Edge Computing Lab

Class: TY-AIEC

School of Computing, MIT Art Design Technology University

Academic Year: 2024-25

Experiment No. 8

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Introduction

The "magic wand" project that can recognize gestures using an accelerometer and an ML classification model on Edge Devices

Objective: Build a project to detect the accelerometer values and convert them into gestures

Tasks:

- Generate the dataset for Accelerometer Motion (Up-Down, Left-Right)
- Configure BLE Sense / Mobile for Edge Impulse
- Building and Training a Model
- Deploy on Nano BLE Sense / Mobile Phone

Introduction

Edge Impulse is a development platform for machine learning on edge devices, targeted at developers who want to create intelligent device solutions. The " Accelerometer Motion "sensor reading equivalent in Edge Impulse would typically involve creating a simple machine learning model that can run on an edge device, like classifying sensor data or recognizing a basic pattern.

Materials Required

- Nano BLE Sense Board

Theory

GPIO (General Purpose Input/Output) pins on the Raspberry Pi are used for interfacing with other electronic components. BCM numbering refers to the pin numbers in the Broadcom SOC channel, which is a more consistent way to refer to the GPIO pins across different versions of the

Here’s a high-level overview of steps you'd follow to create a "Hello World" project on Edge Impulse:

Steps to Configure the Edge Impulse:

1. Create an Account and New Project:
    - Sign up for an Edge Impulse account.

- Create a new project from the dashboard.

2. Connect a Device:

    - You can use a supported development board or your smartphone as a sensor device.
    - Follow the instructions to connect your device to your Edge Impulse project.

3. Collect Data:

    - Use the Edge Impulse mobile app or the Web interface to collect data from the onboard sensors.
    - For a "Hello World" project, you could collect accelerometer data, for instance.

4. Create an Impulse:

    - Go to the 'Create impulse' page.
    - Add a processing block (e.g., time-series data) and a learning block (e.g., classification).
    - Save the impulse, which defines the machine learning pipeline.

5. Design a Neural Network:

    - Navigate to the 'NN Classifier' under the 'Learning blocks'.
    - Design a simple neural network. Edge Impulse provides a default architecture that works well for most basic tasks.

6. Train the Model:

    - Click on the 'Start training' button to train your machine learning model with the collected data.

7. Test the Model:

    - Once the model is trained, you can test its performance with new data in the 'Model Testing' tab.

8. Deploy the Model:

- Go to the 'Deployment' tab.
- Select the deployment method that suits your edge device (e.g., Arduino library, WebAssembly, container, etc.).
- Follow the instructions to deploy the model to your device.

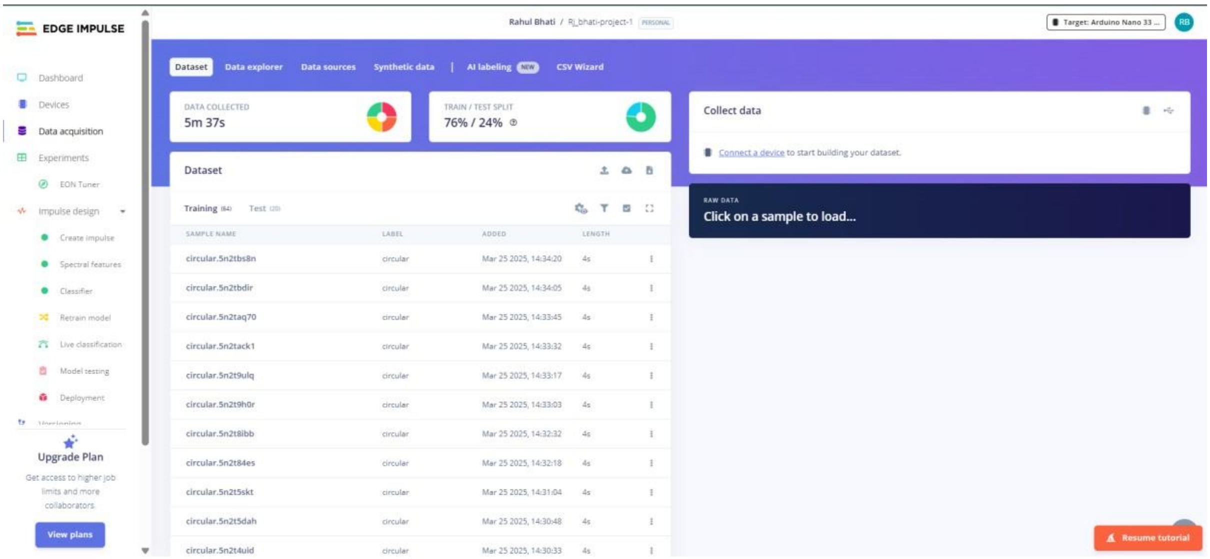
9. Run Inference:

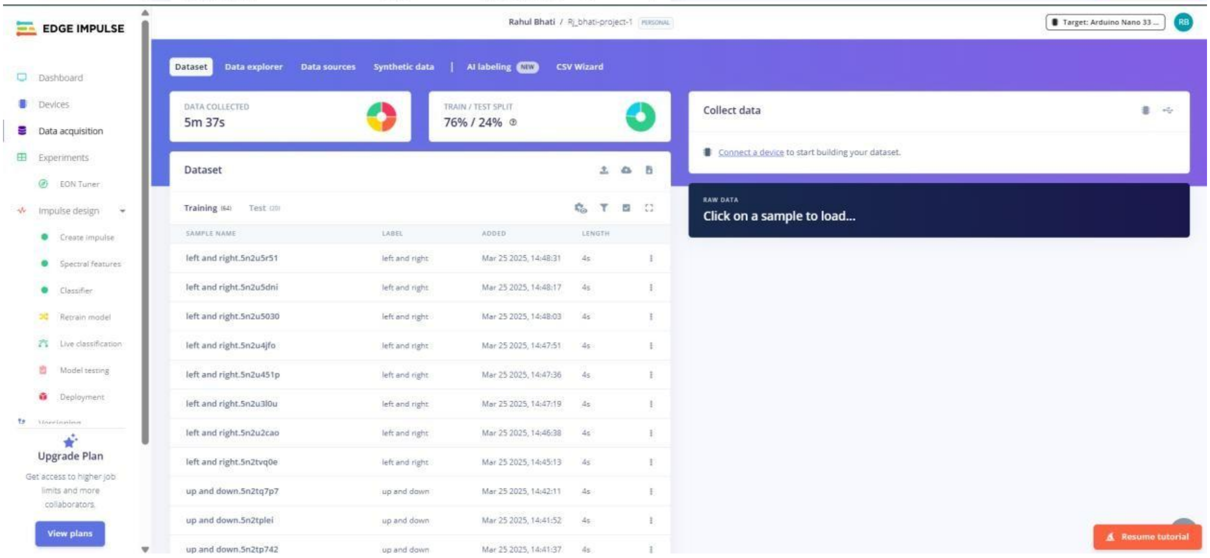
   - With the model deployed, run inference on the edge device to see it classifying data in real-time.

10. Monitor:

    - You can monitor the performance of your device through the Edge Impulse studio.

Paste your Edge Impulse project's Results:


EDGE IMPULSE
Rahul Bhati / Rj_bhati-project-1 PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Spectral features
Classifier
Retrain model
Live classification
Model testing
Deployment
Upgrade Plan
Get access to higher job limits and more collaborators.
View plans
Dataset
Data explorer
Data sources
Synthetic data
AI labeling NEW
CSV Wizard
DATA COLLECTED
5m 37s
TRAIN / TEST SPLIT
76% / 24%
Collect data
Connect a device to start building your dataset.
RAW DATA
Click on a sample to load...
Dataset
Training
Test
SAMPLE NAME
LABEL
ADDED
LENGTH
circular.5n2tbs8n circular Mar 25 2025, 14:34:20 4s
circular.5n2tbdir circular Mar 25 2025, 14:34:05 4s
circular.5n2taq70 circular Mar 25 2025, 14:33:45 4s
circular.5n2tack1 circular Mar 25 2025, 14:33:32 4s
circular.5n2t9ulq circular Mar 25 2025, 14:33:17 4s
circular.5n2t9h0r circular Mar 25 2025, 14:33:03 4s
circular.5n2t8ibb circular Mar 25 2025, 14:32:32 4s
circular.5n2t84es circular Mar 25 2025, 14:32:18 4s
circular.5n2t5skt circular Mar 25 2025, 14:31:04 4s
circular.5n2t5dah circular Mar 25 2025, 14:30:48 4s
circular.5n2t4uid circular Mar 25 2025, 14:30:33 4s
Resume tutorial


EDGE IMPULSE
Rahul Bhati / Rj_bhati-project-1 PERSONAL
Target: Arduino Nano 33 ...
Dashboard
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Impulse design
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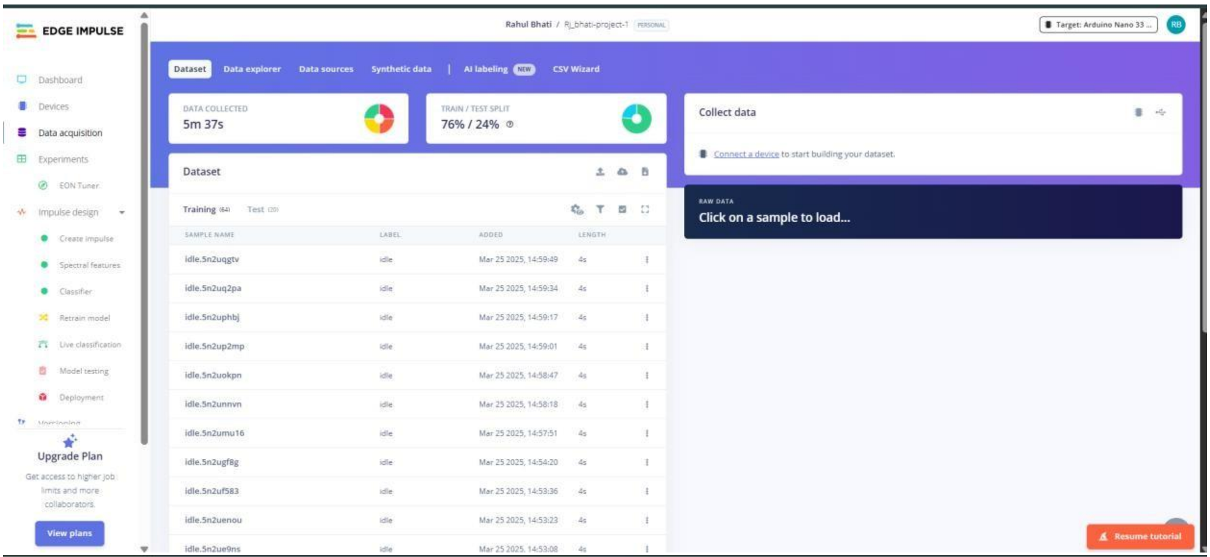
Synthetic data
AI labeling NEW
CSV Wizard
DATA COLLECTED
5m 37s
TRAIN / TEST SPLIT
76% / 24%
Collect data
Connect a device to start building your dataset.
RAW DATA
Click on a sample to load...
Dataset
Training
Test
SAMPLE NAME
LABEL
ADDED
LENGTH
left and right.5n2u5r51 left and right Mar 25 2025, 14:48:31 4s
left and right.5n2u5dni left and right Mar 25 2025, 14:48:17 4s
left and right.5n2u5030 left and right Mar 25 2025, 14:48:03 4s
left and right.5n2u4jfo left and right Mar 25 2025, 14:47:51 4s
left and right.5n2u451p left and right Mar 25 2025, 14:47:36 4s
left and right.5n2u3l0u left and right Mar 25 2025, 14:47:19 4s
left and right.5n2u2cao left and right Mar 25 2025, 14:46:38 4s
left and right.5n2tvq0e left and right Mar 25 2025, 14:45:13 4s
up and down.5n2tq7p7 up and down Mar 25 2025, 14:42:11 4s
up and down.5n2tplei up and down Mar 25 2025, 14:41:52 4s
up and down.5n2tp742 up and down Mar 25 2025, 14:41:37 4s
Resume tutorial


EDGE IMPULSE
Rahul Bhati / Rj_bhati-project-1 PERSONAL
Target: Arduino Nano 33 ...
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Impulse design
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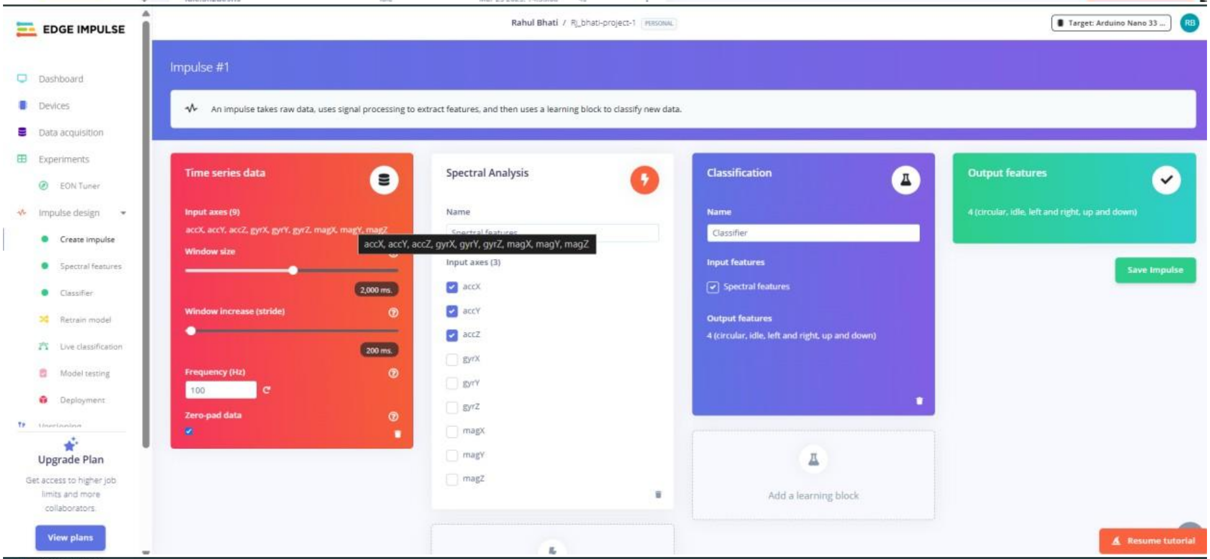
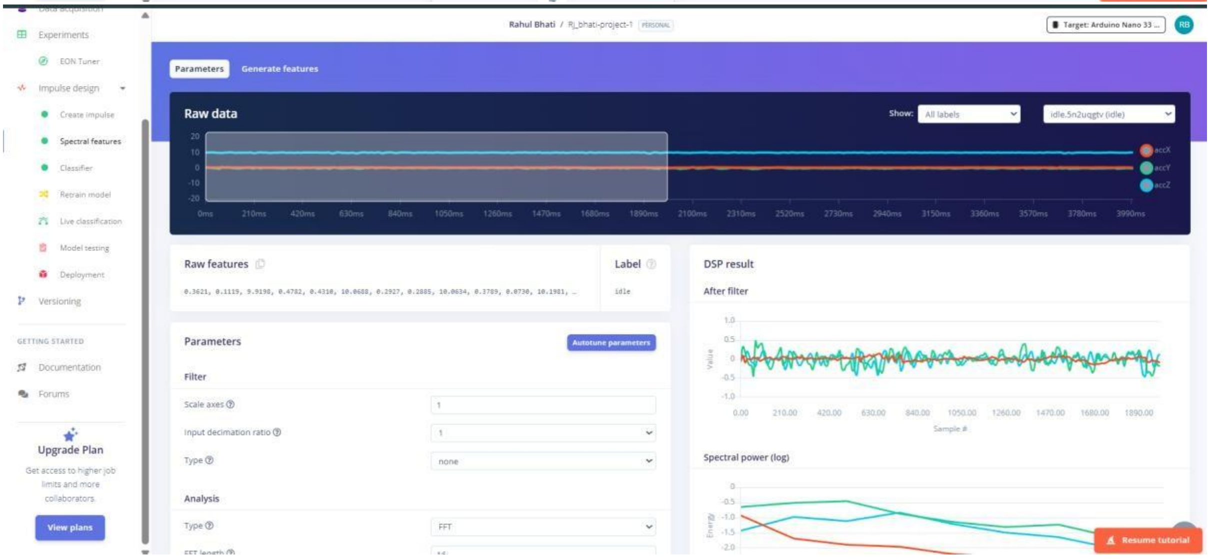
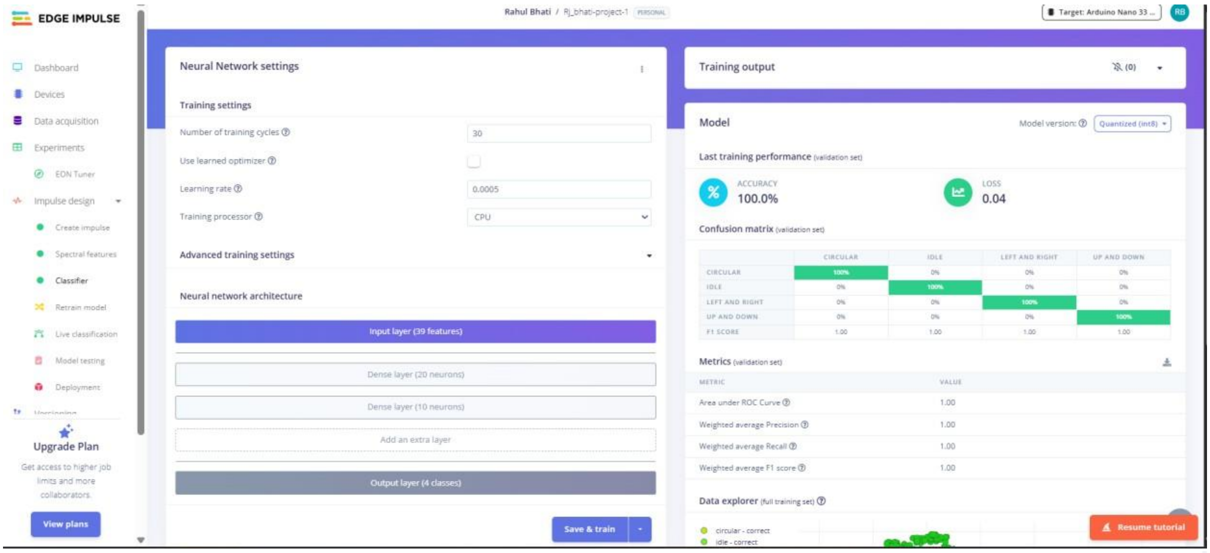
Data sources
Synthetic data
AI labeling
CSV Wizard
DATA COLLECTED
5m 37s
TRAIN / TEST SPLIT
76% / 24%
Collect data
Connect a device to start building your dataset.
RAW DATA
Click on a sample to load...
Dataset
Training
Test
SAMPLE NAME
LABEL
ADDED
LENGTH
idle.5n2uqgtv idle Mar 25 2025, 14:59:49 4s
idle.5n2uq2pa idle Mar 25 2025, 14:59:34 4s
idle.5n2uphbj idle Mar 25 2025, 14:59:17 4s
idle.5n2up2mp idle Mar 25 2025, 14:59:01 4s
idle.5n2uokpn idle Mar 25 2025, 14:58:47 4s
idle.5n2unnvn idle Mar 25 2025, 14:58:18 4s
idle.5n2umu16 idle Mar 25 2025, 14:57:51 4s
idle.5n2ugf8g idle Mar 25 2025, 14:54:20 4s
idle.5n2uf583 idle Mar 25 2025, 14:53:36 4s
idle.5n2uenou idle Mar 25 2025, 14:53:23 4s
idle.5n2ue9ns idle Mar 25 2025, 14:53:08 4s
Resume tutorial


EDGE IMPULSE
Rahul Bhati / Rj_bhati-project-1 PERSONAL
Target: Arduino Nano 33 ...
Impulse #1
An impulse takes raw data, uses signal processing to extract features, and then uses a learning block to classify new data.
Time series data
Input axes (9)
accX, accY, accZ, gyrX, gyrY, gyrZ, magX, magY, magZ
Window size
2,000 ms.
Window increase (stride)
200 ms.
Frequency (Hz)
100
Zero-pad data
Spectral Analysis
Name
Input axes (3)
accX
accY
accZ
gyrX
gyrY
gyrZ
magX
magY
magZ
Classification
Name
Classifier
Input features
Spectral features
Output features
4 (circular, idle, left and right, up and down)
Add a learning block
Output features
4 (circular, idle, left and right, up and down)
Save Impulse
Resume tutorial


Rahul Bhati / Rj_bhati-project-1 PERSONAL
Target: Arduino Nano 33 ...
Parameters
Generate features
Raw data
Show: All labels
idle.5n2uqgtv (idle)
accX
accY
accZ
Raw features
Label
idle
DSP result
After filter
Spectral power (log)
Parameters
Autotune parameters
Filter
Scale axes
1
Input decimation ratio
1
Type
none
Analysis
Type
FFT
Versioning
GETTING STARTED
Documentation
Forums
Upgrade Plan
Get access to higher job limits and more collaborators
View plans
Resume tutorial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Target: Arduino Nano 33 ...
Dashboard
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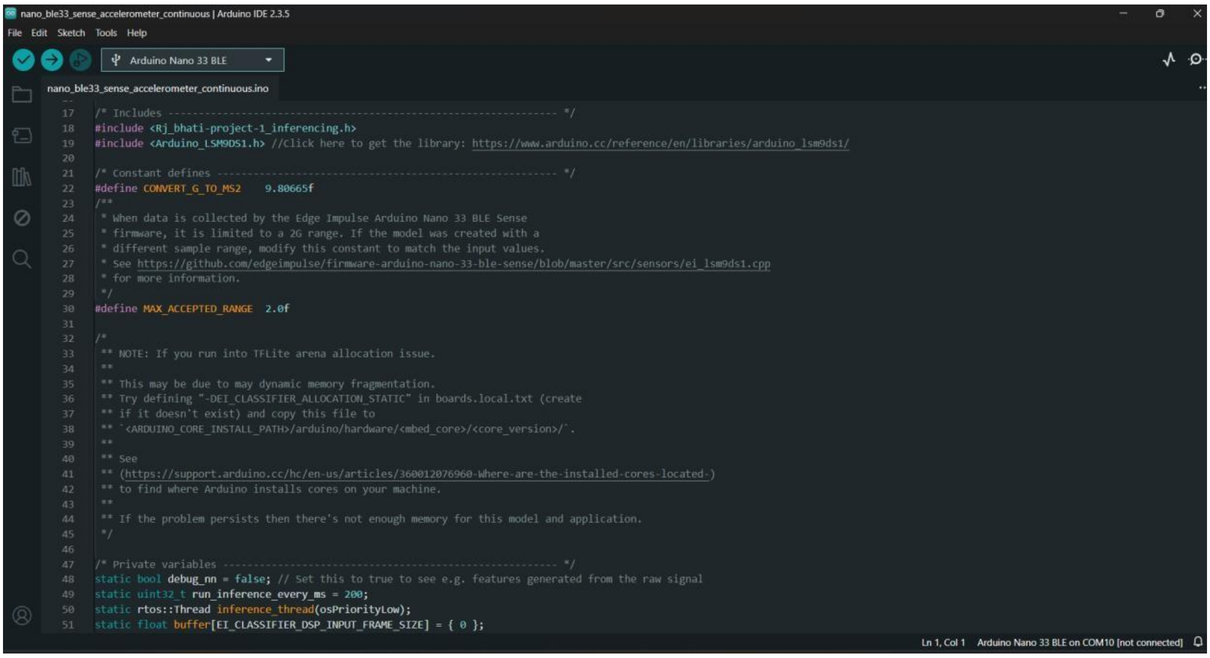
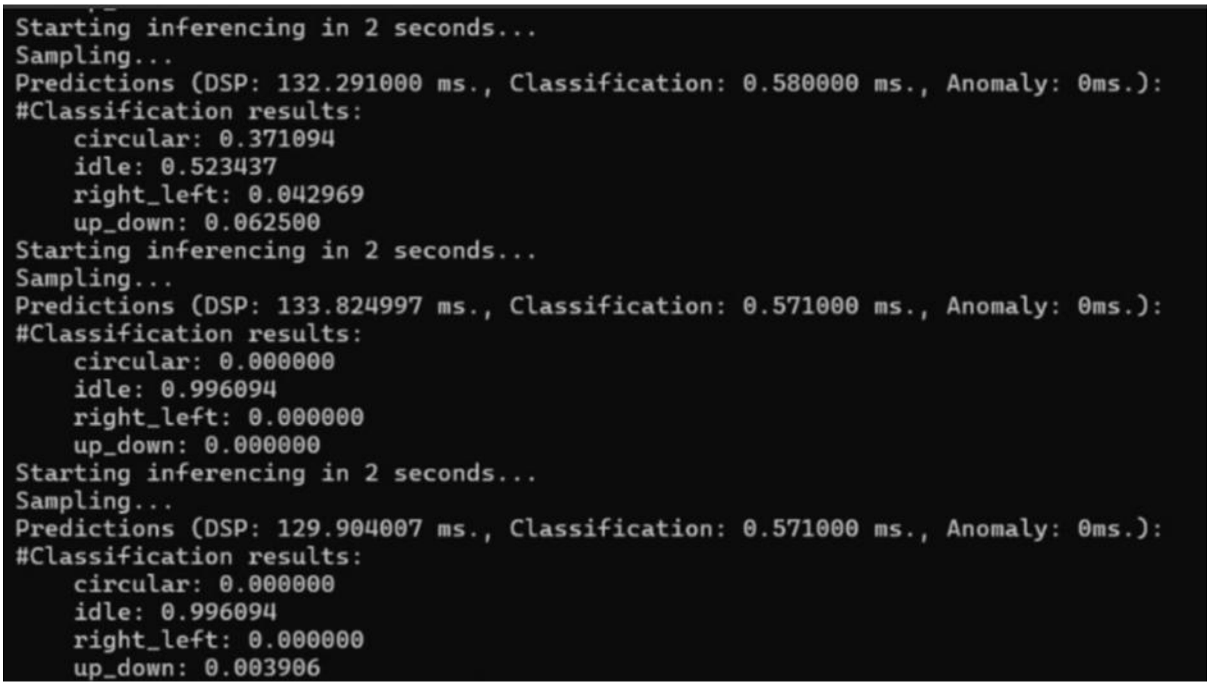
Retrain model
Live classification
Model testing
Deployment
Upgrade Plan
Get access to higher job limits and more collaborators.
View plans
Neural Network settings
Training settings
Number of training cycles
30
Use learned optimizer
Learning rate
0.0005
Training processor
CPU
Advanced training settings
Neural network architecture
Input layer (39 features)
Dense layer (20 neurons)
Dense layer (10 neurons)
Add an extra layer
Output layer (4 classes)
Save & train
Training output
Model
Model version:
Quantized (int8)
Last training performance (validation set)
ACCURACY
100.0%
LOSS
0.04
Confusion matrix (validation set)
Metrics (validation set)
METRIC
VALUE
Area under ROC Curve
1.00
Weighted average Precision
1.00
Weighted average Recall
1.00
Weighted average F1 score
1.00
Data explorer (full training set)
circular - correct
idle - correct
Resume tutorial


Data explorer (full training set)
circular - correct
idle - correct
left and right - correct
up and down - correct
circular - incorrect
up and down - incorrect
On-device performance
Engine:
EON™ Compiler
INFERENCING TIME
1 ms.
PEAK RAM USAGE
1.4K
FLASH USAGE
16.1K





Code:

```
/* Edge Impulse ingestion SDK
 * Copyright (c) 2022 EdgeImpulse Inc.
 *
 * Licensed under the Apache License, Version 2.0 (the "License");
 * you may not use this file except in compliance with the License.
 * You may obtain a copy of the License at
 * http://www.apache.org/licenses/LICENSE-2.0
 *
 * Unless required by applicable law or agreed to in writing, software
 * distributed under the License is distributed on an "AS IS" BASIS,
 * WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or implied.
```

```
 * See the License for the specific language governing permissions and
 * limitations under the License.
 *
 */

/* Includes ---------------------------------------------------------------- */
#include <Rj_bhati-project-1_inferencing.h>
#include <Arduino_LSM9DS1.h> //Click here to get the library: https://www.arduino.cc/reference/en/libraries/arduino_lsm9ds1/

/* Constant defines -------------------------------------------------------- */
#define CONVERT_G_TO_MS2    9.80665f
/**
 * When data is collected by the Edge Impulse Arduino Nano 33 BLE Sense
 * firmware, it is limited to a 2G range. If the model was created with a
 * different sample range, modify this constant to match the input values.
 * See https://github.com/edgeimpulse/firmware-arduino-nano-33-ble-sense/blob/master/src/sensors/ei_lsm9ds1.cpp
 * for more information.
 */
#define MAX_ACCEPTED_RANGE  2.0f

/*
 ** NOTE: If you run into TFLite arena allocation issue.
 **
 ** This may be due to may dynamic memory fragmentation.
 ** Try defining "-DEI_CLASSIFIER_ALLOCATION_STATIC" in boards.local.txt (create
 ** if it doesn't exist) and copy this file to
 ** `<ARDUINO_CORE_INSTALL_PATH>/arduino/hardware/<mbed_core>/<core_version>/`.
 **
 ** See
 ** (https://support.arduino.cc/hc/en-us/articles/360012076960-Where-are-the-installed-cores-located-)
 ** to find where Arduino installs cores on your machine.
 **
 ** If the problem persists then there's not enough memory for this model and application.
 */

/* Private variables ------------------------------------------------------- */
static bool debug_nn = false; // Set this to true to see e.g. features generated from the raw signal
static uint32_t run_inference_every_ms = 200;
static rtos::Thread inference_thread(osPriorityLow);
static float buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE] = { 0 };
static float inference_buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE];

/* Forward declaration */
void run_inference_background();
```

```
/**
* @brief      Arduino setup function
*/
void setup()
{
   // put your setup code here, to run once:
   Serial.begin(115200);
   // comment out the below line to cancel the wait for USB connection (needed for native USB)
   while (!Serial);
   Serial.println("Edge Impulse Inferencing Demo");

   if (!IMU.begin()) {
      ei_printf("Failed to initialize IMU!\r\n");
   }
   else {
      ei_printf("IMU initialized\r\n");
   }

   if (EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME != 3) {
       ei_printf("ERR: EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME should be equal to 3 (the 3 sensor
axes)\n");
      return;
   }

   inference_thread.start(mbed::callback(&run_inference_background));
}

/**
 * @brief Return the sign of the number
 *
 * @param number
 * @return int 1 if positive (or 0) -1 if negative
 */
float ei_get_sign(float number) {
   return (number >= 0.0) ? 1.0 : -1.0;
}

/**
 * @brief      Run inferencing in the background.
 */
void run_inference_background()
{
   // wait until we have a full buffer
   delay((EI_CLASSIFIER_INTERVAL_MS * EI_CLASSIFIER_RAW_SAMPLE_COUNT) + 100);

   // This is a structure that smoothens the output result
   // With the default settings 70% of readings should be the same before classifying.
   ei_classifier_smooth_t smooth;
```

```
  ei_classifier_smooth_init(&smooth, 10 /* no. of readings */, 7 /* min. readings the same */, 0.8 /* min. confidence */, 0.3 /* max anomaly */);

  while (1) {
    // copy the buffer
    memcpy(inference_buffer, buffer, EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE * sizeof(float));

    // Turn the raw buffer in a signal which we can the classify
    signal_t signal;
     int err = numpy::signal_from_buffer(inference_buffer, EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE, &signal);
    if (err != 0) {
      ei_printf("Failed to create signal from buffer (%d)\n", err);
      return;
    }

    // Run the classifier
    ei_impulse_result_t result = { 0 };

    err = run_classifier(&signal, &result, debug_nn);
    if (err != EI_IMPULSE_OK) {
      ei_printf("ERR: Failed to run classifier (%d)\n", err);
      return;
    }

    // print the predictions
    ei_printf("Predictions ");
    ei_printf("(DSP: %d ms., Classification: %d ms., Anomaly: %d ms.)",
      result.timing.dsp, result.timing.classification, result.timing.anomaly);
    ei_printf(": ");

    // ei_classifier_smooth_update yields the predicted label
    const char *prediction = ei_classifier_smooth_update(&smooth, &result);
    ei_printf("%s ", prediction);
    // print the cumulative results
    ei_printf(" [ ");
    for (size_t ix = 0; ix < smooth.count_size; ix++) {
      ei_printf("%u", smooth.count[ix]);
      if (ix != smooth.count_size + 1) {
        ei_printf(", ");
      }
      else {
       ei_printf(" ");
      }
    }
    ei_printf("]\n");

    delay(run_inference_every_ms);
```

```
    }

    ei_classifier_smooth_free(&smooth);
}

/**
* @brief      Get data and run inferencing
*
* @param[in]  debug  Get debug info if true
*/
void loop()
{
    while (1) {
        // Determine the next tick (and then sleep later)
        uint64_t next_tick = micros() + (EI_CLASSIFIER_INTERVAL_MS * 1000);

        // roll the buffer -3 points so we can overwrite the last one
        numpy::roll(buffer, EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE, -3);

        // read to the end of the buffer
        IMU.readAcceleration(
            buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 3],
            buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 2],
            buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 1]
        );

        for (int i = 0; i < 3; i++) {
            if (fabs(buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 3 + i]) > MAX_ACCEPTED_RANGE) {
                buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 3 + i] =
ei_get_sign(buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 3 + i]) * MAX_ACCEPTED_RANGE;
            }
        }

        buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 3] *= CONVERT_G_TO_MS2;
        buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 2] *= CONVERT_G_TO_MS2;
        buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE - 1] *= CONVERT_G_TO_MS2;

        // and wait for next tick
        uint64_t time_to_wait = next_tick - micros();
        delay((int)floor((float)time_to_wait / 1000.0f));
        delayMicroseconds(time_to_wait % 1000);
    }
}

#if !defined(EI_CLASSIFIER_SENSOR) || EI_CLASSIFIER_SENSOR !=
EI_CLASSIFIER_SENSOR_ACCELEROMETER
#error "Invalid model for current sensor"
#endif
```