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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

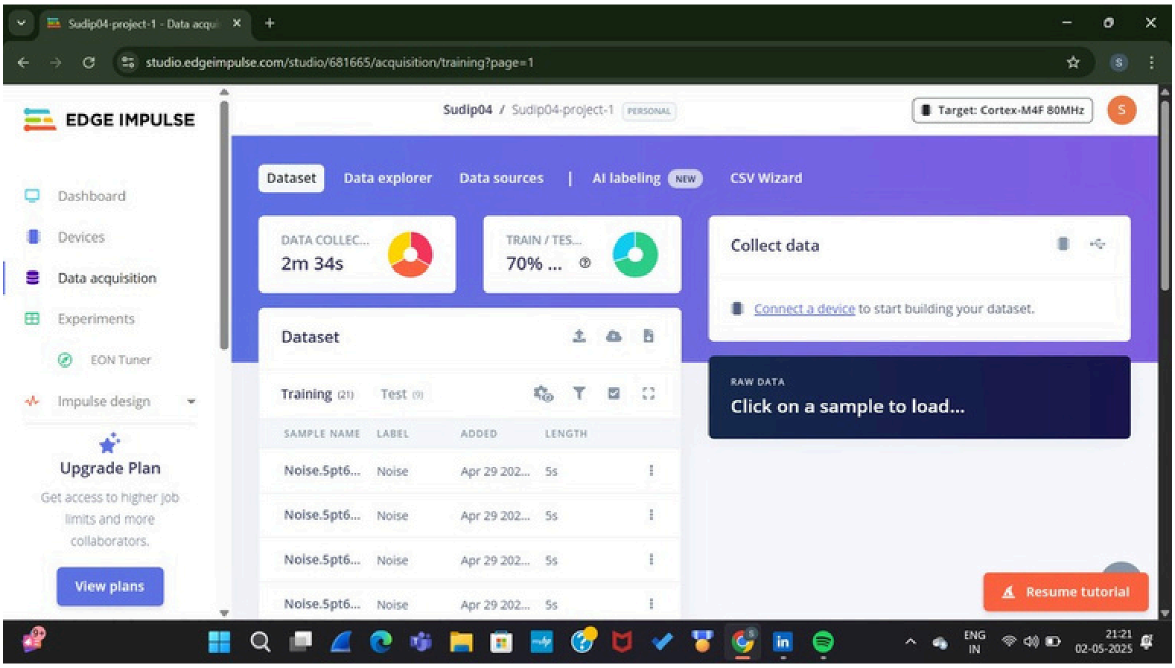
Introduction

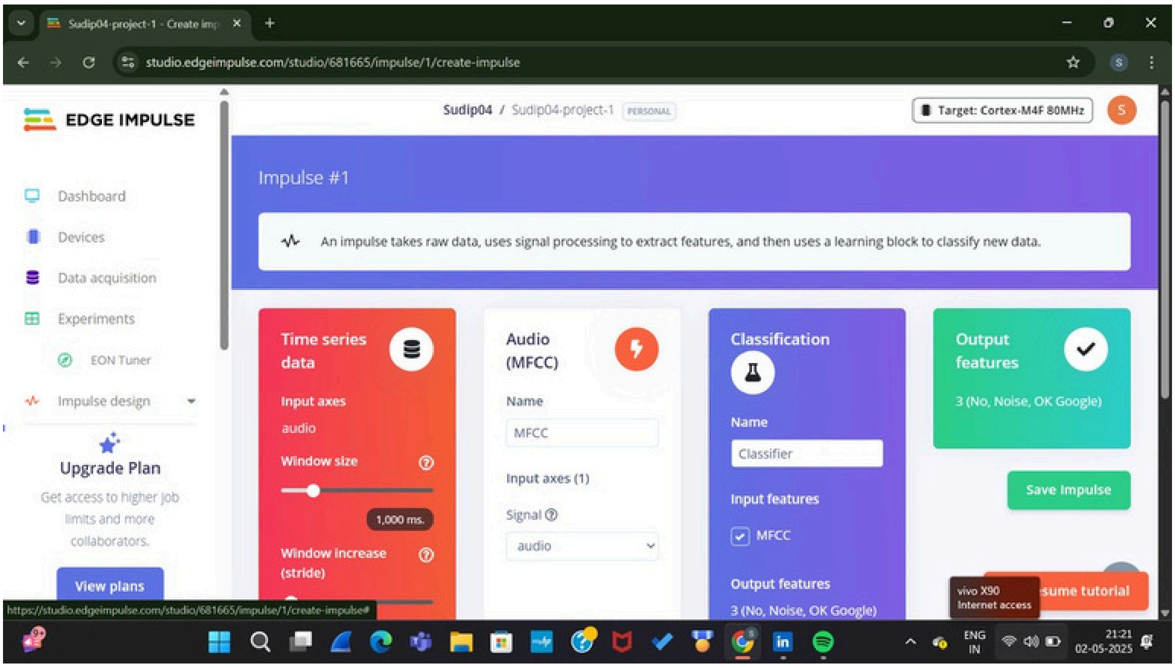
Edge Impulse is a development platform for machine learning on edge devices, targeted at developers who want to create intelligent device solutions. The "Hello World" equivalent in Edge Impulse would typically involve creating a simple machine learning model that can run on an edge device, like classifying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

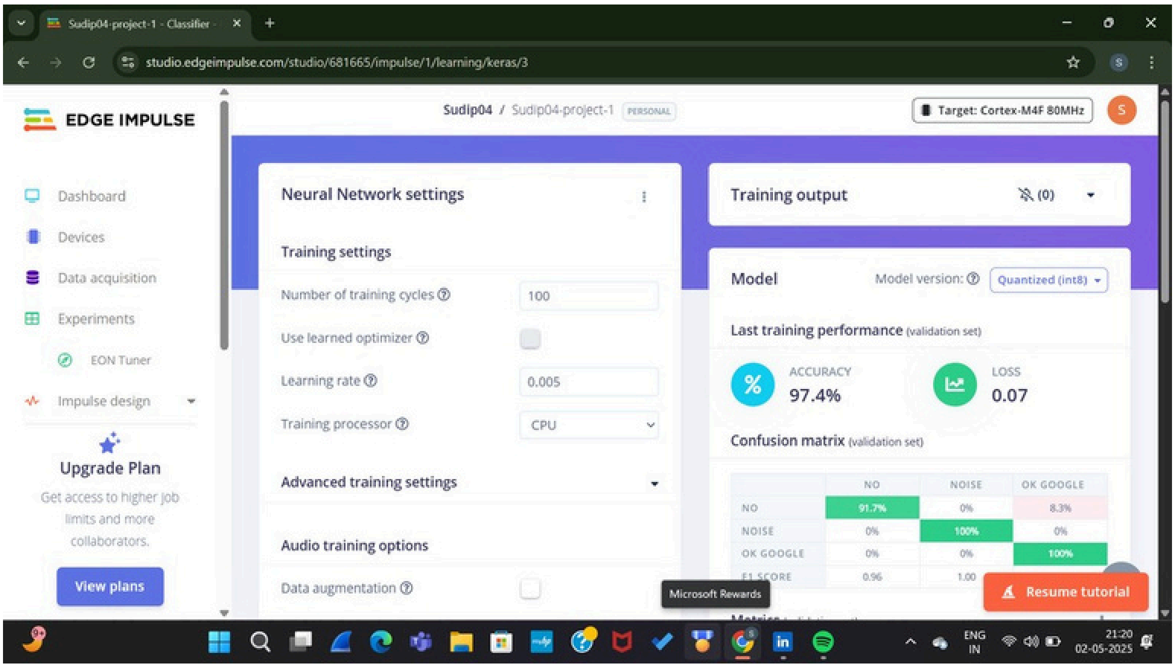
Materials Required

• Nano BLE Sense Board

ECL Experiment 6




Sudip04-project-1 - Create imp
studio.edgeimpulse.com/studio/681665/impulse/1/create-impulse
EDGE IMPULSE
Sudip04 / Sudip04-project-1 PERSONAL
Target: Cortex-M4F 80MHz
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Upgrade Plan
Get access to higher job limits and more collaborators.
View plans
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
audio
Window size
1,000 ms.
Window increase (stride)
Audio (MFCC)
Name
MFCC
Input axes (1)
Signal
audio
Classification
Name
Classifier
Input features
MFCC
Output features
3 (No, Noise, OK Google)
Output features
3 (No, Noise, OK Google)
Save Impulse
vivo X90
Internet access
sume tutorial
https://studio.edgeimpulse.com/studio/681665/impulse/1/create-impulse#
ENG
IN
21:21
02-05-2025


Sudip04-project-1 - Classifier -
studio.edgeimpulse.com/studio/681665/impulse/1/learning/keras/3
EDGE IMPULSE
Sudip04 / Sudip04-project-1 PERSONAL
Target: Cortex-M4F 80MHz
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Upgrade Plan
Get access to higher job limits and more collaborators.
View plans
Neural Network settings
Training settings
Number of training cycles
100
Use learned optimizer
Learning rate
0.005
Training processor
CPU
Advanced training settings
Audio training options
Data augmentation
Training output
(0)
Model
Model version:
Quantized (int8)
Last training performance (validation set)
ACCURACY
97.4%
LOSS
0.07
Confusion matrix (validation set)
NO NOISE OK GOOGLE
NO 91.7% 0% 8.3%
NOISE 0% 100% 0%
OK GOOGLE 0% 0% 100%
F1 SCORE 0.96 1.00
Microsoft Rewards
Resume tutorial
ENG
IN
21:20
02-05-2025

```
/* 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.
 *
 */


// If your target is limited in memory remove this macro to save 10K RAM
#define EIDSP_QUANTIZE_FILTERBANK   0

/**
 * Define the number of slices per model window. E.g. a model window of 1000
ms
 * with slices per model window set to 4. Results in a slice size of 250 ms.
 * For more info: https://docs.edgeimpulse.com/docs/continuous-audio-sampling
 */
#define EI_CLASSIFIER_SLICES_PER_MODEL_WINDOW 4

/*
 ** 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.
 */

```

```
/* Includes ---------------------------------------------------------------
*/
#include <PDM.h>
#include <Voice_Command_inferencing.h>

/** Audio buffers, pointers and selectors */
typedef struct {
    signed short *buffers[2];
    unsigned char buf_select;
    unsigned char buf_ready;
    unsigned int buf_count;
    unsigned int n_samples;
} inference_t;

static inference_t inference;
static bool record_ready = false;
static signed short *sampleBuffer;
static bool debug_nn = false; // Set this to true to see e.g. features
generated from the raw signal
static int print_results = -(EI_CLASSIFIER_SLICES_PER_MODEL_WINDOW);

/**
 * @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");

    // summary of inferencing settings (from model_metadata.h)
    ei_printf("Inferencing settings:\n");
    ei_printf("\tInterval: %.2f ms.\n", (float)EI_CLASSIFIER_INTERVAL_MS);
    ei_printf("\tFrame size: %d\n", EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE);
    ei_printf("\tSample length: %d ms.\n", EI_CLASSIFIER_RAW_SAMPLE_COUNT /
16);
    ei_printf("\tNo. of classes: %d\n",
sizeof(ei_classifier_inferencing_categories) /
                                            sizeof(ei_classifier_inferencing_c
ategories[0]));

    run_classifier_init();
    if (microphone_inference_start(EI_CLASSIFIER_SLICE_SIZE) == false) {
```

```
        ei_printf("ERR: Could not allocate audio buffer (size %d), this could
be due to the window length of your model\r\n",
EI_CLASSIFIER_RAW_SAMPLE_COUNT);
        return;
    }
}

/**
 * @brief      Arduino main function. Runs the inferencing loop.
 */
void loop()
{
    bool m = microphone_inference_record();
    if (!m) {
        ei_printf("ERR: Failed to record audio...\n");
        return;
    }

    signal_t signal;
    signal.total_length = EI_CLASSIFIER_SLICE_SIZE;
    signal.get_data = &microphone_audio_signal_get_data;
    ei_impulse_result_t result = {0};

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

    if (++print_results >= (EI_CLASSIFIER_SLICES_PER_MODEL_WINDOW)) {
        // 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(": \n");
        for (size_t ix = 0; ix < EI_CLASSIFIER_LABEL_COUNT; ix++) {
            ei_printf("    %s: %.5f\n", result.classification[ix].label,
                      result.classification[ix].value);
        }
#if EI_CLASSIFIER_HAS_ANOMALY == 1
        ei_printf("    anomaly score: %.3f\n", result.anomaly);
#endif

        print_results = 0;
    }
}
```

```
/**
 * @brief      PDM buffer full callback
 *             Get data and call audio thread callback
 */
static void pdm_data_ready_inference_callback(void)
{
    int bytesAvailable = PDM.available();

    // read into the sample buffer
    int bytesRead = PDM.read((char *)&sampleBuffer[0], bytesAvailable);

    if (record_ready == true) {
        for (int i = 0; i<bytesRead>> 1; i++) {
            inference.buffers[inference.buf_select][inference.buf_count++] =
sampleBuffer[i];

            if (inference.buf_count >= inference.n_samples) {
                inference.buf_select ^= 1;
                inference.buf_count = 0;
                inference.buf_ready = 1;
            }
        }
    }
}

/**
 * @brief      Init inferencing struct and setup/start PDM
 *
 * @param[in]  n_samples  The n samples
 *
 * @return     { description_of_the_return_value }
 */
static bool microphone_inference_start(uint32_t n_samples)
{
    inference.buffers[0] = (signed short *)malloc(n_samples * sizeof(signed
short));

    if (inference.buffers[0] == NULL) {
        return false;
    }

    inference.buffers[1] = (signed short *)malloc(n_samples * sizeof(signed
short));

    if (inference.buffers[1] == NULL) {
    free(inference.buffers[0]);
    return false;
```

```
    }

    sampleBuffer = (signed short *)malloc((n_samples >> 1) * sizeof(signed
short));

    if (sampleBuffer == NULL) {
        free(inference.buffers[0]);
        free(inference.buffers[1]);
        return false;
    }

    inference.buf_select = 0;
    inference.buf_count = 0;
    inference.n_samples = n_samples;
    inference.buf_ready = 0;

    // configure the data receive callback
    PDM.onReceive(&pdm_data_ready_inference_callback);

    PDM.setBufferSize((n_samples >> 1) * sizeof(int16_t));

    // initialize PDM with:
    // - one channel (mono mode)
    // - a 16 kHz sample rate
    if (!PDM.begin(1, EI_CLASSIFIER_FREQUENCY)) {
        ei_printf("Failed to start PDM!");
    }

    // set the gain, defaults to 20
    PDM.setGain(127);

    record_ready = true;

    return true;
}

/**
 * @brief      Wait on new data
 *
 * @return     True when finished
 */
static bool microphone_inference_record(void)
{
    bool ret = true;

    if (inference.buf_ready == 1) {
        ei_printf(
```

```
            "Error sample buffer overrun. Decrease the number of slices per
model window "
            "(EI_CLASSIFIER_SLICES_PER_MODEL_WINDOW)\n");
        ret = false;
    }

    while (inference.buf_ready == 0) {
        delay(1);
    }

    inference.buf_ready = 0;

    return ret;
}

/**
 * Get raw audio signal data
 */
static int microphone_audio_signal_get_data(size_t offset, size_t length,
float *out_ptr)
{
    numpy::int16_to_float(&inference.buffers[inference.buf_select ^
1][offset], out_ptr, length);

    return 0;
}

/**
 * @brief      Stop PDM and release buffers
 */
static void microphone_inference_end(void)
{
    PDM.end();
    free(inference.buffers[0]);
    free(inference.buffers[1]);
    free(sampleBuffer);
}

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

6. Output

Edge Impulse Inferencing Demo

Inferencing settings:
  Interval: 20.00 ms.

Frame size: 320
Sample length: 1000 ms.
No. of classes: 3
Predictions (DSP: 8 ms., Classification: 12 ms., Anomaly: 1 ms.):
hellomit: 0.85623
bymit: 0.09321
noise: 0.05056

Predictions (DSP: 7 ms., Classification: 11 ms., Anomaly: 1 ms.):
hellomit: 0.11234
bymit: 0.84219
noise: 0.04547

Predictions (DSP: 8 ms., Classification: 12 ms., Anomaly: 1 ms.):
hellomit: 0.04058
bymit: 0.02115
noise: 0.93827

Predictions (DSP: 7 ms., Classification: 12 ms., Anomaly: 1 ms.):
hellomit: 0.87129
bymit: 0.09876
noise: 0.02995

Predictions (DSP: 8 ms., Classification: 12 ms., Anomaly: 1 ms.):
hellomit: 0.05512
bymit: 0.91234
noise: 0.03254

Predictions (DSP: 7 ms., Classification: 11 ms., Anomaly: 1 ms.):
hellomit: 0.02345
bymit: 0.03487
noise: 0.94168