Edge Computing Lab

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Experiment No. 6

Title

Keyword Spotting Project like “OK, Google,” “Alexa,” on Edge Devices using Microphone

Objective: Build a project to detect the keywords using a built-in sensor on Nano BLE Sense / Mobile Phone

Tasks:

- Generate the dataset for keyword
- Configure BLE Sense / Mobile for Edge Impulse
- Building and Training a Model

Run the project Keyword Spotting like “OK, Google,” “Alexa

Introduction

Edge Impulse is a development platform for machine learning on edge devices, targeted at developers who want to create intelligent device solutions. The "Hello World" 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:

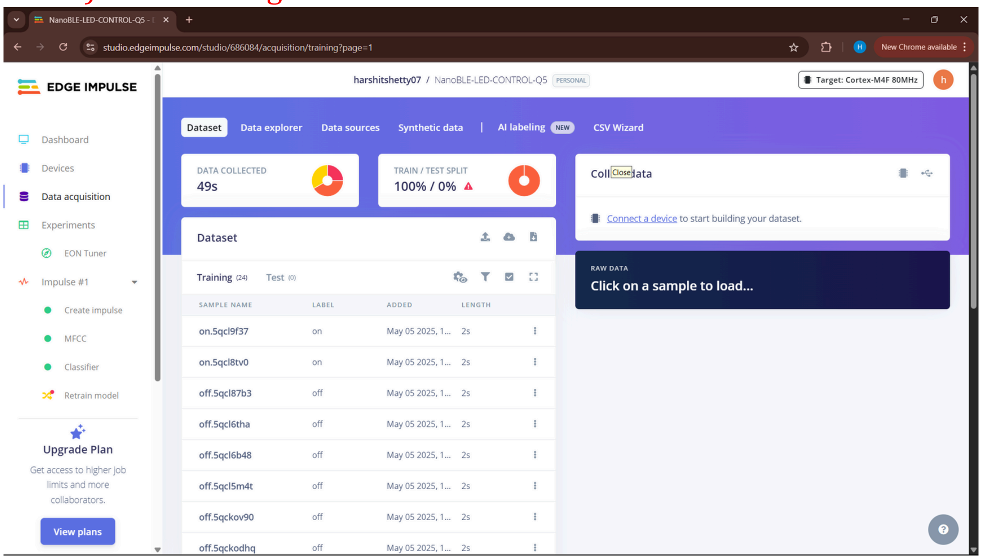
- With the model deployed, run inference on the edge device to see it classifying data in real-time.

10. Monitor:

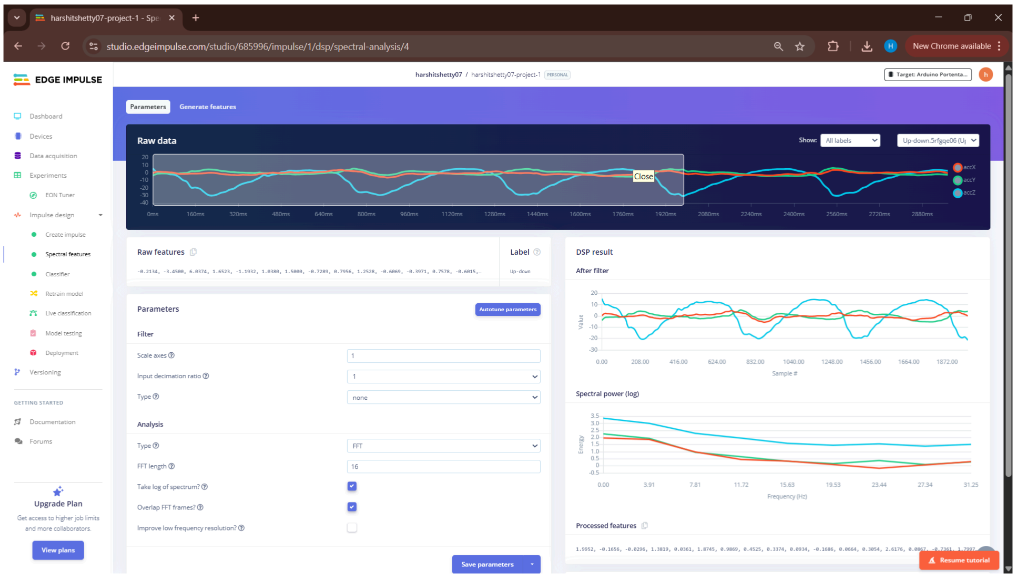
- You can monitor the performance of your device through the Edge Impulse studio.

Paste your Edge Impulse project's Results:

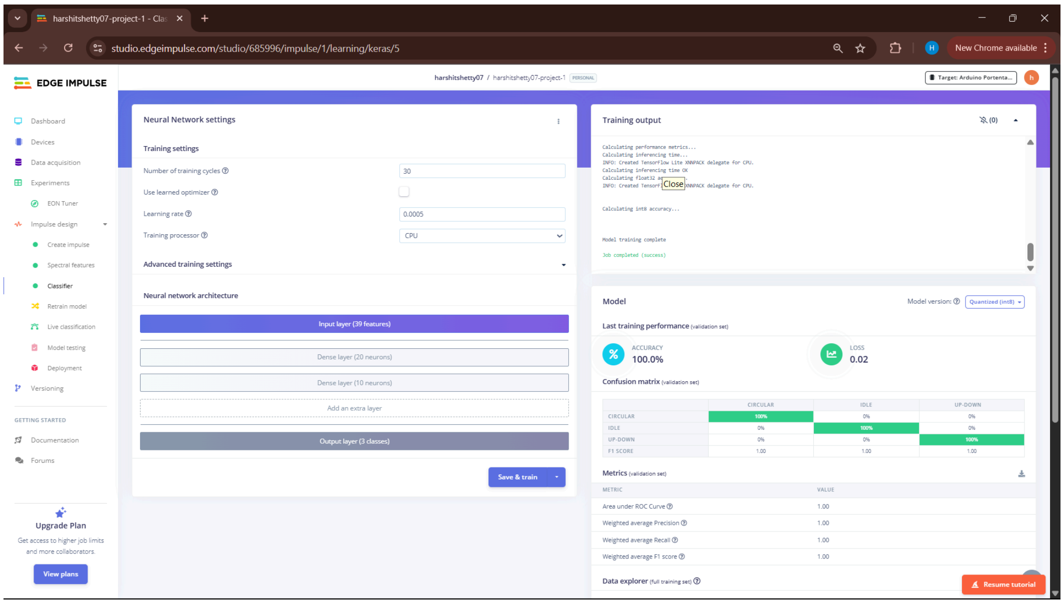
1) Dataset Image



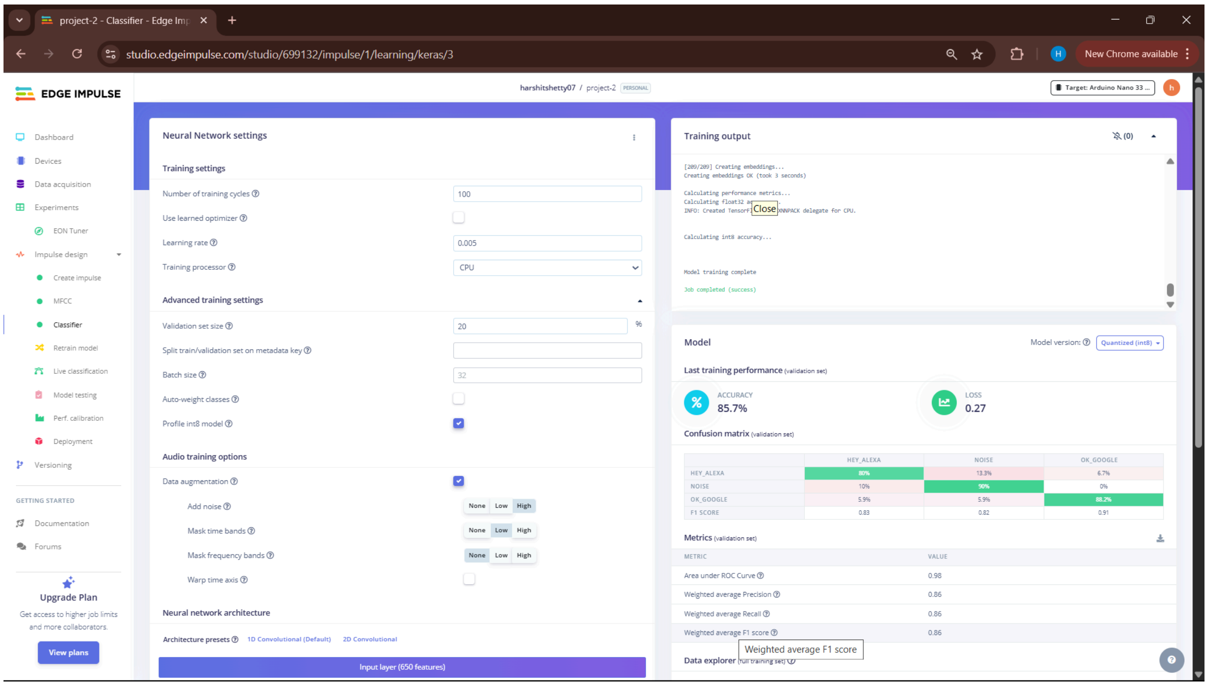
2) Feature extraction – Image



3) Accuracy / Loss - Confusion Matrix – image



4) Validation Result – Image



5) Copy the code of Arduino Sketch

```
/* 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 <fazal357-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
// -DEI_CLASSIFIER_ALLOCATION_STATIC


/*
 ** 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
```

6) Screen shot of Arduino Terminal – Result

```
5:43:05.664 -> Predictions (DSP: 104 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 0, 10, 0, 0, ]
5:43:05.997 -> Predictions (DSP: 104 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 0, 10, 0, 0, ]
5:43:06.323 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 0, 10, 0, 0, ]
5:43:06.634 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 1, 9, 0, 0, ]
5:43:06.901 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 1, 8, 1, 0, ]
5:43:07.214 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): left-right  [ 0, 0, 1, 7, 2, 0, ]
5:43:07.523 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): uncertain  [ 0, 0, 1, 6, 3, 0, ]
5:43:07.848 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): uncertain  [ 0, 0, 2, 5, 3, 0, ]
5:43:08.172 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): uncertain  [ 0, 0, 2, 4, 4, 0, ]
5:43:08.448 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): uncertain  [ 0, 0, 3, 3, 4, 0, ]
```

```
15:43:17.775 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:18.041 -> Predictions (DSP: 104 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:18.373 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:18.686 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:18.970 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:19.314 -> Predictions (DSP: 104 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:19.589 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:19.936 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:20.206 -> Predictions (DSP: 104 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 10, 0, 0, 0, ]
15:43:20.542 -> Predictions (DSP: 106 ms., Classification: 0 ms., Anomaly: 0 ms.): idle  [ 0, 0, 9, 0, 1, 0, ]
```