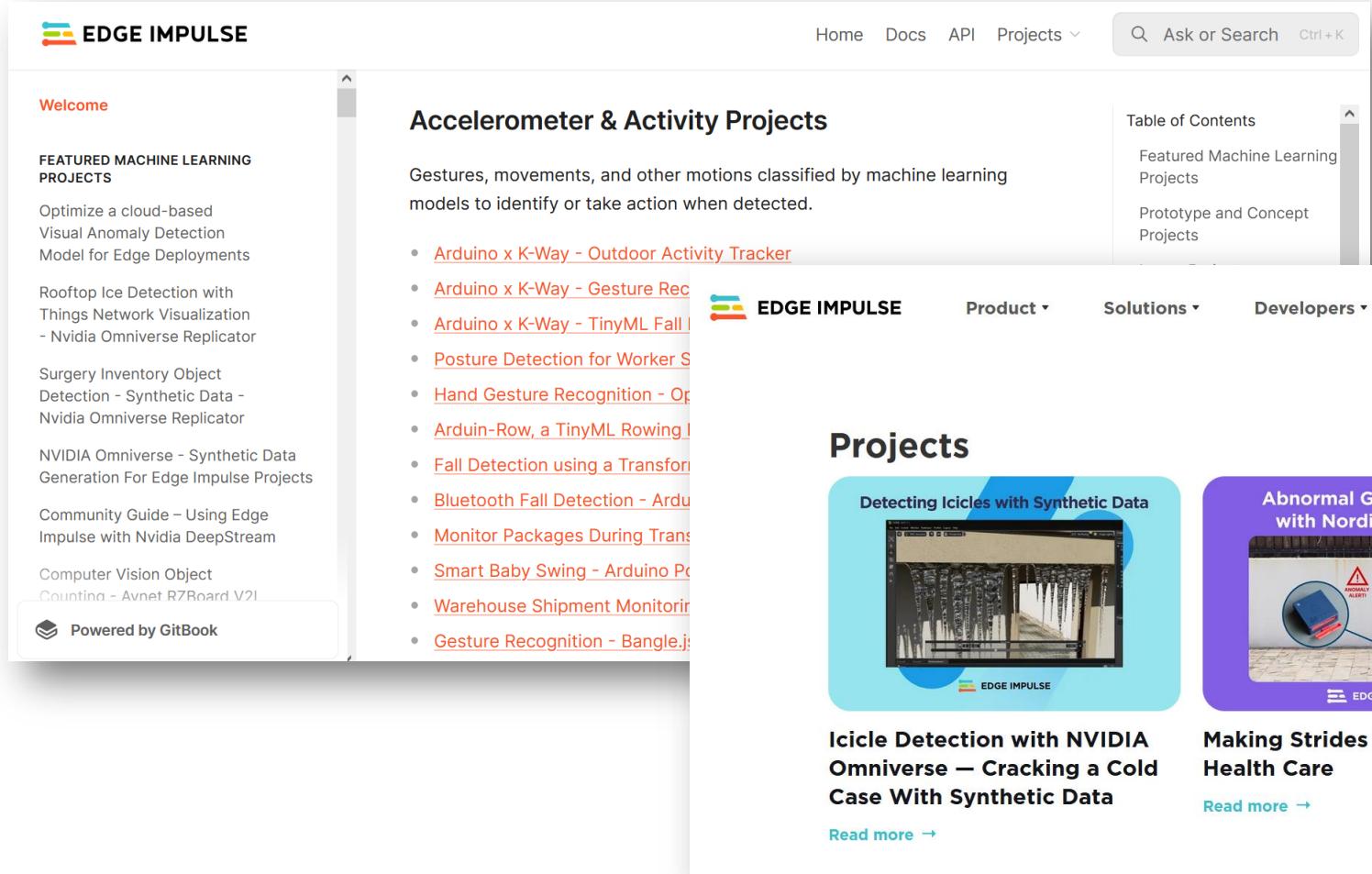
競速分析 / 駕駛習慣
(打龜號 / 車涯 04 事件)



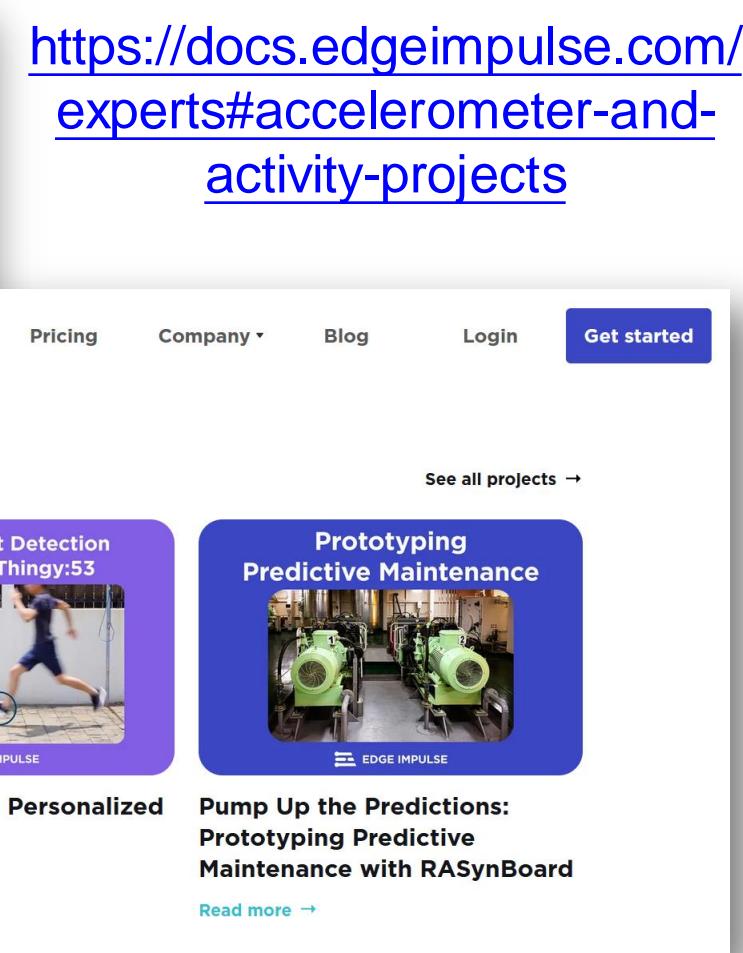
自動平衡
(自動平衡車 / 無人機)



Edge Impulse 運動感測相關案例

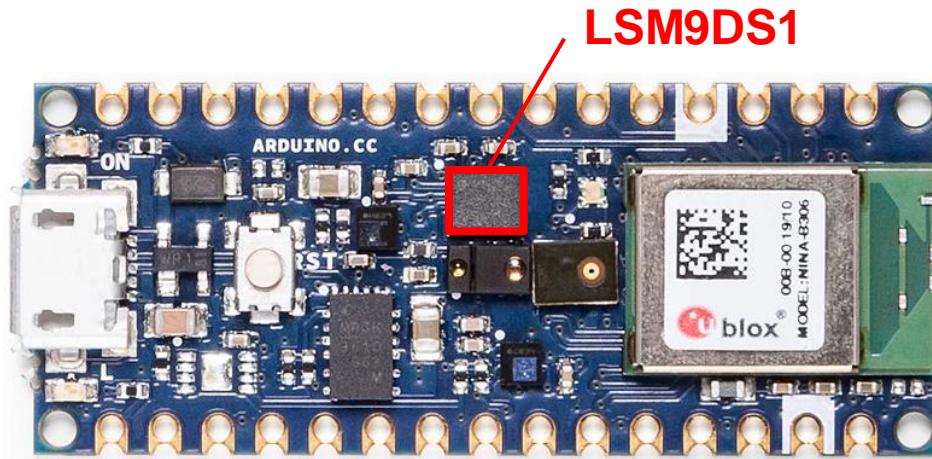


<https://docs.edgeimpulse.com/experts#accelerometer-and-activity-projects>

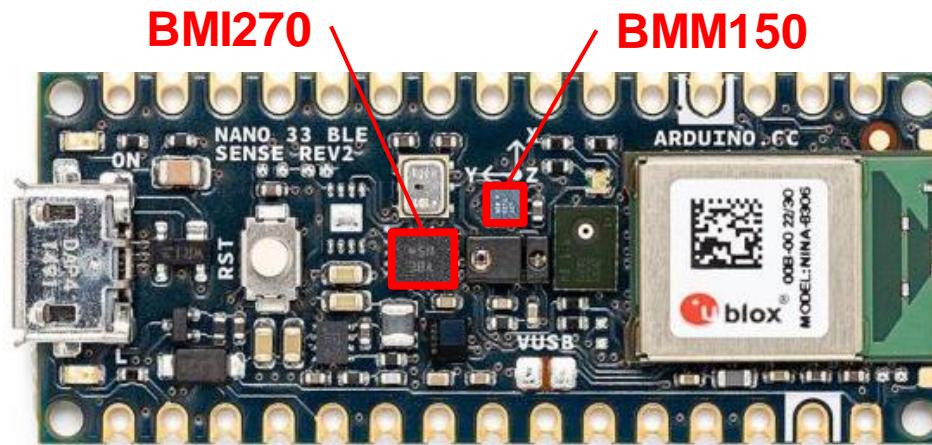


<https://edgeimpulse.com/blog/>

Arduino Nano 33 BLE Sense



LSM9DS1



BMI270

BMM150

Rev1版

LSM9DS1基本規格（加速度計、陀螺儀、地磁計）

- $\pm 2/\pm 4/\pm 8/\pm 16\text{g}$ linear acceleration full scale (多選一)
- $\pm 245/\pm 500/\pm 2000\text{dps}$ angular rate full scale (多選一)
- $\pm 4/\pm 8/\pm 12/\pm 16\text{ gauss}$ magnetic full scale (多選一)
- 16-bit, I2C/SPI data output

<https://store-usa.arduino.cc/products/arduino-nano-33-ble-sense>

Rev2版

BMI270基本規格（加速度計、陀螺儀）

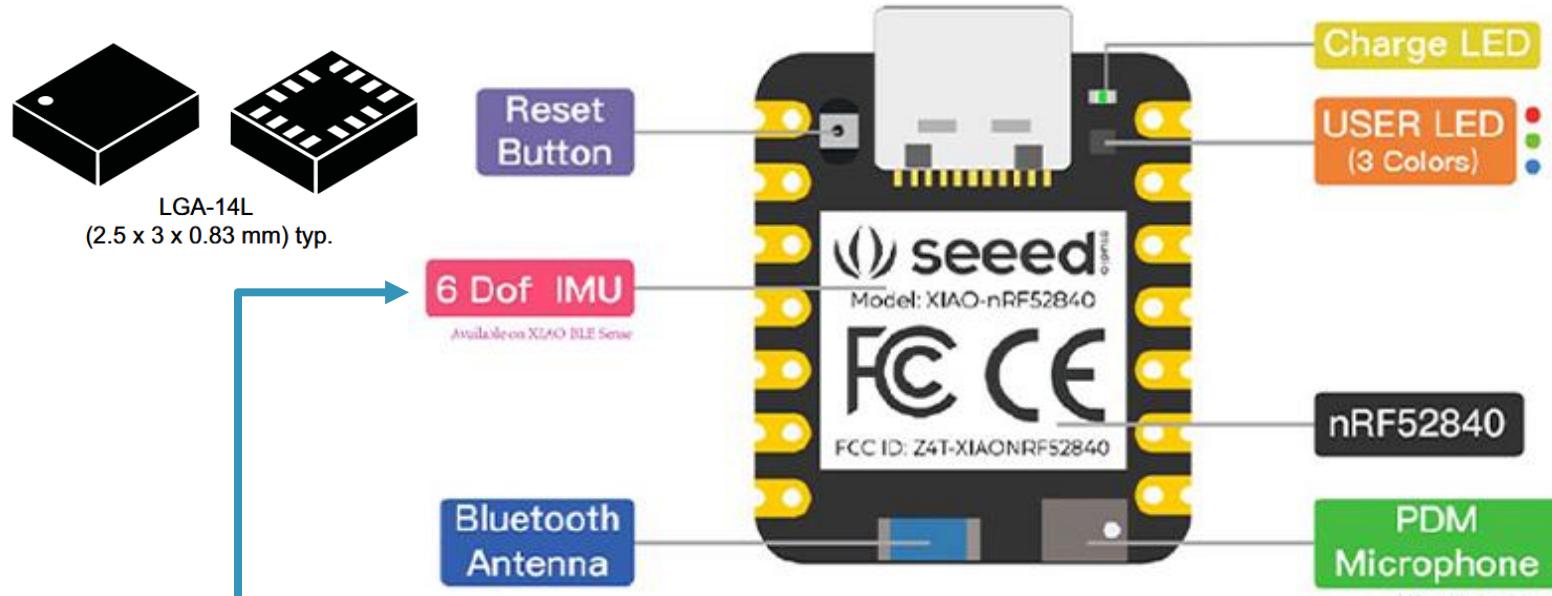
- $\pm 2/\pm 4/\pm 8/\pm 16\text{g}$ linear acceleration full scale (多選一)
- $\pm 125/\pm 250/\pm 500/\pm 1000/\pm 2000\text{dps}$ (多選一)
- 16-bit, 104Hz, I2C/SPI data output

BMM150基本規格（地磁計）

- Magnetic field range typical: $\pm 1300\mu\text{T}$ (x, y-axis), $\pm 2500\mu\text{T}$ (z-axis), Magnetic field resolution of $\sim 0.3\mu\text{T}$
- 16-bit, 20Hz, I2C/SPI data output

<https://store-usa.arduino.cc/products/nano-33-ble-sense-rev2>

Seeed Xiao nRF52840 Sense

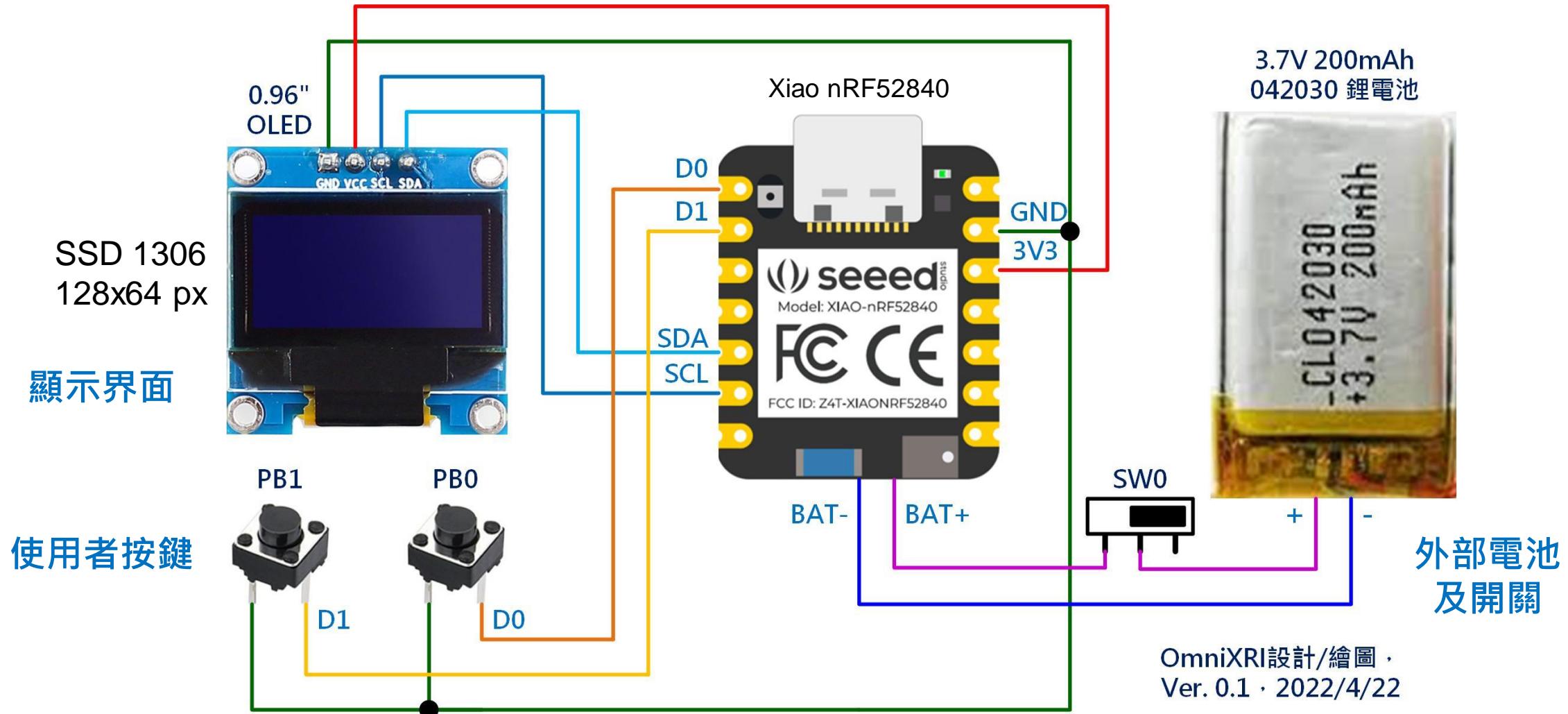


LSM6DS3TR-C

- 3D加速度計 : $\pm 2/\pm 4/\pm 8/\pm 16$ g full scale
- 3D陀螺儀 : $\pm 125/\pm 250/\pm 500/\pm 1000/\pm 2000$ dps full scale
- 工作電壓 : 1.71 V to 3.6 V
- 通訊界面 : SPI & I2 C serial interface

資料來源：https://wiki.seeedstudio.com/cn/XIAO_BLE/

Xiao nRF52840 Sense 模組 – 參考電路



穿戴式智慧人工智慧裝置 – 參考外形



Xiao nRF52840 Sense 模組 – 連接開發板

以 USB Type C 纜線連接電腦和開發板，檢查「裝置管理員」下「連接埠 (COM 和 LPT)」是否有多一個「USB 序列裝置 (COMxx)」。xx即為埠號，會隨電腦即插入USB位置每次都隨機配置。若沒有產生序列裝置，則可快速按開發板「Reset」鍵二次，令其進入模式。



OmniXRI 整理製作, 2024/05/09

快速操作指令表



The screenshot shows a GitHub repository interface. On the left, the file tree for the 'main' branch is visible, with the 'IMU_Quick_Guide.md' file highlighted. The main content area displays the Markdown file's content, which includes the title 'OmniXRI's Edge AI & TinyML 小學堂【第13講】實作案例—運動辨識（快速指令表）', author information ('講師：歐尼克斯實境互動工作室 許哲豪(Jack Hsu)博士 2024/05/28 整理製作'), and a section titled '13.1. 實驗器材及開發平台' with three bullet points linking to external resources: 'Seeed Wiki - Xiao nRF52840 Sense (英文)', 'Arduino Software Downloads', and 'Edge Impulse Document'. Below this section, there is a note about development environment setup and a link to another guide.

Edge_AI_TinyML_Course_2024 / Ch13_Motion_Recognition / IMU_Quick_Guide.md

OmniXRI Update IMU_Quick_Guide.md

1046b3e · now History

Preview Code Blame 292 lines (250 loc) · 13.5 KB Code 55% faster with GitHub Copilot Raw ⌂ ⌄ ⌁ ⌂ ⌃

OmniXRI's Edge AI & TinyML 小學堂【第13講】實作案例 —運動辨識（快速指令表）

講師：歐尼克斯實境互動工作室 許哲豪(Jack Hsu)博士 2024/05/28 整理製作

13.1. 實驗器材及開發平台

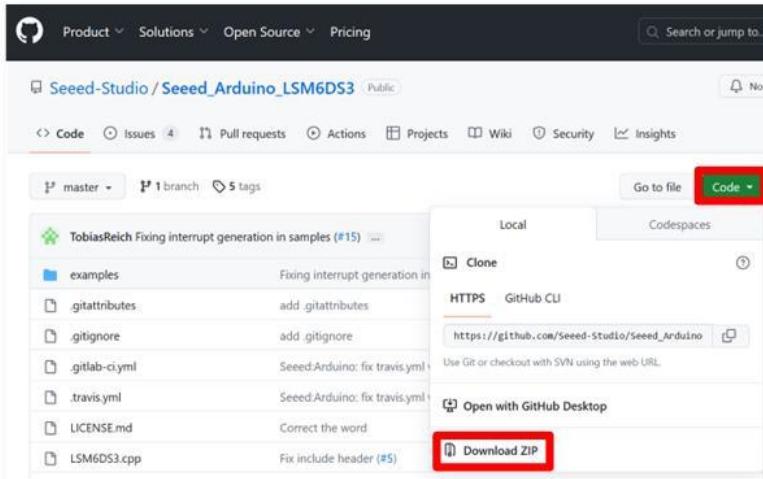
- [Seeed Wiki - Xiao nRF52840 Sense \(英文\)](#)
- [Arduino Software Downloads](#)
- [Edge Impulse Document](#)

相關開發環境建置請參考
[OmniXRI's Edge AI & TinyML 小學堂【第12講】實作案例—語音辨識（快速指令表）](#)

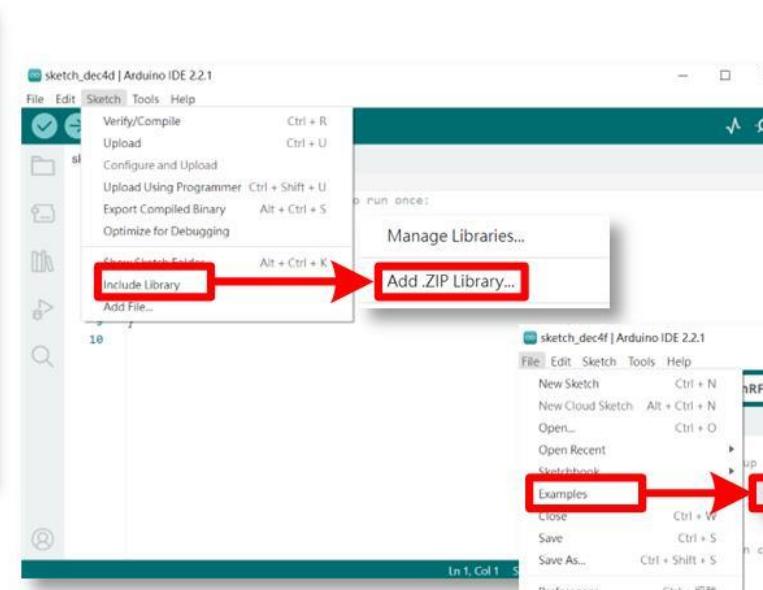
https://github.com/OmniXRI/Edge_AI_TinyML_Course_2024/blob/main/Ch13_Motion_Recognition/IMU_Quick_Guide.md

測試程式：運動感測器（IMU）(1/3)

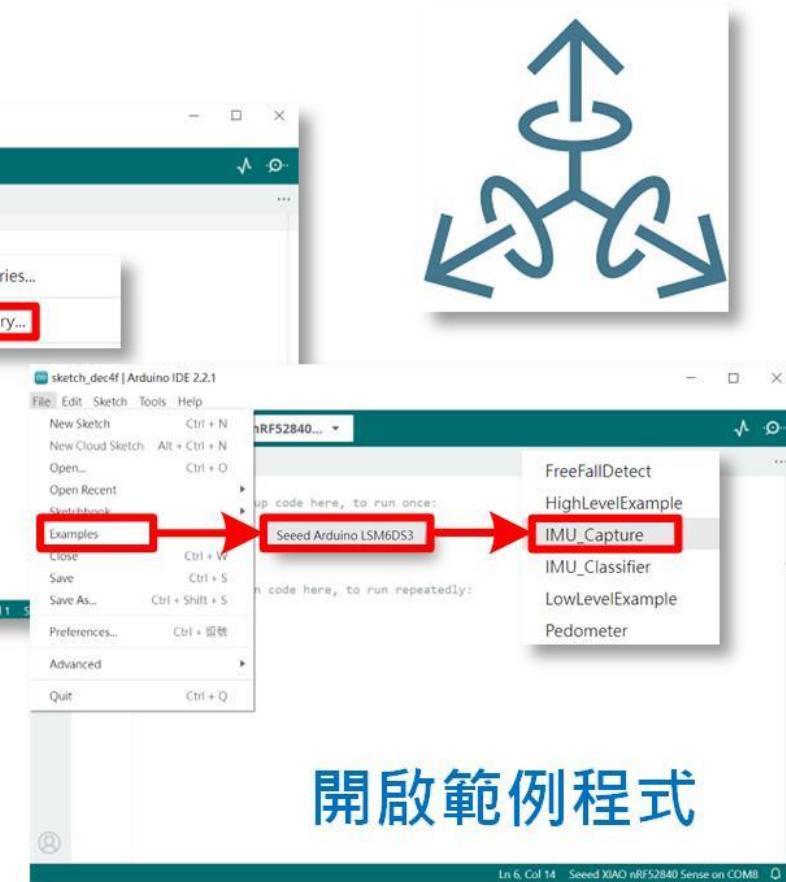
https://github.com/Seeed-Studio/Seeed_Arduino_LSM6DS3



Seeed_Arduino_LSM6DS3-master.zip
下載運動感測器函式庫



安裝函式庫



開啟範例程式

OmniXRI整理製作, 2023/12/08

測試程式：運動感測器（IMU）(2/3)

File > Examples > Seeed Arduino LSM6DS3 > IMU_capture

```
#include <LSM6DS3.h>
#include <Wire.h>
LSM6DS3 myIMU(I2C_MODE, 0x6A); // 建立LSM6DS3實例並設定I2C裝置位址
float aX, aY, aZ, gX, gY, gZ; // 儲存三軸加速度及陀螺儀數值變數
const float accelerationThreshold = 2.5; // 加速度門檻值
const int numSamples = 119; // 樣本數量
int samplesRead = numSamples; // 讀取樣本數量
void setup() { // 初始化設定
    Serial.begin(9600); // 設定串例通信速度(bps)
    while (!Serial); // 等待串列埠初始化完成
    if (myIMU.begin() != 0) { // 初始化運動感測器
        Serial.println("Device error");
    } else {
        Serial.println("aX,aY,aZ,gX,gY,gZ");
    }
}
void loop() { // 無限迴圈
    // 等待取得足夠數量樣本
    while (samplesRead == numSamples) {
        // 讀取加速度計值
        aX = myIMU.readFloatAccelX();
        aY = myIMU.readFloatAccelY();
        aZ = myIMU.readFloatAccelZ();
        // 求得加速度值總合
        float aSum = fabs(aX) + fabs(aY) + fabs(aZ);
        // 檢查是否超過門檻值，若是重置已讀樣本數量
        if (aSum >= accelerationThreshold) {
            samplesRead = 0;
            break;
        }
    }
}
```

觸發值大於
門檻才輸出

初始化資料字串

```
// 檢查自上次檢測到顯著運動以來是否已讀取所有必需的樣本
while (samplesRead < numSamples) {
    samplesRead++; // 已讀取樣本數加1
    // print the data in CSV format
    Serial.print(myIMU.readFloatAccelX(), 3);
    Serial.print(',');
    Serial.print(myIMU.readFloatAccelY(), 3);
    Serial.print(',');
    Serial.print(myIMU.readFloatAccelZ(), 3);
    Serial.print(',');
    Serial.print(myIMU.readFloatGyroX(), 3);
    Serial.print(',');
    Serial.print(myIMU.readFloatGyroY(), 3);
    Serial.print(',');
    Serial.print(myIMU.readFloatGyroZ(), 3);
    Serial.println();
    // 若已讀樣本數已足夠則列印換行
    if (samplesRead == numSamples) {
        Serial.println();
    }
}
```

輸出
加速計值

輸出
陀螺儀值

練習：將板子以不同方向移動及旋
轉測試讀值是否正常

測試程式：IMU 連續取值輸出 (3/3)

```

1 #include <LSM6DS3.h>
2 #include <Wire.h>
3
4 //Create a instance of class LSM6DS3
5 LSM6DS3 myIMU(I2C_MODE, 0x6A);      //I2C device address 0x6A
6 float aX, aY, aZ, gX, gY, gZ;
7 // const float accelerationThreshold = 2.5; // threshold of significant in G's
8 // const int numSamples = 119;
9 // int samplesRead = numSamples;
10
11 void setup() {
12   // put your setup code here, to run once:
13   Serial.begin(115200);
14   while (!Serial);
15   //Call .begin() to configure the IMUs
16   if (myIMU.begin() != 0) {
17     Serial.println("Device error");
18   } else {
19     Serial.println("aX,aY,aZ,gX,gY,gZ");
20   }
21 }
22
23 void loop() {
24   // wait for significant motion
25   // while (samplesRead == numSamples) {
26   //   // read the acceleration data
27   //   aX = myIMU.readFloatAccelX();
28   //   aY = myIMU.readFloatAccelY();
29   //   aZ = myIMU.readFloatAccelZ();
30
31   //   // sum up the absolutes
32   //   float aSum = fabs(aX) + fabs(aY) + fabs(aZ);
33
34   //   // check if it's above the threshold

```

註解或刪除
紅色框區域

```

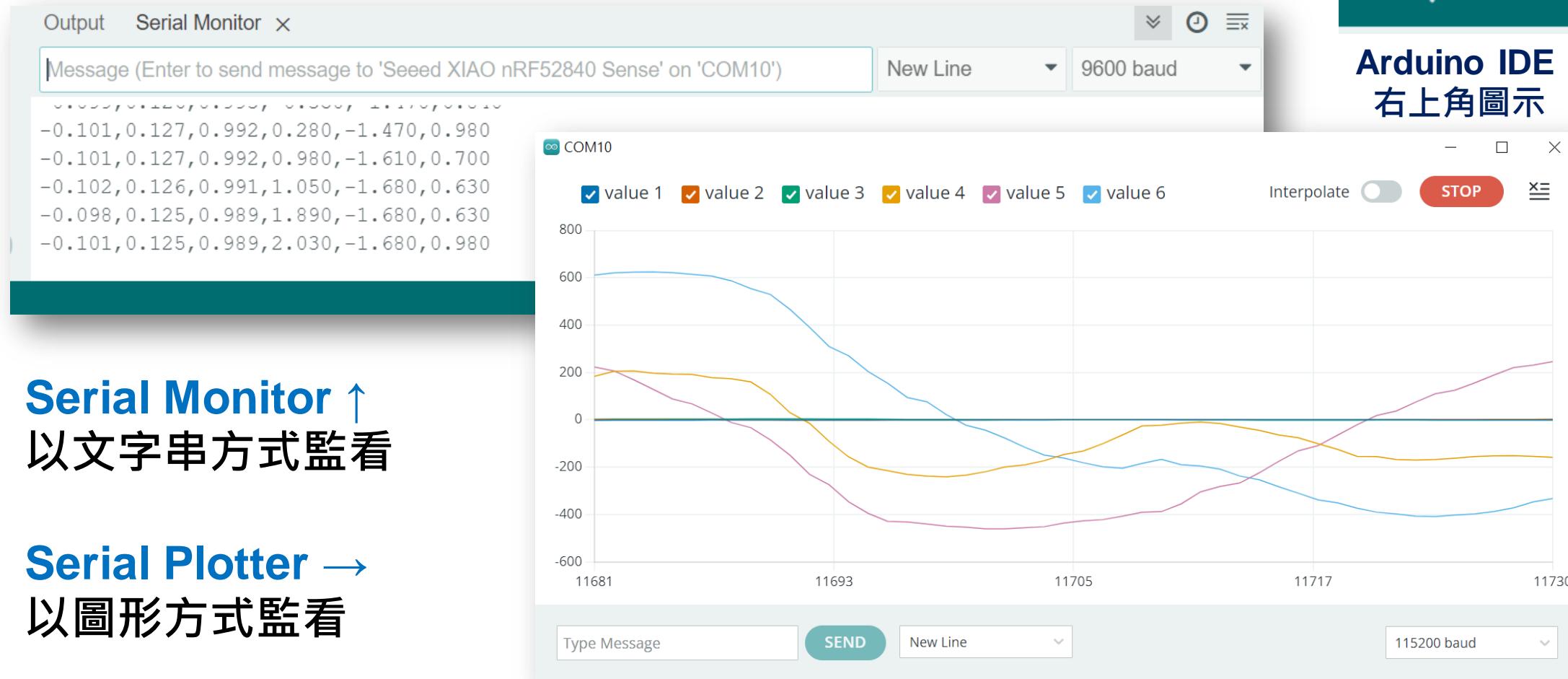
35   //   if (aSum >= accelerationThreshold) {
36   //     // reset the sample read count
37   //     samplesRead = 0;
38   //     break;
39   //   }
40   //
41
42   //   // check if the all the required samples have been read since
43   //   // the last time the significant motion was detected
44   //   while (samplesRead < numSamples) {
45   //     // check if both new acceleration and gyroscope data is
46   //     // available
47   //     // read the acceleration and gyroscope data
48
49   //     samplesRead++;
50
51   //   print the data in CSV format
52   Serial.print(myIMU.readFloatAccelX(), 3);
53   Serial.print(',');
54   Serial.print(myIMU.readFloatAccelY(), 3);
55   Serial.print(',');
56   Serial.print(myIMU.readFloatAccelZ(), 3);
57   Serial.print(',');
58   Serial.print(myIMU.readFloatGyroX(), 3);
59   Serial.print(',');
60   Serial.print(myIMU.readFloatGyroY(), 3);
61   Serial.print(',');
62   Serial.print(myIMU.readFloatGyroZ(), 3);
63   Serial.println();
64
65   //   if (samplesRead == numSamples) {
66   //     // add an empty line if it's the last sample
67   //     Serial.println();
68   //   }
69   //
70 }

```

連續取值並輸出至 COM
搭配 edge-impulse-data-forwarder 可將感測器值送到雲端
另可搭配計時功能
控制輸出頻率

監看運動感測器輸出值

File > Tools > Serial Monitor or Serial Plotter



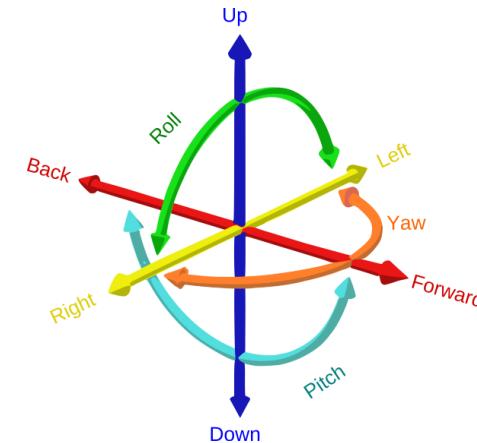
Serial Monitor ↑

以文字串方式監看

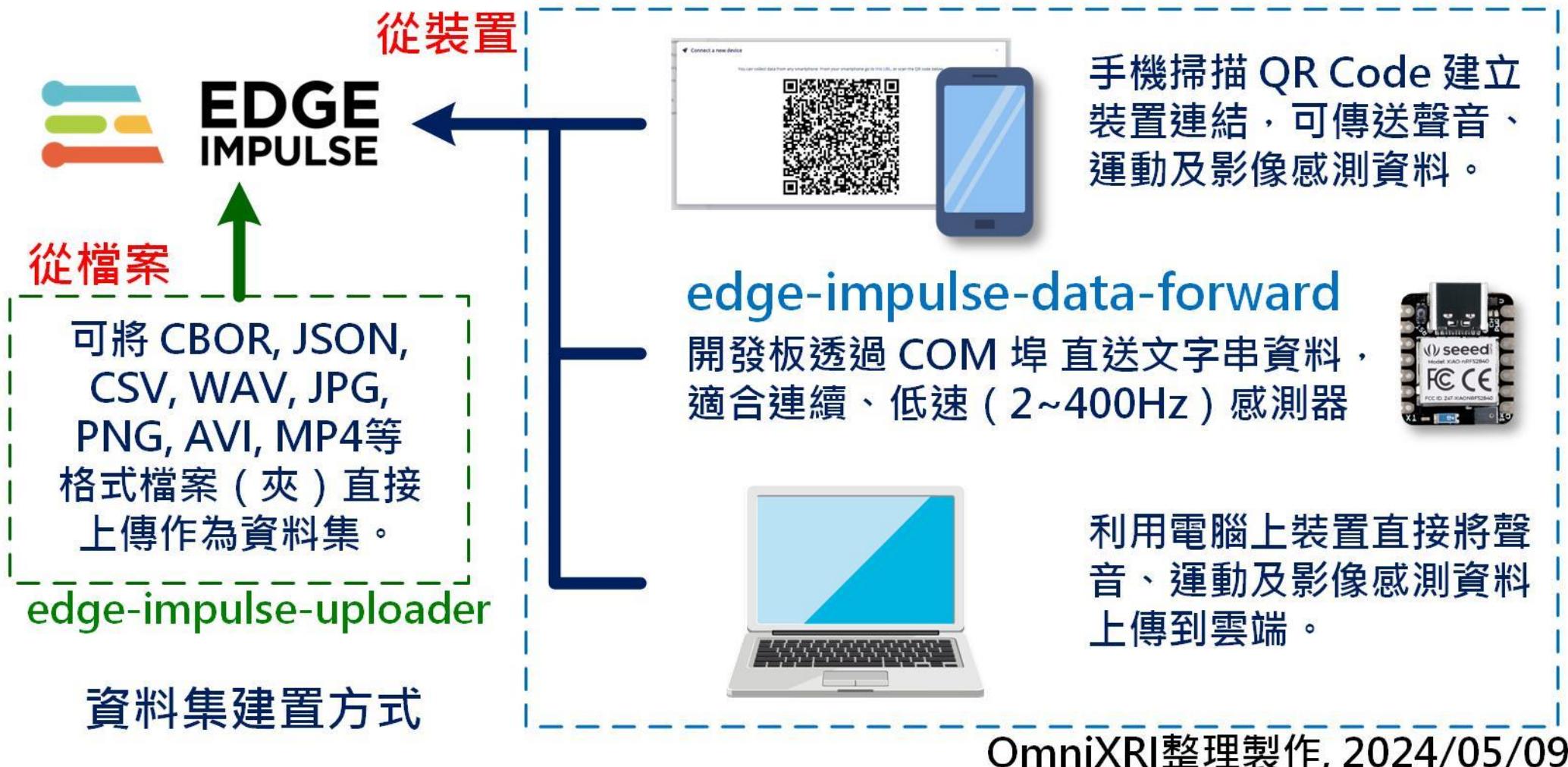
Serial Plotter → 以圖形方式監看

設計操作手勢

- Start – 向前張開手掌
- Next – 由左向右快速平移並有頓點
- Prev – 由下向上擺動並有頓點
- Stop – 雙手快速交叉於胸口
- Unknow – 任意輕微擺動或不動，可為任意姿勢。
- 運動感測器必須**固定在手部特定位**置以免相同動作但感測值差異過大
- 動作設定最好於**不同軸向有明顯差異**可只用**加速度計而不使用陀螺儀**



Edge Impulse 資料集建置方式

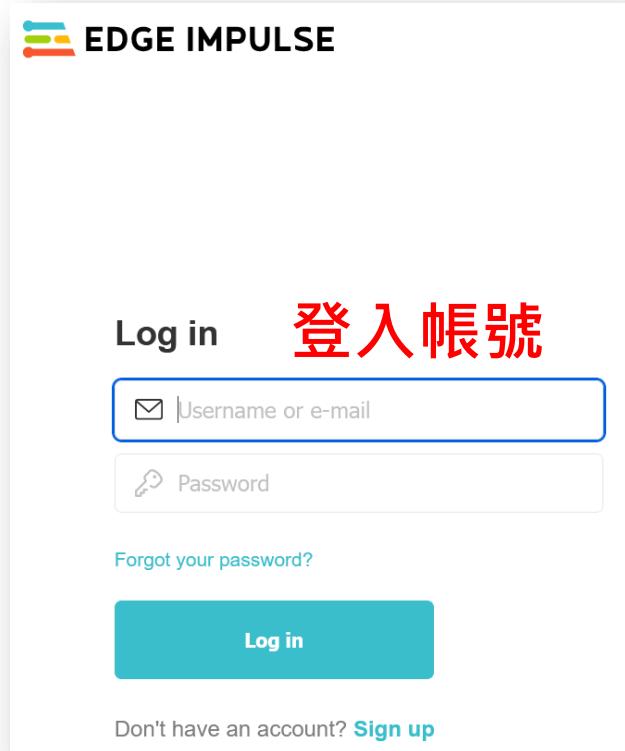


13.4. Edge Impulse 手勢辨識案例



- 建立專案
- 選用模型
- 裝置連線
- 設定參數
- 收集資料
- 特徵提取
- 上傳資料
- 訓練模型
- 分割標註
- 部署測試

建立 Edge Impulse 新專案



The screenshot shows a "Create a new project" dialog box overlaid on the Edge Impulse interface. The dialog has a purple header with the text "Create a new project". Inside, there is a text input field with the placeholder "Enter the name for your new project:" and a red border around it. Below this is a sub-section titled "2. 輸入專案名稱" (Input project name). The main body of the dialog contains three sections:

- Choose your project type:**
 - Personal **3. 選擇專業類型** (Selected)
 - Enterprise
- Choose your project setting:**
 - Public **4. 設定專案屬性 (私有僅限2個)** (Selected)
 - Private (1 of 2 remaining)
- A note at the bottom: "Want access to all features and unlimited projects? Try Enterprise free."

At the bottom right of the dialog is a green "Create new project" button with a red border around it. To the right of the dialog, the main Edge Impulse interface shows a sidebar with "OmniXRI" and a "+ Create new project" button, along with other project cards.

參考資料：<https://wiki.seeedstudio.com/cn/XIAO-BLE-PDM-EI/>

啟動edge-impulse-data-forwarder

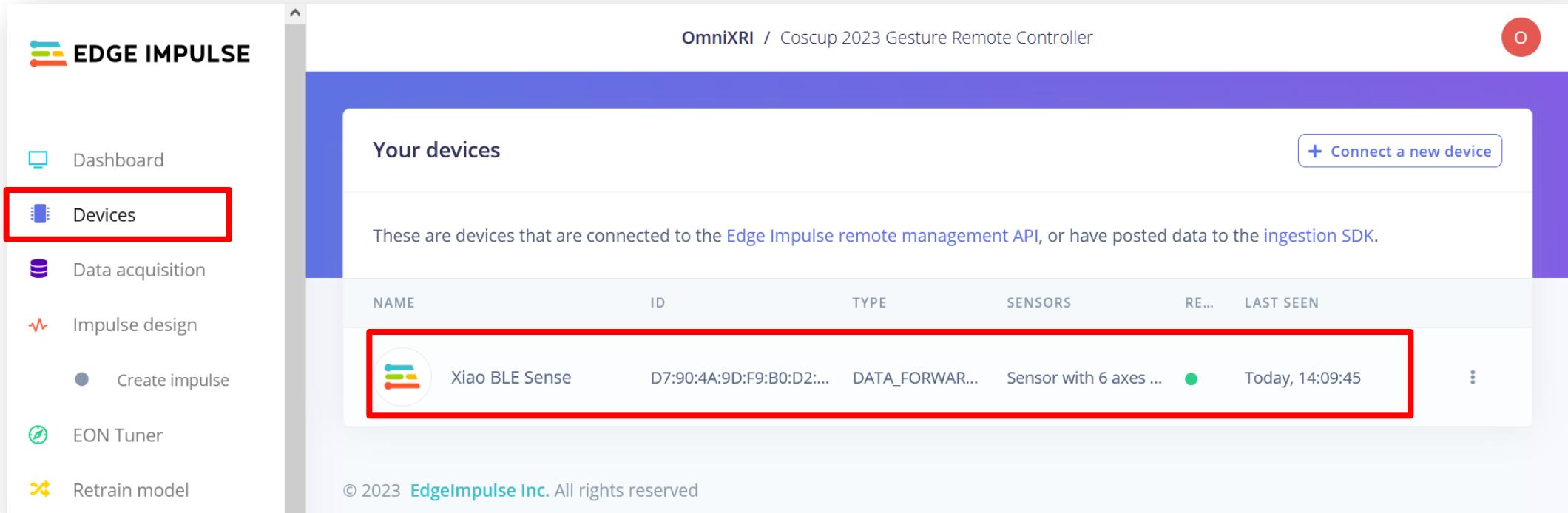
```
C:\WINDOWS\system32\cmd.exe - "node" "C:\Users\jack_\AppData\Roaming\npm\node_modules\edge-impulse-cli\build\cli\data-forwarder --clean"
C:\Users\jack_>edge-impulse-data-forwarder --clean edge-impulse-data-forwarder --clean
Edge Impulse data forwarder v1.24.1
? What is your user name or e-mail address (edgeimpulse.com)? omnixri@gmail.com 輸入帳號
? What is your password? [hidden] 輸入密碼
Endpoints:
  Websocket: wss://remote-mgmt.edgeimpulse.com
  API: https://studio.edgeimpulse.com
  Ingestion: https://ingestion.edgeimpulse.com

[SER] Connecting to COM8
[SER] Serial is connected (7F:63:29:74:0B:F4:EA:69)
[WS ] Connecting to wss://remote-mgmt.edgeimpulse.com
[WS ] Connected to wss://remote-mgmt.edgeimpulse.com

? To which project do you want to connect this device? OmniXRI / Xiao_nRF52840_IMU_Test 選擇對應專案
[SER] Detecting data frequency...
[SER] Detected data frequency: 130Hz
? 6 sensor axes detected (example values: [-0.02,-0.005,1.001,0.49,-1.4,0.84]). What do you want to call them? Separate the names with ',' : aX,aY,aX,gX,gY,gZ 輸入資料數量及名稱
[WS ] Device "XiaoSense" is now connected to project "Xiao_nRF52840_IMU_Test". To connect to another project, run `edge-impulse-data-forwarder --clean`.
[WS ] Go to https://studio.edgeimpulse.com/studio/391754/acquisition/training to build your machine learning model!
[WS ] Incoming sampling request {
    path: '/api/training/data',
    label: 'OK',
    length: 10000,
    interval: 7.6923076923076925,
    hmacKey: 'd00f5918c1020b658b18569f9ee881c5',
    sensor: 'Sensor with 6 axes (aX, aY, aX, gX, gY, gZ)'
}
```

輸入帳號密碼並選定專案。準備接收來自開發板傳送的資料並給予並應的名稱。傳送的資料頻度必須大於**2Hz**。
若無法連接 **COM** 埠，請按開發板重置鍵一次，並請關閉 **Arduino** 及有可能佔用 **COM** 之程式。

檢查裝置是否已連線

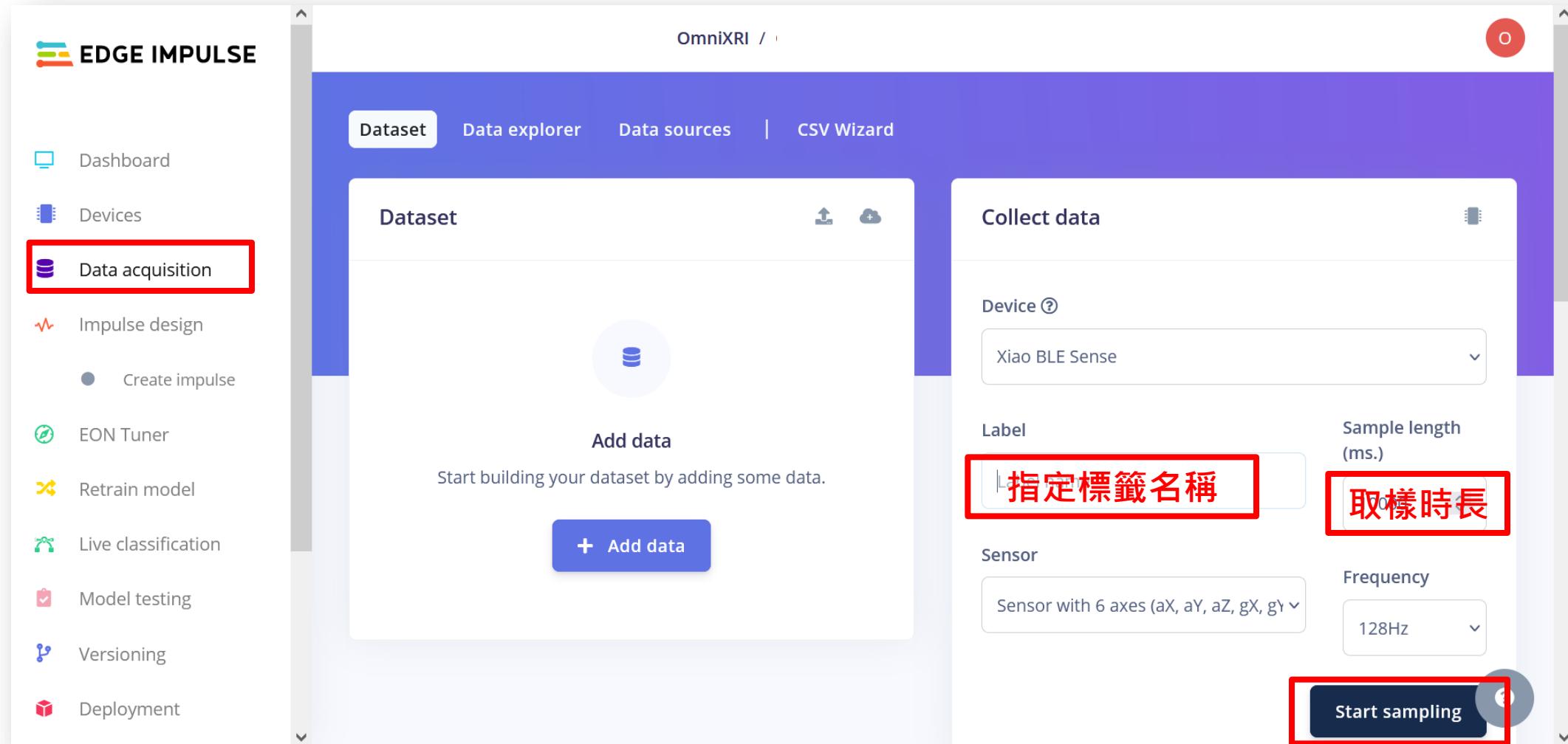


The screenshot shows the Edge Impulse web interface. On the left, a sidebar menu lists several options: EDGE IMPULSE, Dashboard, Devices (which is highlighted with a red box), Data acquisition, Impulse design, Create impulse, EON Tuner, and Retrain model. The main content area is titled "Your devices" and displays a table of connected devices. The table has columns for NAME, ID, TYPE, SENSORS, RE..., and LAST SEEN. One device, "Xiao BLE Sense", is listed with the following details: ID D7:90:4A:9D:F9:B0:D2:..., TYPE DATA_FORWARDER, SENSORS Sensor with 6 axes ..., LAST SEEN Today, 14:09:45. A red box highlights both the "Devices" menu item and the "Xiao BLE Sense" device row.

NAME	ID	TYPE	SENSORS	RE...	LAST SEEN
Xiao BLE Sense	D7:90:4A:9D:F9:B0:D2:...	DATA_FORWARDER	Sensor with 6 axes ...	●	Today, 14:09:45

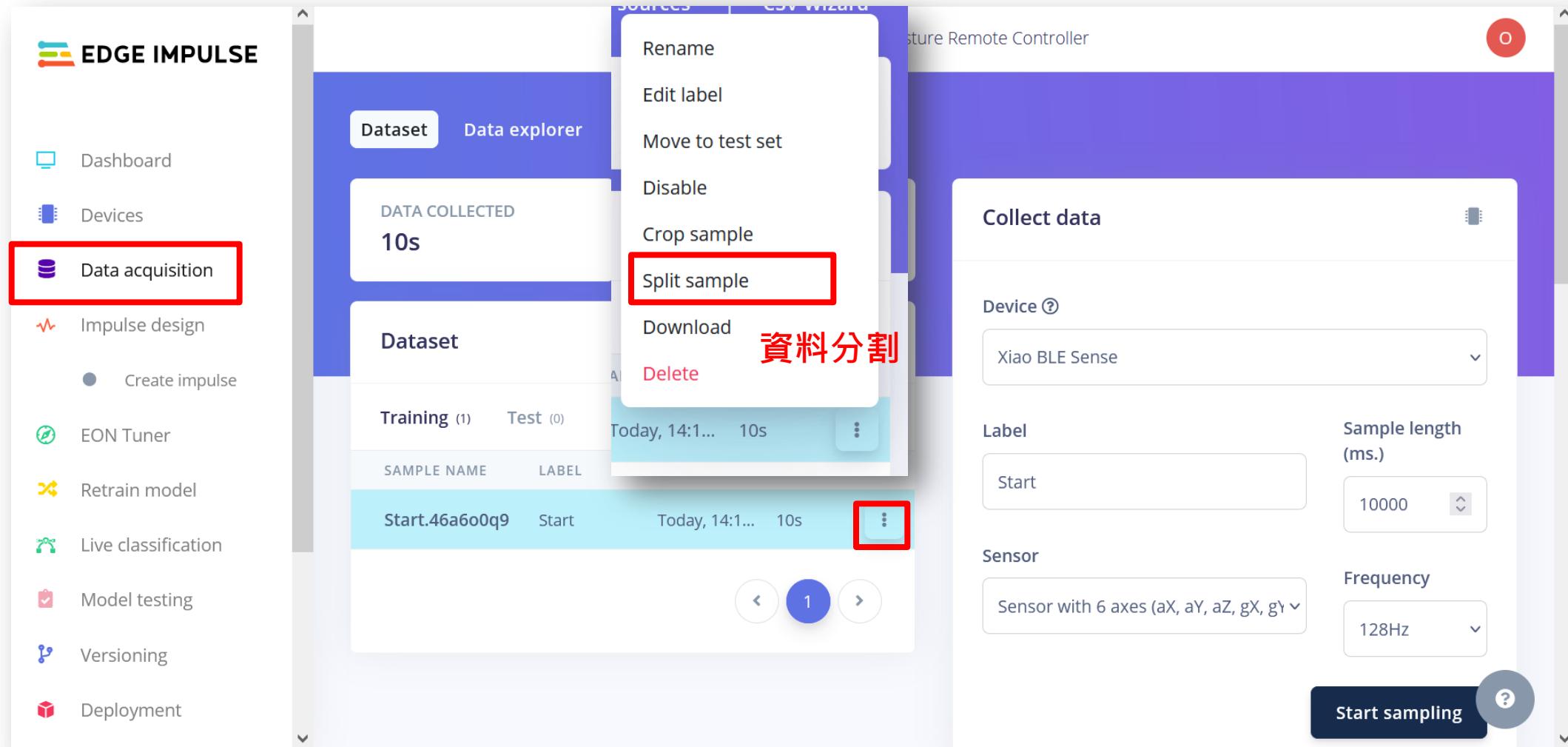
- 開發板運行IMU連續取值輸出程式。
- 啟動 **edge-impulse-data-forwarder**，將裝置連線到雲端。
- 將開發板輸出之內容，傳送到雲端。

從外部裝置取得資料



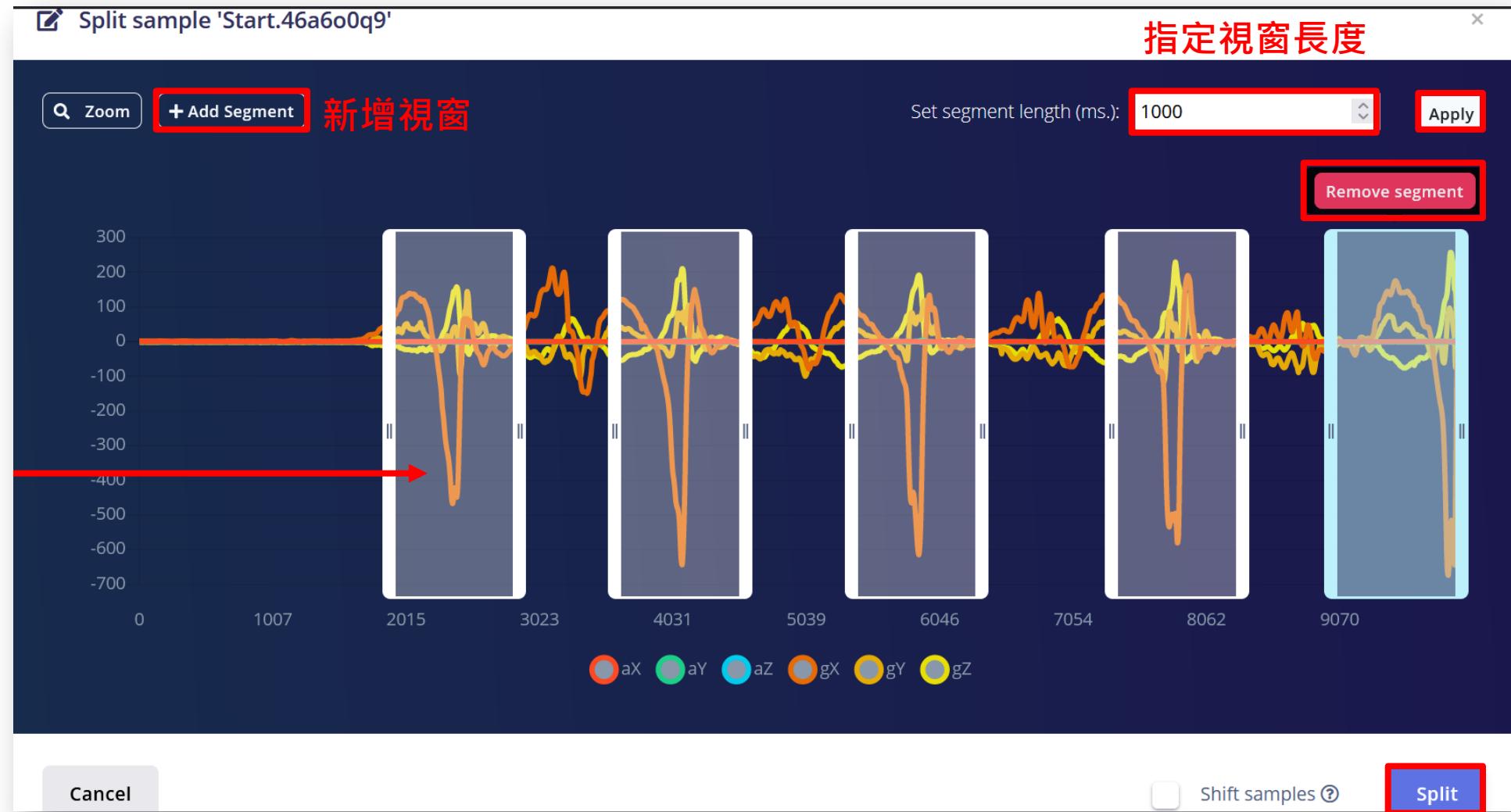
The screenshot shows the OmniXRI Edge Impulse interface. On the left sidebar, the 'Data acquisition' option is highlighted with a red box. The main area has tabs for 'Dataset', 'Data explorer', 'Data sources', and 'CSV Wizard'. The 'Dataset' tab is selected. It features a central 'Add data' button and a 'Collect data' panel on the right. The 'Collect data' panel includes fields for 'Device' (set to 'Xiao BLE Sense'), 'Label' (highlighted with a red box and labeled '指定標籤名稱'), 'Sample length (ms.)' (highlighted with a red box and labeled '取樣時長'), 'Sensor' (set to 'Sensor with 6 axes (aX, aY, aZ, gX, gY)'), 'Frequency' (set to '128Hz'), and a 'Start sampling' button (highlighted with a red box).

大量收集樣本並分割成獨立可訓練樣本

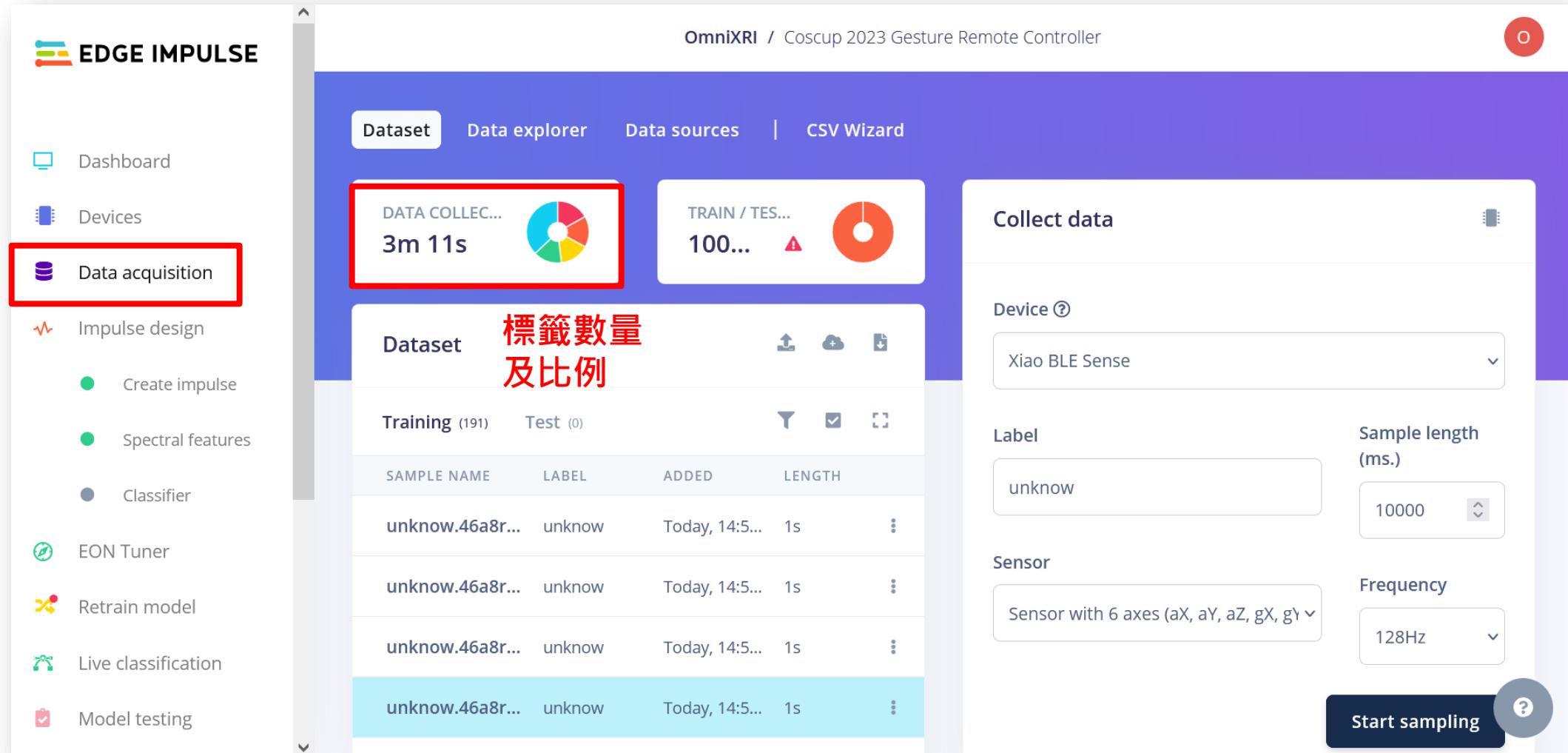


The screenshot shows the Edge Impulse web interface. On the left sidebar, the 'Data acquisition' option is selected and highlighted with a red box. In the main area, the 'Data explorer' tab is active, displaying a dataset titled 'Dataset' with a collection time of '10s'. A context menu is open over this dataset, with the 'Split sample' option highlighted and also enclosed in a red box. To the right of the menu, the text '資料分割' (Data Splitting) is overlaid in red. The 'Collect data' panel on the right shows settings for a 'Xiao BLE Sense' device, a 'Start' label, a sample length of 10000 ms, a sensor with 6 axes, and a frequency of 128Hz. A large blue button at the bottom right says 'Start sampling'.

原始資料與自動分割



反複收集分割，建立完整資料集



Dataset **Data explorer** **Data sources** | **CSV Wizard**

DATA COLLECT... **TRAIN / TES...**

3m 11s **100...**

標籤數量及比例

Device ? **Xiao BLE Sense**

Label **unknow**

Sample length (ms.) **10000**

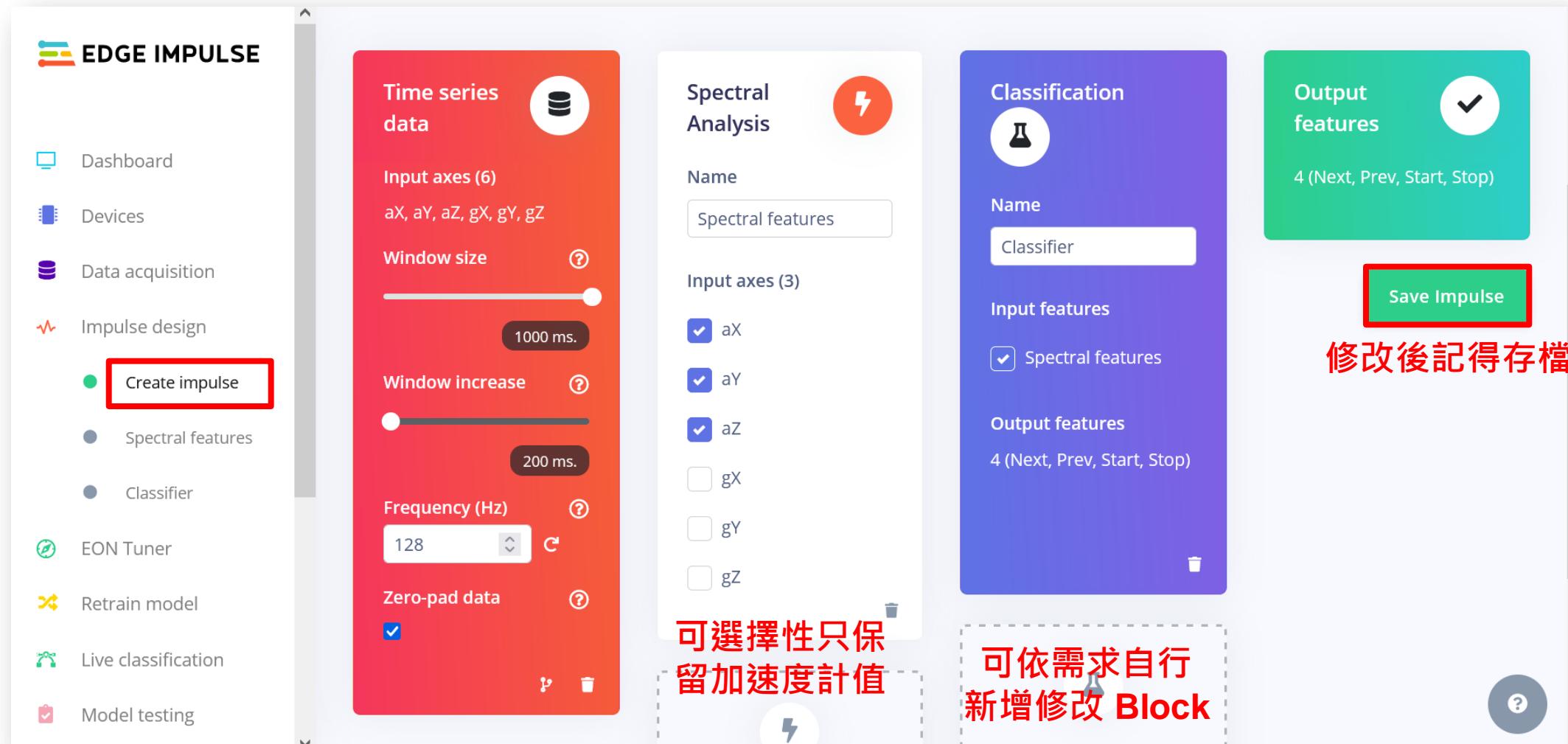
Sensor **Sensor with 6 axes (aX, aY, aZ, gX, gY)**

Frequency **128Hz**

Start sampling

SAMPLE NAME	LABEL	ADDED	LENGTH
unknow.46a8r...	unknow	Today, 14:5...	1s
unknow.46a8r...	unknow	Today, 14:5...	1s
unknow.46a8r...	unknow	Today, 14:5...	1s
unknow.46a8r...	unknow	Today, 14:5...	1s

選擇模型及設定必要參數



EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
- Create impulse**
- Spectral features
- Classifier
- EON Tuner
- Retrain model
- Live classification
- Model testing

Time series data

Spectral Analysis

Classification

Output features

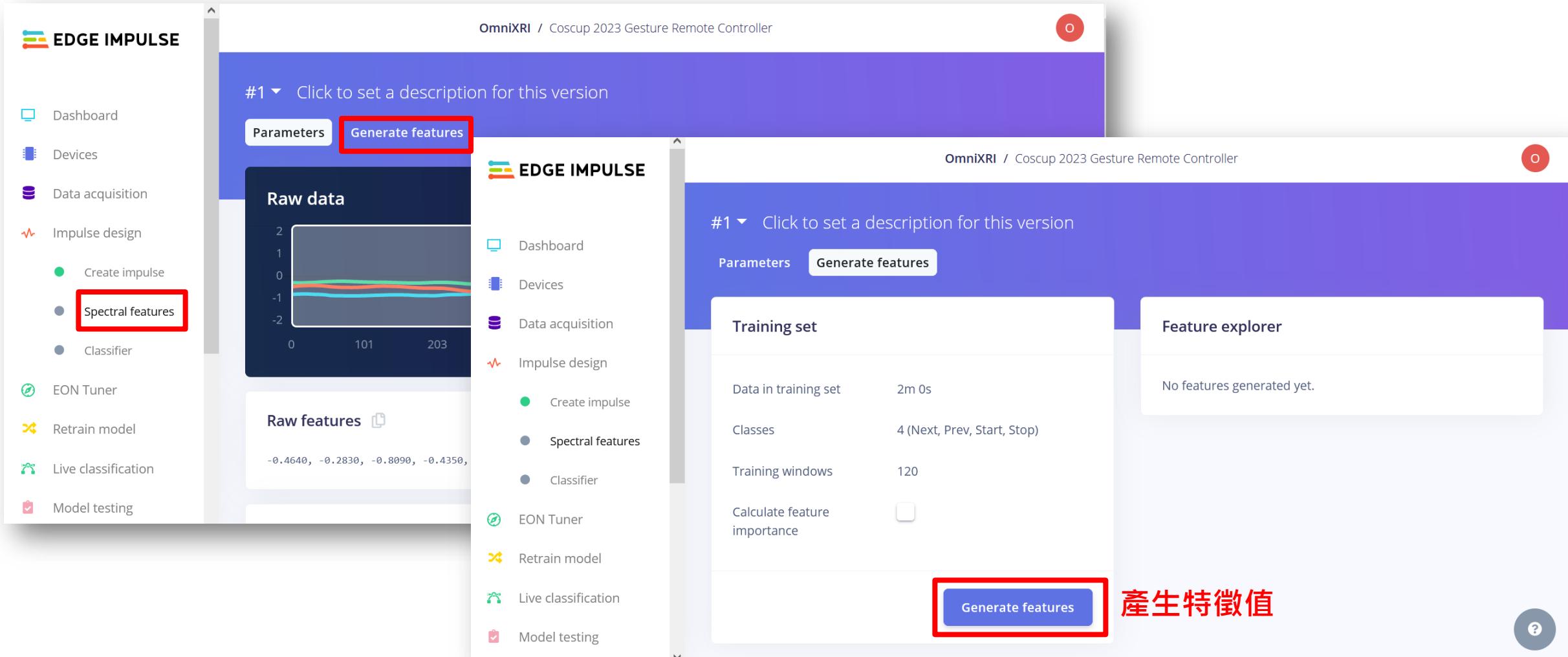
Save Impulse

修改後記得存檔

可選擇性只保留加速度計值

可依需求自行新增修改 Block

提取資料特徵



The screenshot shows the OmniXRI Edge Impulse interface for a project titled "Coscup 2023 Gesture Remote Controller".

Left Sidebar:

- Dashboard
- Devices
- Data acquisition
- Impulse design
- Create impulse
- Spectral features** (highlighted with a red box)
- Classifier
- EON Tuner
- Retrain model
- Live classification
- Model testing

Main Area (Top Left):

#1 ▾ Click to set a description for this version

Buttons: Parameters (disabled), **Generate features**

Raw data: A line graph showing raw data over time. The x-axis ranges from 0 to 203, and the y-axis ranges from -2 to 2. Multiple colored lines represent different sensor data.

Raw features: A list of feature values: -0.4640, -0.2830, -0.8090, -0.4350.

Main Area (Bottom Left):

#1 ▾ Click to set a description for this version

Buttons: Parameters (disabled), **Generate features**

Training set:

- Data in training set: 2m 0s
- Classes: 4 (Next, Prev, Start, Stop)
- Training windows: 120
- Calculate feature importance:

Feature explorer: No features generated yet.

Bottom Center: A large red box highlights the **Generate features** button.

Bottom Right: A red text overlay: **產生特徵值** (Generate Features)

提取特徵結果

Feature generation output

```
still running...
completed 0 / 500 epochs
completed 50 / 500 epochs
completed 100 / 500 epochs
completed 150 / 500 epochs
completed 200 / 500 epochs
completed 250 / 500 epochs
completed 300 / 500 epochs
completed 350 / 500 epochs
completed 400 / 500 epochs
completed 450 / 500 epochs
Fri Jul 28 06:54:26 2023 Finished embedding
Reducing dimensions for visualizations OK
Job completed
```

Feature explorer

- Next
- Prev
- Start
- Stop
- unknown



On-device performance ?

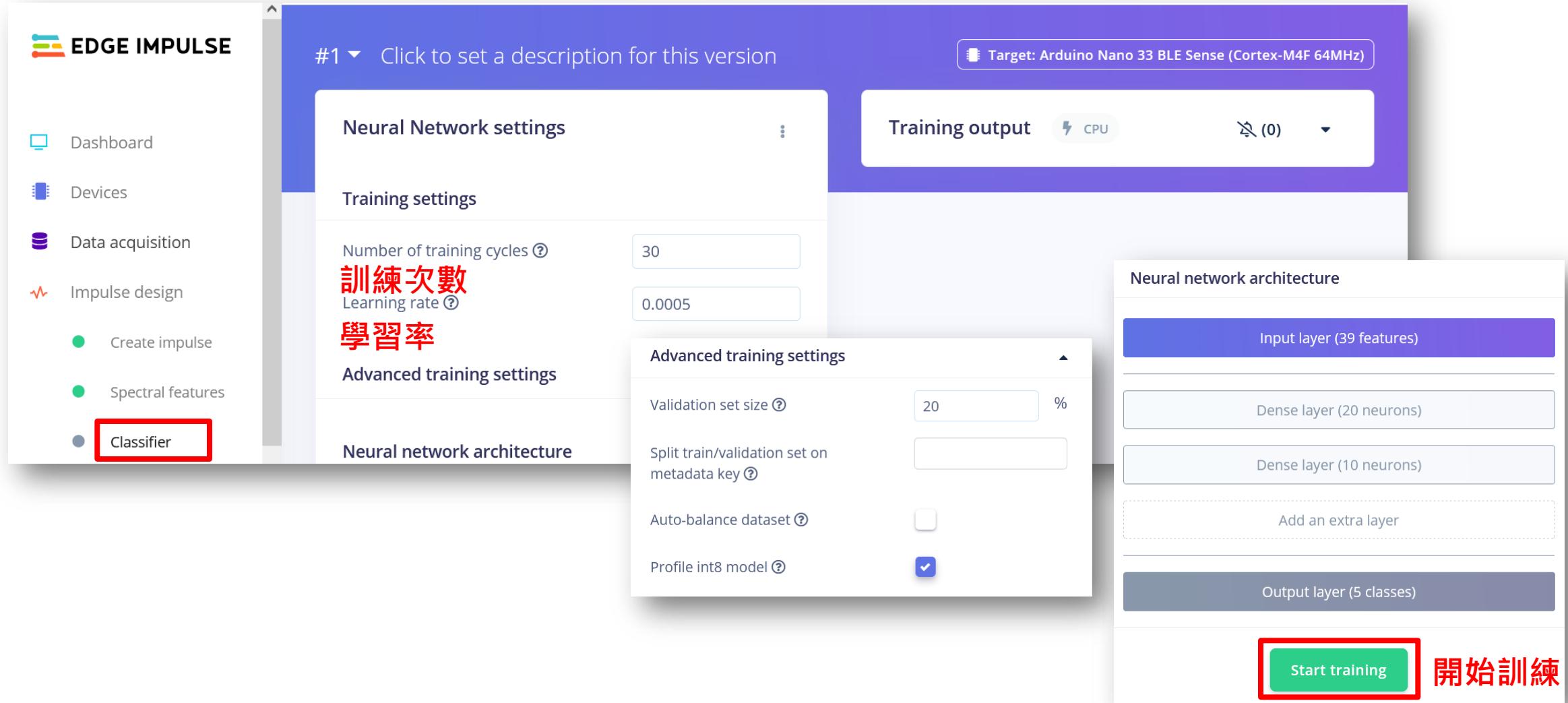
🕒
PROCESSING TIME
23 ms.

🐏 PEAK RAM USAGE

2 KB

以指定的硬體進行資源
使用及推論時間估測

設定分類訓練相關參數



The screenshot shows the Edge Impulse Classifier setup interface. On the left sidebar, the 'Classifier' option is highlighted with a red box. The main area displays training settings and neural network architecture.

Training settings:

- Number of training cycles: 30
- Learning rate: 0.0005

Advanced training settings:

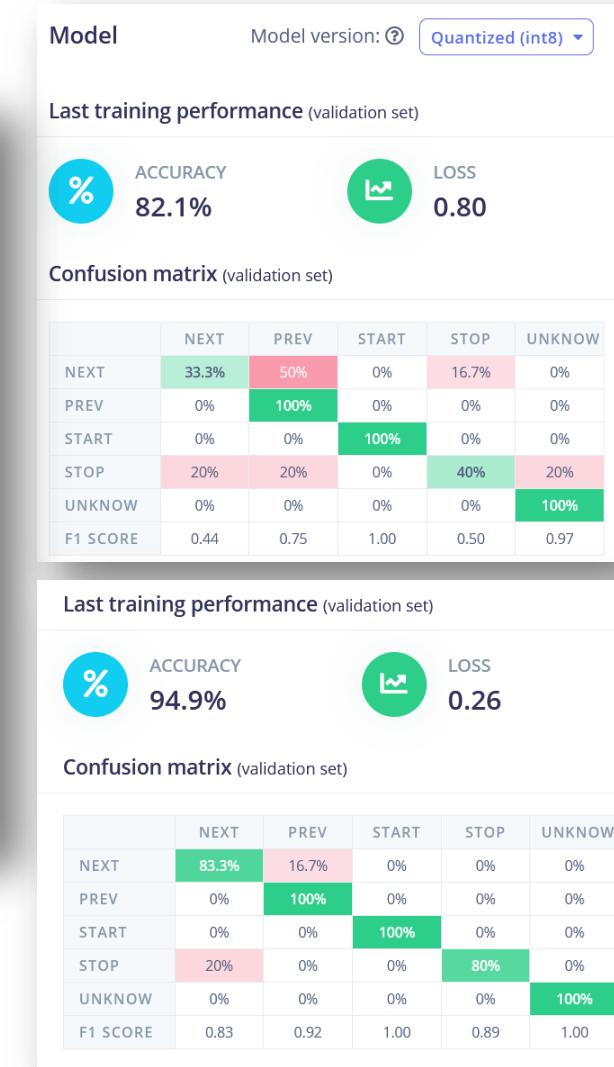
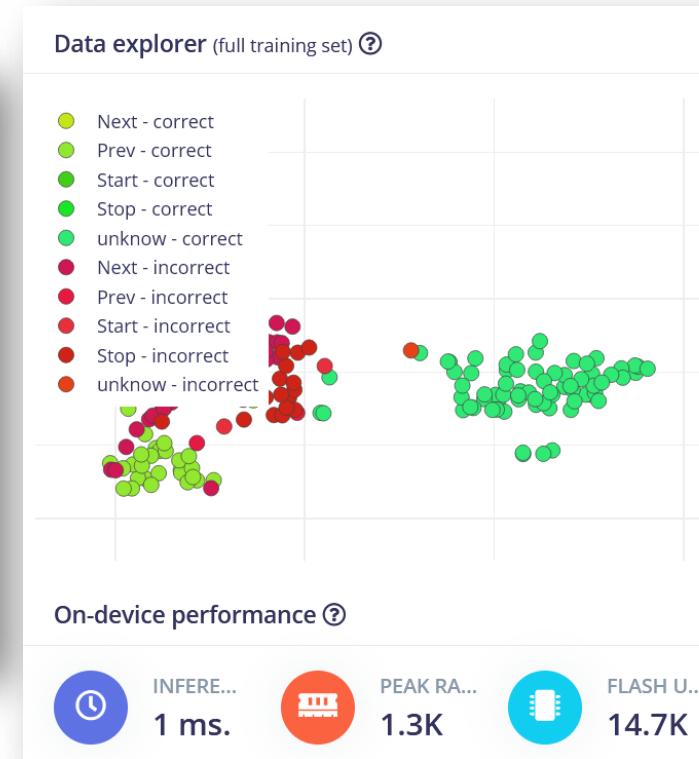
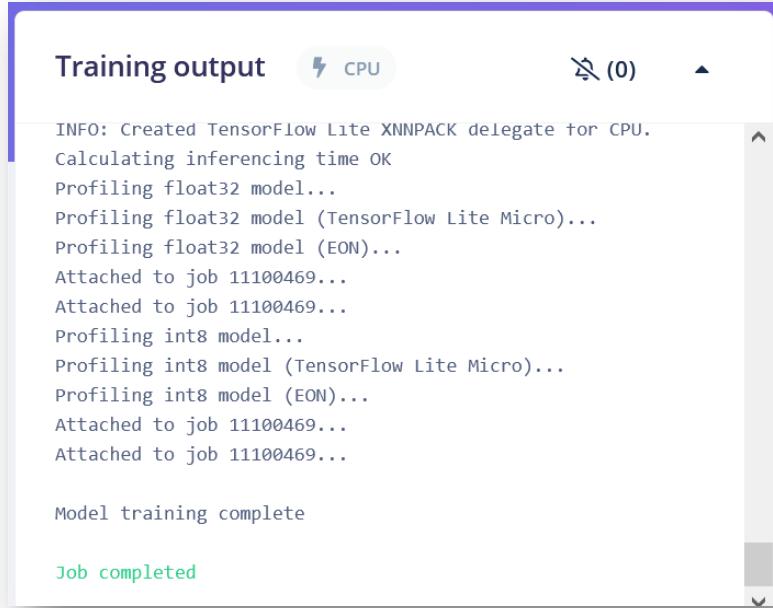
- Validation set size: 20 %
- Split train/validation set on metadata key
- Auto-balance dataset:
- Profile int8 model:

Neural network architecture:

- Input layer (39 features)
- Dense layer (20 neurons)
- Dense layer (10 neurons)
- Add an extra layer
- Output layer (5 classes)

A green button labeled 'Start training' is highlighted with a red box at the bottom right of the architecture section. The text '開始訓練' (Start Training) is overlaid in red next to it.

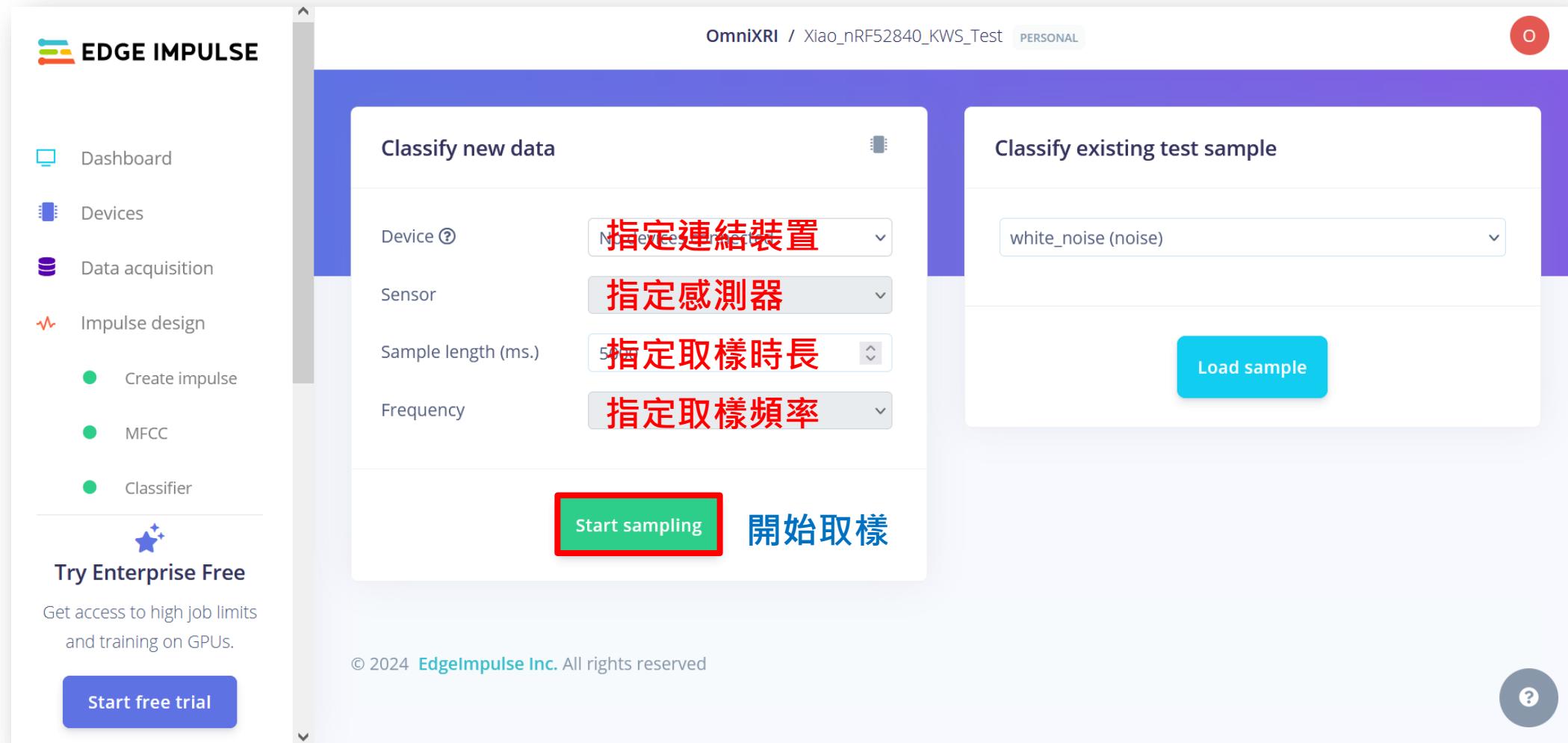
開始進行模型訓練及結果顯示



30
Epoch
結果

100
Epoch
結果

線上測試（從外部裝置取樣）



The screenshot shows the Edge Impulse web interface for a project titled "OmniXRI / Xiao_nRF52840_KWS_Test". The left sidebar includes options like Dashboard, Devices, Data acquisition, Impulse design, Create impulse, MFCC, Classifier, and Try Enterprise Free. The main area has two sections: "Classify new data" and "Classify existing test sample". The "Classify new data" section contains fields for Device (set to "No device selected"), Sensor (highlighted with a red box and labeled "指定連接裝置"), Sample length (ms.) (set to 500), Frequency (highlighted with a red box and labeled "指定取樣頻率"), and a "Start sampling" button (highlighted with a red box and labeled "開始取樣"). The "Classify existing test sample" section shows a dropdown set to "white_noise (noise)" and a "Load sample" button.

選擇部署種類及設定參數

EDGE IMPULSE

- Dashboard
- Devices
- Data acquisition
- Impulse design
 - Create impulse
 - Spectral features
 - Classifier
- EON Tuner
- Retrain model
- Live classification

Configure your deployment

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.](#)

Arduino library x

SELECTED DEPLOYMENT

Arduino library
An Arduino library with examples that runs on most Arm-based Arduino development boards.

MODEL OPTIMIZATIONS
Model optimizations can increase on-device performance but may reduce accuracy.

Enable EON™ Compiler
Same accuracy, up to 50% less memory. [Learn more](#)

	SPECTRAL	CLASSIFIER	TOTAL
LATENCY	23 ms.	1 ms.	24 ms.
RAM	2.2K	1.3K	2.2K
FLASH	-	14.7K	-
ACCURACY			

	SPECTRAL	CLASSIFIER	TOTAL
LATENCY	23 ms.	27 ms.	50 ms.
RAM	2.2K	1.3K	2.2K
FLASH	-	13.6K	-
ACCURACY			

To compare model accuracy, run model testing for all available optimizations. **Run model testing**

Estimate for Arduino Nano 33 BLE Sense (Cortex-M4F 64MHz) [Change target](#)

Build

Latest build

 v2 (Arduino library)
Today, 15:34:05 View docs

Build output

Container image pulled!
Job started
Writing templates...
Writing templates OK

Scheduling job in cluster...
Container image pulled!
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



Built Arduino library

Add this library through the Arduino IDE via:
[Sketch > Include Library > Add .ZIP Library...](#)

Examples can then be found under:
[File > Examples > Xiao_nRF52840_IMU_Test_inferencing](#)



以 Arduino 函式庫(*.zip)方式輸出
預設檔名為「ei-專案名稱-arduino-版本序號.zip」

導入 Arduino 函式庫並進行推論測試(1/2)

- 新增函式庫 **Sketch > Include Library > Add .ZIP Library ...**
- 新增範例 **File > Examples > ei- 專案名稱_inferencing > nano_ble33_sense > nano_ble33_sense_accelerometer** (原始範例輸出結果從 COM 輸出文字串)
- 經編譯會在「**#error “Invalid model for current sensor”**」這列出現「**“invalid model for current sensor”**」，主要原因為Edge Impulse打包時是以Sensor_Fusion方式處理而不是Accelerometer方式造成。
- 點擊選單 **File > Preferences** 找到 Sketchbook Folder，進到該路徑後，進到 \libraries\專案名稱_inferencing\src\model-parameters\ 開啟 **model_metadata.h**。找到「**#define EI_CLASSIFIER_SENSOR EI_CLASSIFIER_SENSOR_FUSION**」，將定義改成「**EI_CLASSIFIER_SENSOR_ACCELEROMETER**」存檔即可。

導入 Arduino 函式庫並進行推論測試(2/2)

- 回到 Arduino 範例後會發現使用的運動感測器不同，所以需將「`#include <Arduino_LSM9DS1.h>`」註解掉並新增下列程式

```
#include <LSM6DS3.h>
#include <Wire.h>
LSM6DS3 myIMU(I2C_MODE, 0x6A);
```

- 在Setup函式中的初始化也要將「`if (!IMU.begin()) {`」修改為「`if (!myIMU.begin()) {`」

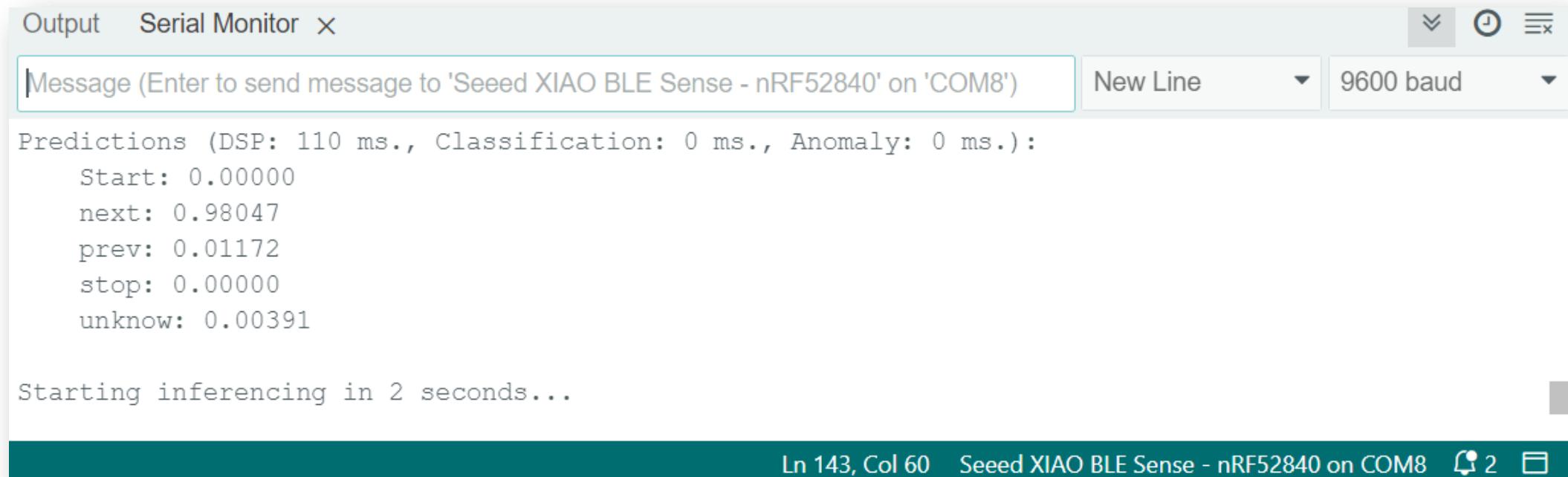
- 另外由於讀取IMU運動感測器函式不同因此也需修改如左。

- 重新編譯前確認開發板是設定在「**Seeed nRF52 mbed-enabled Boards** > Seeed XIAO BLE Sense - nRF52840」，不然程式運行後會找不到IMU LSM6DS3。

```
17  /* Includes -----
18  #include <Xiao_nRF52840_IMU_Test_inferencing.h>
19  // #include <Arduino_LSM9DS1.h> //Click here to get the libr
20  #include <LSM6DS3.h>
21  #include <Wire.h>
22  /* Constant defines -----
23  #define CONVERT_G_TO_MS2      9.80665f
24  #define MAX_ACCEPTED_RANGE    2.0f           // starting 03/2022
25
26  LSM6DS3 myIMU(I2C_MODE, 0x6A);      //I2C device address 0x6A|
```

```
99   //           IMU.readAcceleration(buffer[ix], buffer[ix + 1],
100  buffer[ix]     = myIMU.readFloatAccelX();
101  buffer[ix + 1] = myIMU.readFloatAccelY();
102  buffer[ix + 2] = myIMU.readFloatAccelZ();
```

手勢辨識結果（Arduino部份）



The screenshot shows the Arduino Serial Monitor interface. The top bar includes tabs for 'Output' and 'Serial Monitor' (with a close button), and various control icons. The main area displays the following text:

```
Message (Enter to send message to 'Seeed XIAO BLE Sense - nRF52840' on 'COM8')  
New Line 9600 baud  
  
Predictions (DSP: 110 ms., Classification: 0 ms., Anomaly: 0 ms.):  
Start: 0.00000  
next: 0.98047  
prev: 0.01172  
stop: 0.00000  
unknow: 0.00391  
  
Starting inferencing in 2 seconds...  
  
Ln 143, Col 60 Seeed XIAO BLE Sense - nRF52840 on COM8 2
```

- 推論結果，包括前處理(DSP)、分類及異常時間(ms)
- 將五個標籤的置信度顯示出來，1.0為完全正確，0.0為完全不正確，可設置門檻值來限制置信度不高之答案。
- **No Code**型式，範例程式直接編譯上傳，不需改寫任何程式，輸出結果由 COM 接收文字串。

使用 Google TensorFlow 完成訓練部署



The screenshot shows a dark-themed wiki page from [Seeed Studio](https://wiki.seeedstudio.com). The left sidebar contains a navigation menu with sections like "Zephyr(RTOS) 编程", "编程语言", "硬件基础教学", "蓝牙使用", "嵌入式机器学习", "基于 Edge Impulse 的运动识别", "基于 Edge Impulse 的语音识别", "基于 TensorFlow Lite 的运动识别" (which is highlighted in green), "基于 TensorFlow Lite 的语音识别", "实用教程", "XIAO ESP32C3", "XIAO ESP32S3 (Sense)", and "XIAO 的兼容扩展板". The main content area has a breadcrumb trail: Home > XIAO nRF52840 (Sense) > 嵌入式机器学习 > 基于 TensorFlow Lite 的运动识别. The title of the page is "基于 TensorFlow Lite 的运动识别". It features the TensorFlow Lite logo and an image of the XIAO nRF52840 Sense module. A descriptive text at the bottom states: "本 wiki 将演示如何在 Seeed Studio XIAO nRF52840 Sense 上使用 TensorFlow Lite，并使用板载加速度计检测打孔和弯曲等手势。在这里，数据训练将在设备本身上完成。"

<https://wiki.seeedstudio.com/cn/XIAO-BLE-Sense-TFLite-Getting-Started/>

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<https://omnixri.blogspot.com/2024/05/20240509tinym12.html>
- iThome 2021 (13屆) 鐵人賽【arm platforms組】完賽記錄－爭什麼，把AI和MCU摻在一起做tinyML就對了！
<https://omnixri.blogspot.com/2021/10/ithome-2021-13-arm-platforms-aimcutinyml.html>
- 純電科技(Seeed Studio) Wiki 文档平台 - XIAO nRF52840 (Sense) 开发板
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<https://atadiat.com/en/e-towards-understanding-imu-basics-of-accelerometer-and-gyroscope-sensors/>

- Leonardo Cavagnis, Gesture Recognition with Edge Impulse and Arduino

<https://leonardocavagnis.medium.com/gesture-recognition-with-edge-impulse-and-arduino-0da09c0873d5>

- 【iCShop開箱趣】ep7 Seeed Studio XIAO nRF52840 Sense Review | 把神經網路放到MCU原來這麼簡單？TinyML Tutorial 範例教學

https://youtu.be/Faka_ahto0o

- 林士允(Felix Lin) · 【Maker 玩 AI】XIAO nRF52840 Sense - 入門 TinyML 就靠它！

<https://vmaker.tw/archives/65534>

沒有最邊



只有更邊



歐尼克斯實境互動

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[開 源 : https://github.com/OmniXRI](#)

[YOUTUBE 直播 : https://www.youtube.com/@omnidri1784streams](#)