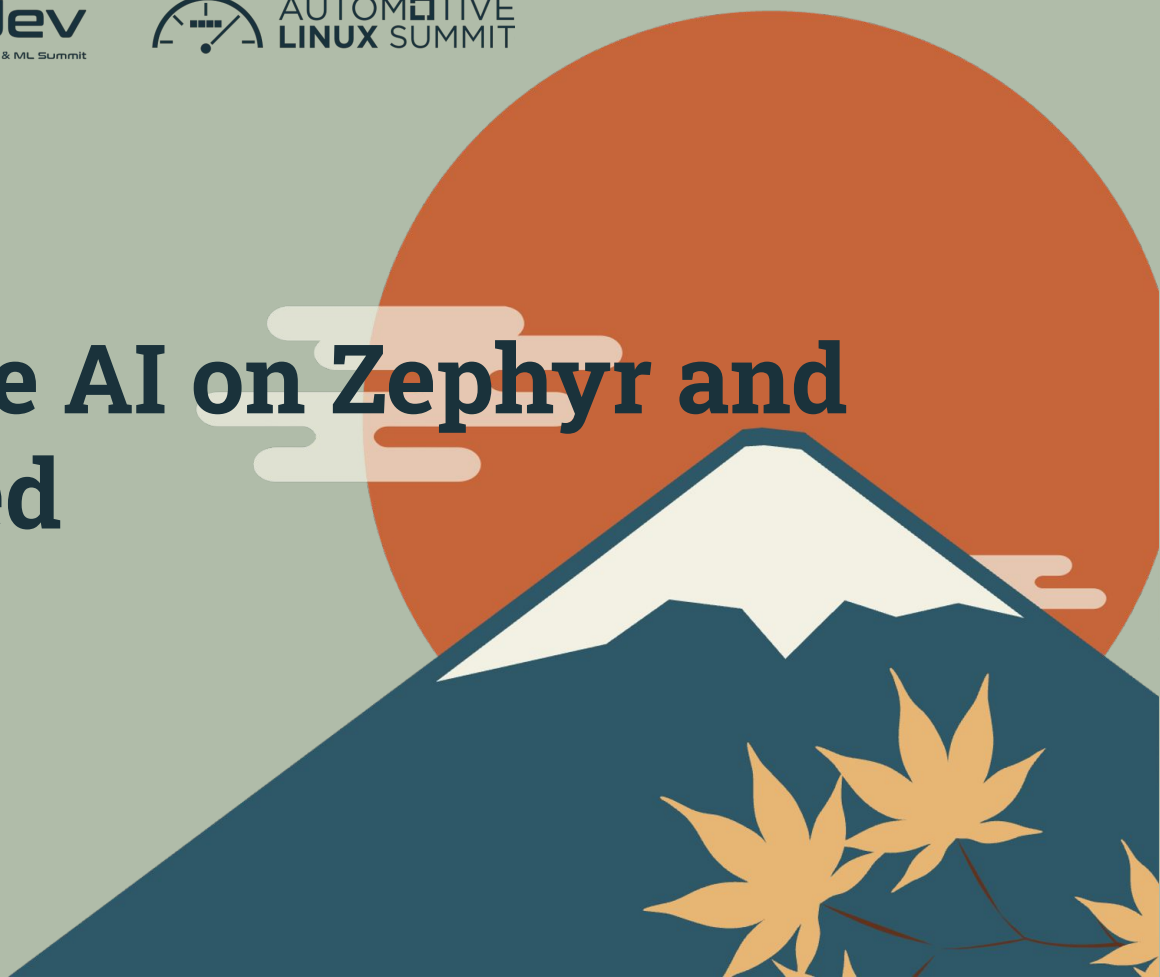


Lightning Talk:

Debugging Edge AI on Zephyr and Lessons Learned



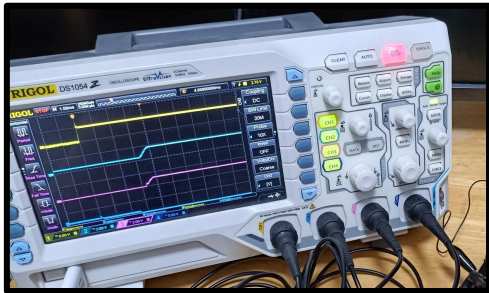
About Me

I am a Hardware and Hobbyist Engineer

Tomohiro Kaneko
Brother Industries, Ltd.

This presentation is **about My Hobby.**
(Not work-related!)

Occupation: Hardware Engineer.



Agenda

An Beginner Introduction to Edge AI on Zephyr

- The State of Edge AI on Zephyr
- A Beginner-Friendly Approach
- Hardware That Worked for Me & Short Demo
- Summary

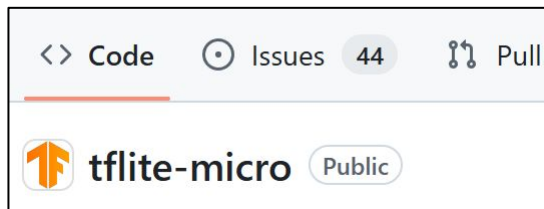
Lightning Talk:
(About 10~15 minutes)

The State of Edge AI on Zephyr

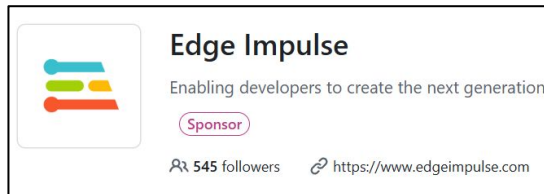
Zephyr already provides support

Major Edge AI frameworks already support for Zephyr.

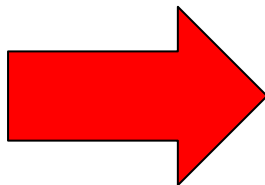
Edge AI Models



<https://github.com/tensorflow/tflite-micro>

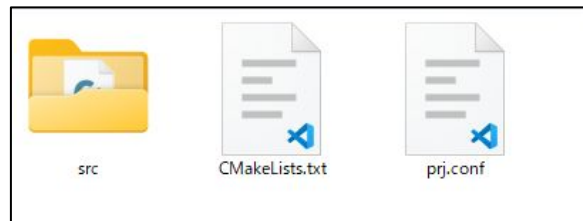


<https://edgeimpulse.com/>



**We can build
together.**

Zephyr Project



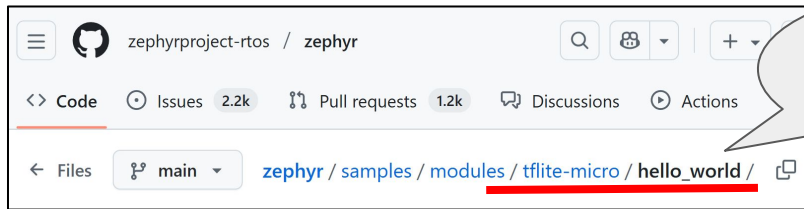
<https://www.zephyrproject.org/>

It's easy to deploy and run Edge AI models directly on Zephyr.

Many official support

There's a lot of support, including Samples, SDKs, Boards.

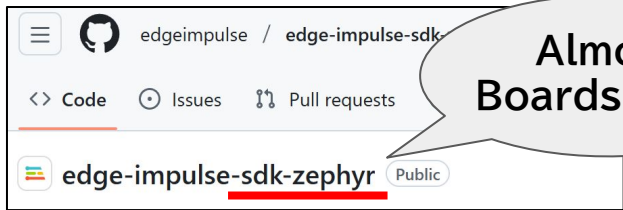
• Zephyr Sample (Hello World)



Almost
Boards Work

<https://github.com/zephyrproject-rtos/zephyr/tree/main/samples/modules/tflite-micro>

• Edge Impulse SDK Zephyr



Almost
Boards Work

<https://github.com/edgeimpulse/edge-impulse-sdk-zephyr>

• Edge Impulse Complete Samples with sensors



Temp, Humidity, Accel...
sensors implemented

Many official
Board support

Example

<https://github.com/edgeimpulse/firmware-nordic-thingy91>

<https://www.nordicsemi.jp/tools/thingy91/>

For Beginner (and Me)...

To make it easier to Debug Edge AI on Zephyr...

But I don't have official
support board...



≒\$100~\$150 ?

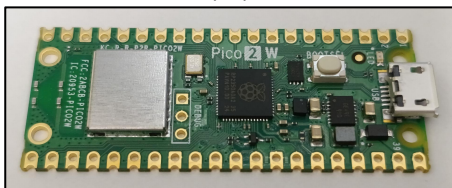
Temp, Humidity, Accel...
sensors implemented



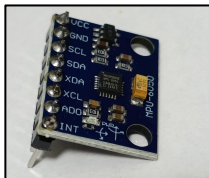
How I Got Started?

Useful & Low-Cost Boards

Pico2(W) ≒\$10



+



Accel Sensor
≒\$3

OR



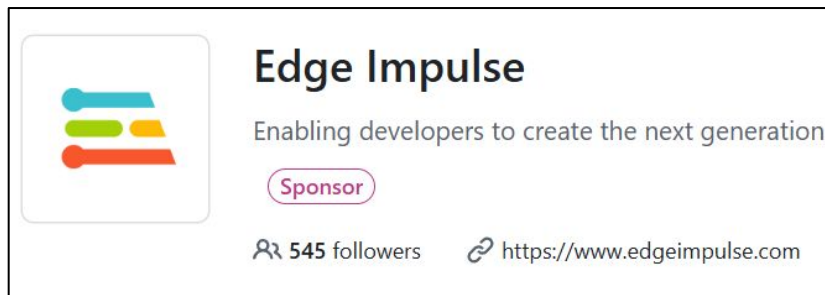
XIAO nRF54L15
Sense ≒\$15

Integrated with
• Accel sensor
• Micropone

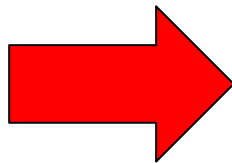
A Beginner-Friendly Approach

Edge Impulse

A development platform for lightweight AI models.



<https://edgeimpulse.com/>



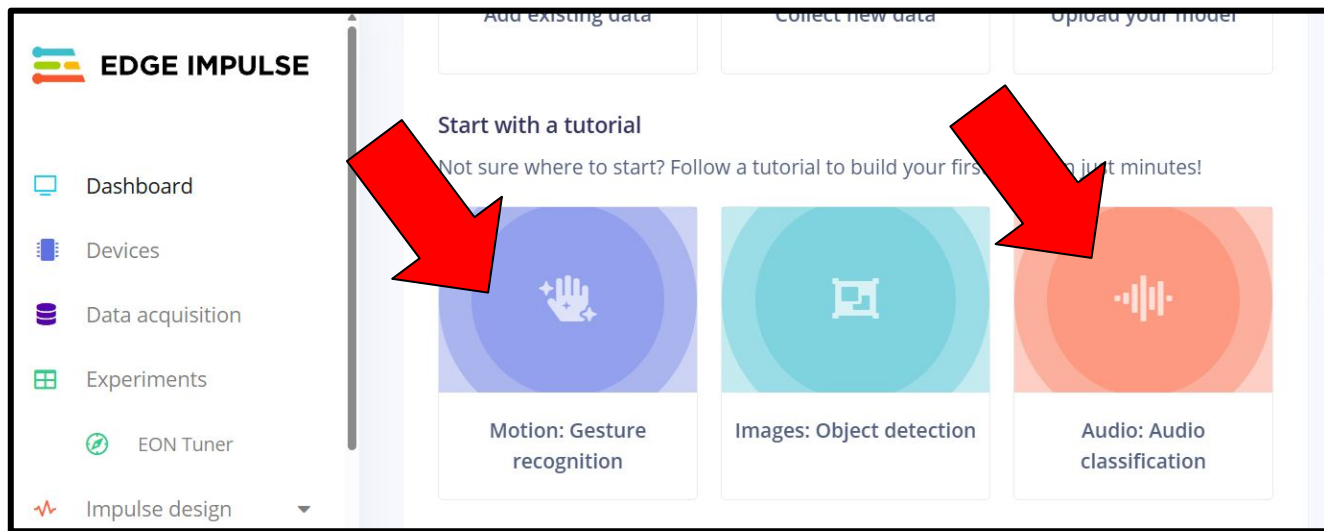
<https://www.zephyrproject.org/>

■ Overview:

- Easily create AI models (machine learning models) from sensor data.
- Create lightweight models → Integrate them into Zephyr.

What kind of models can you build?

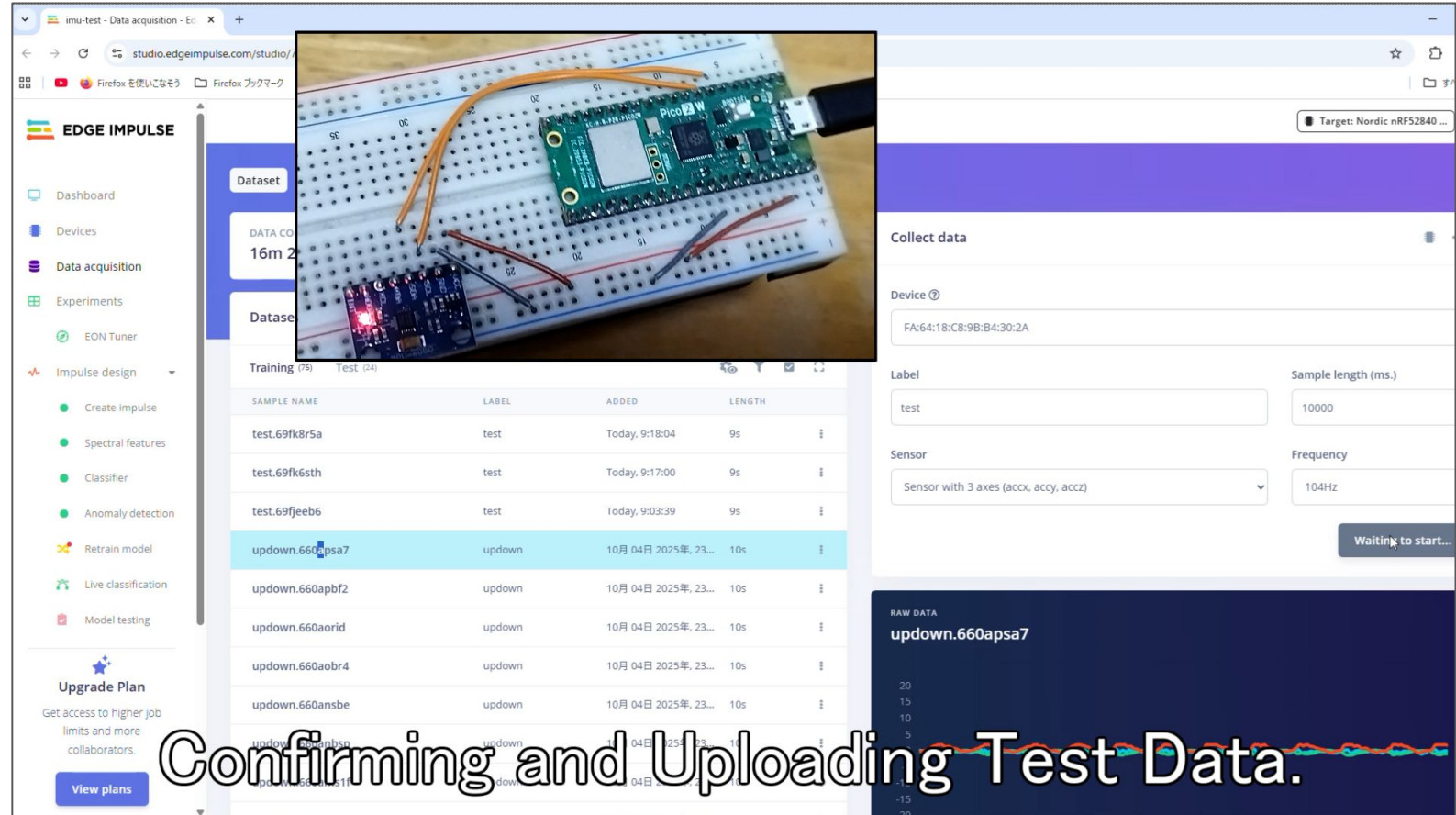
Lightweight AI models for Motion, Images, and Audio...



<https://edgeimpulse.com/>

■ Today, I will introduce "Motion" and "Audio" example with useful Board.

Uploading Demo for Edge Impulse



The screenshot displays the Edge Impulse Studio web interface. On the left is a sidebar with navigation options: Dashboard, Devices, Data acquisition, Experiments, EON Tuner, and Impulse design. The main area is divided into sections for Dataset, Training, and Test data. A table lists training samples, with 'updown.660apsa7' highlighted. The Test section shows configuration options for data collection, including device ID, label, sample length, sensor type, and frequency. A 'Waiting to start...' button is visible. An inset image shows a Pico 2 W microcontroller on a breadboard connected to a USB cable.

SAMPLE NAME	LABEL	ADDED	LENGTH
test.69fk8r5a	test	Today, 9:18:04	9s
test.69fk6sth	test	Today, 9:17:00	9s
test.69fjeeb6	test	Today, 9:03:39	9s
updown.660apsa7	updown	10月 04日 2025年, 23...	10s
updown.660apbf2	updown	10月 04日 2025年, 23...	10s
updown.660aorid	updown	10月 04日 2025年, 23...	10s
updown.660aobr4	updown	10月 04日 2025年, 23...	10s
updown.660ansbe	updown	10月 04日 2025年, 23...	10s

Collect data

Device ②
FA:64:18:C8:9B:B4:30:2A

Label
test

Sample length (ms.)
10000

Sensor
Sensor with 3 axes (accx, accy, accz)

Frequency
104Hz

Waiting to start...

RAW DATA
updown.660apsa7

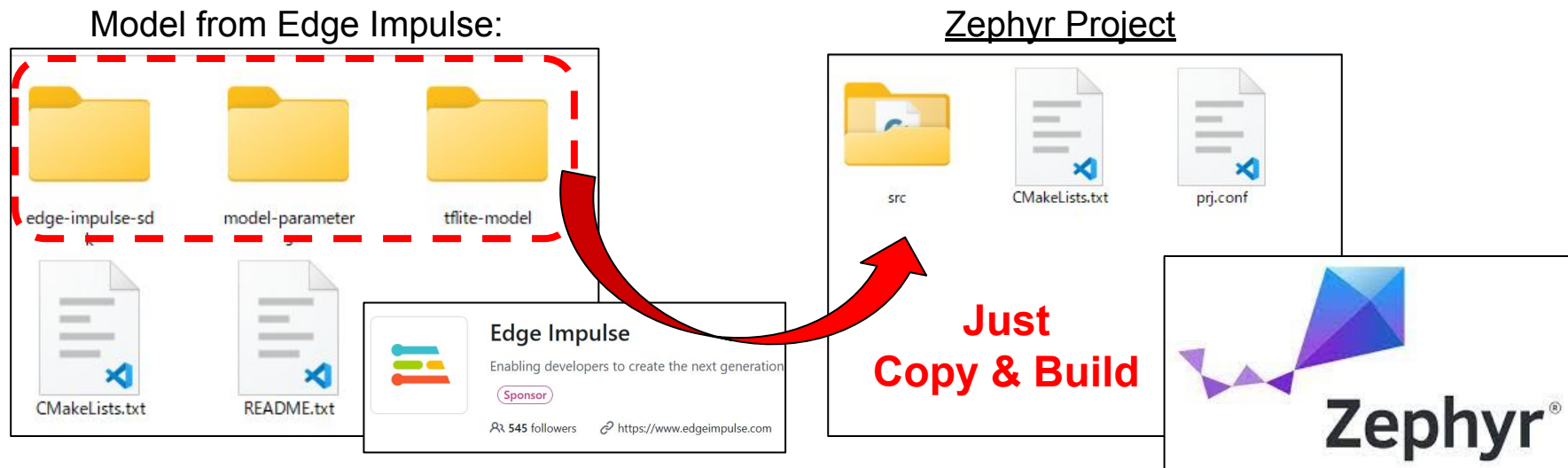
20
15
10
5
0
-5
-10
-15
-20

Confirming and Uploading Test Data.

<https://youtu.be/5CdPXB99Jo0>

Integrating a Lightweight AI Model

The program and instructions are available on GitHub.



■ My Test Overview

- Audio : Loop of [Save 1 second of Mic data] → [Run inference]
- Motion: Loop of [Save 2 seconds of Accel data] → [Run inference]

Good Thing for Zephyr

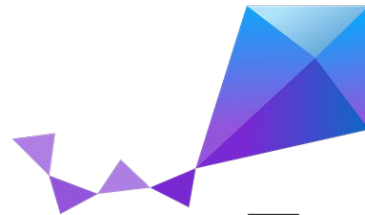
Zephyr & Edge AI fit in small RAM and ROM.

- Build result example (Motion Recognition)

ROM:177kB, RAM:27kB

Match Low-end
SoCs/CPU's

```
Memory region    Used Size  Region Size  %age Used
  FLASH:         176816 B      4 MB      4.22%
  RAM:           26640 B     520 KB      5.00%
  IDT_LIST:       0 GB       32 KB      0.00%
Generating files from C:/Users/ioten/zephyrproject/test/
/zephyr/zephyr.elf for board: rpi_pico2
Converted to uf2, output size: 353792, start address: 0x
Wrote 353792 bytes to zephyr.uf2
```



Zephyr®

■ Including the AI model, fits into kBytes of RAM and ROM.

Hardware That Worked for Me & Short Demo

My Test Example

These were made for hobby, so please use just as a reference.

■ GitHub

- zephyr-ei-xiao-nrf-demo

XIAO nRF54L15 Sense

<https://github.com/iotengineer22/zephyr-ei-xiao-nrf-demo>

We can use
Useful & Low-Cost Boards

- pico2-ei-zephyr-demo

Raspberry Pi Pico 2(W) & Sensor Board

<https://github.com/iotengineer22/pico2-ei-zephyr-demo>

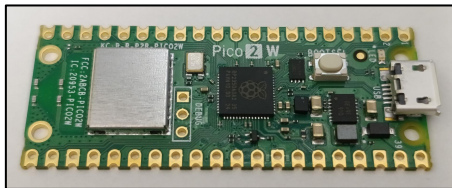
XIAO nRF54L15 Sense ≒\$15



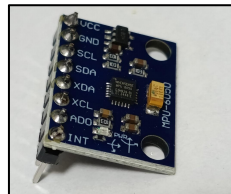
Integrated with

- Accel sensor
- Microphone

Pico2(W) ≒\$10



Sensor ≒\$3



Motion Demo (XIAO nRF54L15 Sense)

The screenshot displays the nRF Connect GUI for the XIAO nRF54L15 Sense module. The main window shows a video feed of a red textured surface with a white sensor. The console window displays the following text:

```
imu_real_inference
main.cpp 3, U x
filed 2-second cycle loop
onds of data ---
es for the next inference...\n", NUM_SAMPLES_PER_IN

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms):
circle: 0.00000
flick: 0.00000
idle: 0.99609
updown: 0.00391
anomaly score: -0.065

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms):
circle: 0.71894
flick: 0.00391
idle: 0.00391
updown: 0.28125
anomaly score: 0.138

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 37 ms, Classification: 0 ms, Anomaly: 1 ms):
circle: 0.21875
flick: 0.76172
idle: 0.00391
updown: 0.01172
anomaly score: 0.757

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 38 ms, Classification: 0 ms, Anomaly: 0 ms):
circle: 0.23828
flick: 0.71484
idle: 0.00391
updown: 0.04297
anomaly score: 0.985

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms):
circle: 0.40234
flick: 0.55078
idle: 0.00391
updown: 0.04688
anomaly score: 0.998

Collecting 208 samples for the next inference...
.....
Data collection complete. Running inference...
Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms):
circle: 0.40234
flick: 0.55078
idle: 0.00391
updown: 0.04688
anomaly score: 0.998
```

The console window also shows the following text:

```
imu_real_inference (1 configuration | 2 C...
build sysbuild
imu_real_inference XIAO nRF54L15
+ Add build configuration

IMU_REAL_INFERENCE build
nRF Connect SDK v3.0.0
> Output files
> Config files

ACTIONS build
nRF Connect SDK Toolchain v2.0.0
Build
Debug
Flash
nRF Kconfig GUI

CONNECTED DEVICES
master 72.0.1
```

Three specific inference results are highlighted with colored boxes:

- Red box: Collecting 208 samples for the next inference... Data collection complete. Running inference... Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms): circle: 0.00000, flick: 0.00000, idle: 0.99609, updown: 0.00391, anomaly score: -0.065
- Cyan box: Collecting 208 samples for the next inference... Data collection complete. Running inference... Predictions (DSP: 37 ms, Classification: 1 ms, Anomaly: 0 ms): circle: 0.71894, flick: 0.00391, idle: 0.00391, updown: 0.28125, anomaly score: 0.138
- Green box: Collecting 208 samples for the next inference... Data collection complete. Running inference... Predictions (DSP: 37 ms, Classification: 0 ms, Anomaly: 1 ms): circle: 0.21875, flick: 0.76172, idle: 0.00391, updown: 0.01172, anomaly score: 0.757

A large text overlay at the bottom center reads "Flick testing..."

<https://youtu.be/FqW0INMxQlQ>

Motion Demo (Raspberry Pi Pico 2(W))

Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):

- circle: 0.00000
- flick: 0.00000
- idle: 0.99609
- updown: 0.00000
- anomaly score: -0.058

Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):

- circle: 0.00391
- flick: 0.00000
- idle: 0.15234
- updown: 0.84375
- anomaly score: 0.320

Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):

- circle: 0.05469
- flick: 0.88281
- idle: 0.02734
- updown: 0.03516
- anomaly score: 0.573

Terminal Output:

```
[00:00:58.992,000] <inf> main: idle: 0.31641
[00:00:58.993,000] <inf> main: updown: 0.68359
[00:00:58.994,000] <inf> main: anomaly score: 0.230
[00:00:58.994,000] <inf> main: Collecting 200 samples for the next inference...
[00:01:00.867,000] <inf> main: Data collection complete.
[00:01:00.909,000] <inf> main: Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):
[00:01:00.909,000] <inf> main: circle: 0.00000
[00:01:00.909,000] <inf> main: flick: 0.00000
[00:01:00.910,000] <inf> main: idle: 0.42188
[00:01:00.910,000] <inf> main: updown: 0.57812
[00:01:00.911,000] <inf> main: anomaly score: 0.268
[00:01:00.911,000] <inf> main: Collecting 200 samples for the next inference...
[00:01:02.785,000] <inf> main: Data collection complete.
[00:01:02.827,000] <inf> main: Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):
[00:01:02.827,000] <inf> main: circle: 0.00391
[00:01:02.828,000] <inf> main: flick: 0.00000
[00:01:02.829,000] <inf> main: idle: 0.28125
[00:01:02.829,000] <inf> main: updown: 0.71484
[00:01:02.830,000] <inf> main: anomaly score: 0.382
[00:01:02.830,000] <inf> main: Collecting 200 samples for the next inference...
[00:01:04.702,000] <inf> main: Data collection complete.
[00:01:04.743,000] <inf> main: Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):
[00:01:04.744,000] <inf> main: circle: 0.40625
[00:01:04.744,000] <inf> main: flick: 0.00000
[00:01:04.745,000] <inf> main: idle: 0.18750
[00:01:04.746,000] <inf> main: updown: 0.34766
[00:01:04.746,000] <inf> main: anomaly score: 0.539
[00:01:04.747,000] <inf> main: Collecting 200 samples for the next inference...
[00:01:06.619,000] <inf> main: Data collection complete.
[00:01:06.661,000] <inf> main: Predictions (DSP: 39 ms, Classification: 0 ms, Anomaly: 0 ms):
[00:01:06.662,000] <inf> main: circle: 0.57422
[00:01:06.662,000] <inf> main: flick: 0.30859
[00:01:06.663,000] <inf> main: idle: 0.01562
[00:01:06.663,000] <inf> main: updown: 0.10156
[00:01:06.664,000] <inf> main: anomaly score: 0.576
[00:01:06.664,000] <inf> main: Collecting 200 samples for the next inference...
[00:01:08.536,000] <inf> main: Data collection complete.
```

Flick testing...

シリアル ポートに送信するメッセージを入力し、送信を押す

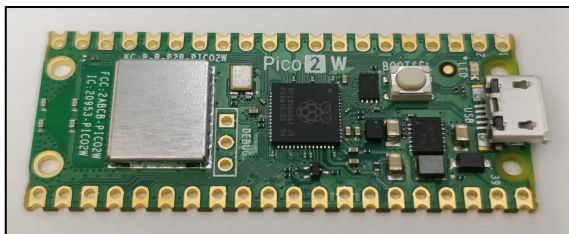
テキストとして送信 Ctrl +

行 21, 列 23 UTF-8 LF C++ Win32 pico-imu_inference

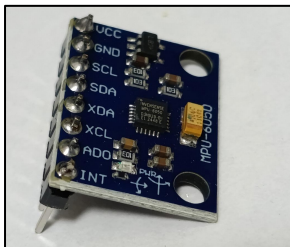
<https://youtu.be/kFZd0z9Mo5U>

Motion Recognition Live Demo (Idle, Flick, Updown)

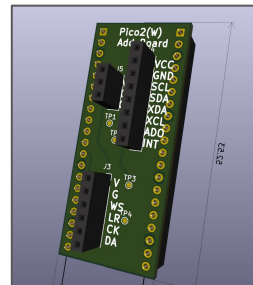
Pico2(W) ÷ \$10



Accel Sensor
(MPU-6050) ÷ \$3

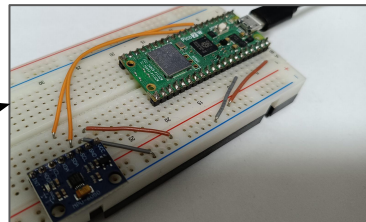


Pico2(W) Add Board ÷ \$5



■PCB_DATA(GitHub)
<https://github.com/iotengin/er22/pico2-ei-zephyr-demo/tree/main/pcb>

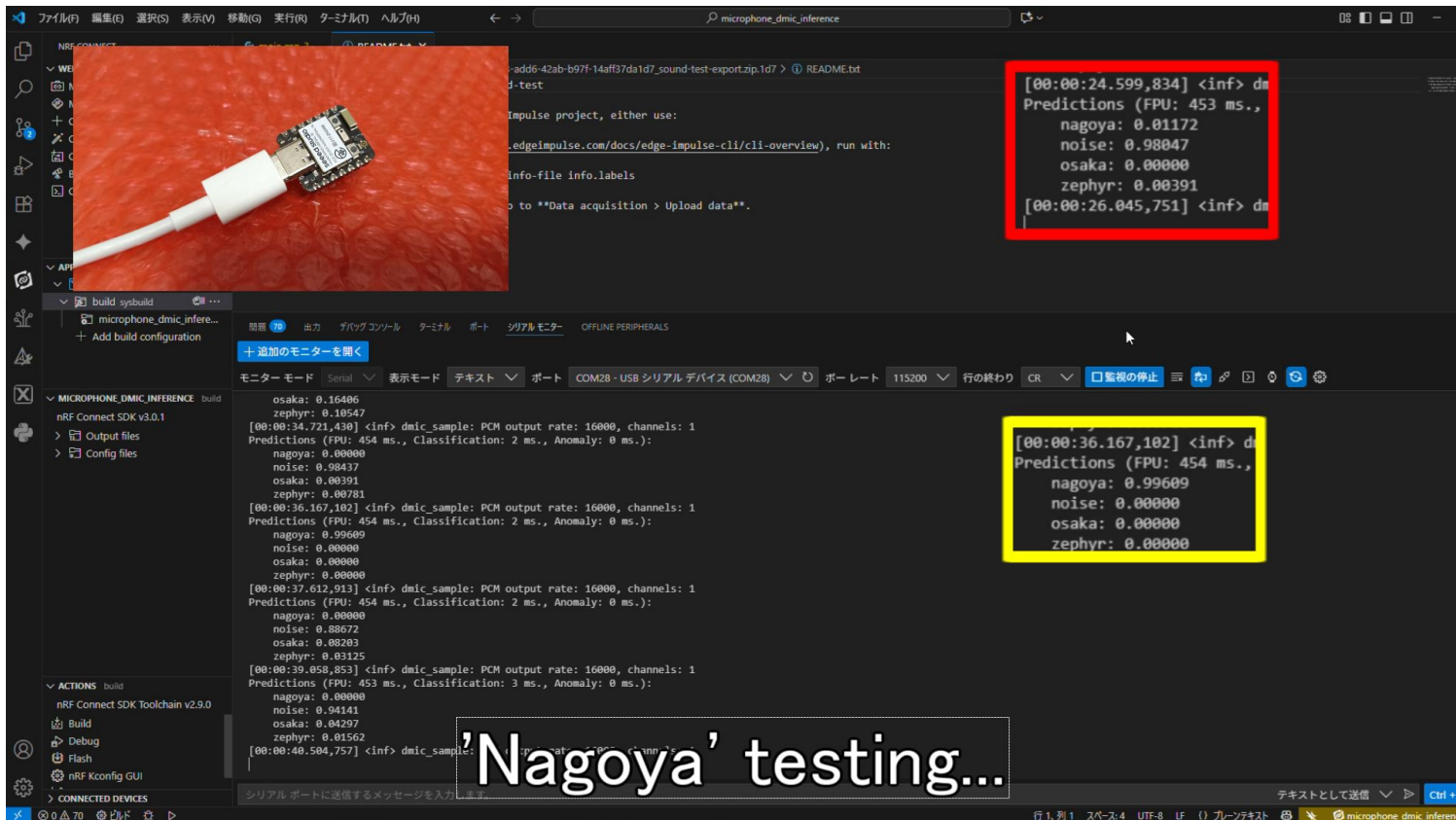
(Or Bread Board with Wire ÷ \$10)



Pico2(W)	Sensor (MPU-6050)
39 (VSYS)	1 (VCC)
38 (GND)	2 (GND)
7 (I2C0 SCL)	3 (SCL)
6 (I2C0 SDA)	4 (SDA)

*Anyone can buy from Online marketplaces

Audio Demo (XIAO nRF54L15 Sense)



microphone_dmic_inference

[00:00:24.599,834] <inf> dm
Predictions (FPU: 453 ms.,
nagoya: 0.01172
noise: 0.98047
osaka: 0.00000
zephyr: 0.00391
[00:00:26.045,751] <inf> dm

+追加のモニターを開く

モニターモード Serial 表示モード テキスト ポート COM28 - USB シリアル デバイス (COM28) ボーレート 115200 行の終わり CR 監視の停止

MICROPHONE_DMIC_INFERENCE build
nRF Connect SDK v3.0.1
Output files
Config files

ACTIONS build
nRF Connect SDK Toolchain v2.9.0
Build
Debug
Flash
nRF Kconfig GUI

CONNECTED DEVICES

シリアルポートに送信するメッセージを入力

行 1, 列 1 スペース 4 UTF-8 LF () プレーンテキスト microphone_dmic_inferenc

'Nagoya' testing...

<https://youtu.be/lbxTMiPwFTU>

Audio Recognition Live Demo (Tokyo, Japan, Zephyr)

XIAO nRF54L15 Sense ≐ \$15



Integrated with

- Accel sensor
- Microphone

*Anyone can buy from Online marketplaces

Summary

Summary

I was able to debug Edge AI on Zephyr with useful boards !



- XIAO nRF54L15 Sense & Pico 2(W)
match for debugging Edge AI on Zephyr.
- Lightweight Edge AI model fit Zephyr.
(Including the AI model, fits into kBytes of RAM/ROM.)
- If you're interested, please debug it.
(Zephyr already provides many support for Edge AI.)

In Closing

Thank you for your attention.

Q&A Example:1

Question	Answer
Can we test this <u>on other boards</u> ?	Yes, likely. Edge Impulse supports many ICs (e.g., Arduino, NXP, Renesas, ST). https://docs.edgeimpulse.com/hardware
Is Edge Impulse <u>free to use</u> ?	Yes. Individuals can use the service for free with some limitations, which is sufficient for this demo level. https://edgeimpulse.com/pricing
<u>How long</u> did the training take?	Very short time— about 1 minute for both audio and motion data.
<u>Which deployment mode</u> did you use in Edge Impulse?	We deployed using the C++ Library . (They recently added Zephyr support, which might be worth testing.) https://www.edgeimpulse.com/blog/announcing-the-edge-impulse-zephyr-module/
Can we run the <u>Audio demo</u> on Raspberry Pi Pico 2?	Maybe. It should be possible by reading I2S/PDM data using PIO mode. (Scheduled for testing during the winter break.)
Is a <u>Video(Image) demo</u> possible?	Maybe. We believe it can be implemented even on low-spec SoCs using an SPI camera. (Scheduled for testing during the winter break.)
Why is the model <u>so lightweight</u> ?	The model matrices are hard-coded into the .h files. This trades off generality and flexibility for extremely light weight .

Q&A Example:2

Question	Answer
What was the most <u>difficult point</u>?	Setting up the configuration files (CMakeLists and prj.conf) for Zephyr. Since there were many examples for Arduino + Edge Impulse, I adapted those. Also, managing naming conflicts, especially in the USB serial area, between the recent Edge Impulse SDK and Zephyr device names.
<u>Why did you choose</u> Edge Impulse?	I first used it for the Hardware contest. I found the platform interesting, so I have continued testing and debugging with it. (I will talk about this further in the session starting at 16:40.)