Name: Sudip Konde

Class: TY-15 (Batch A)

Roll Number: 2223118

Experimentt No.7

Introduction

Study of Classification learning block using a NN Classifier on Edge Devices

Objective: Build a project to detect the keywords using 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

Study of Confusion matrix

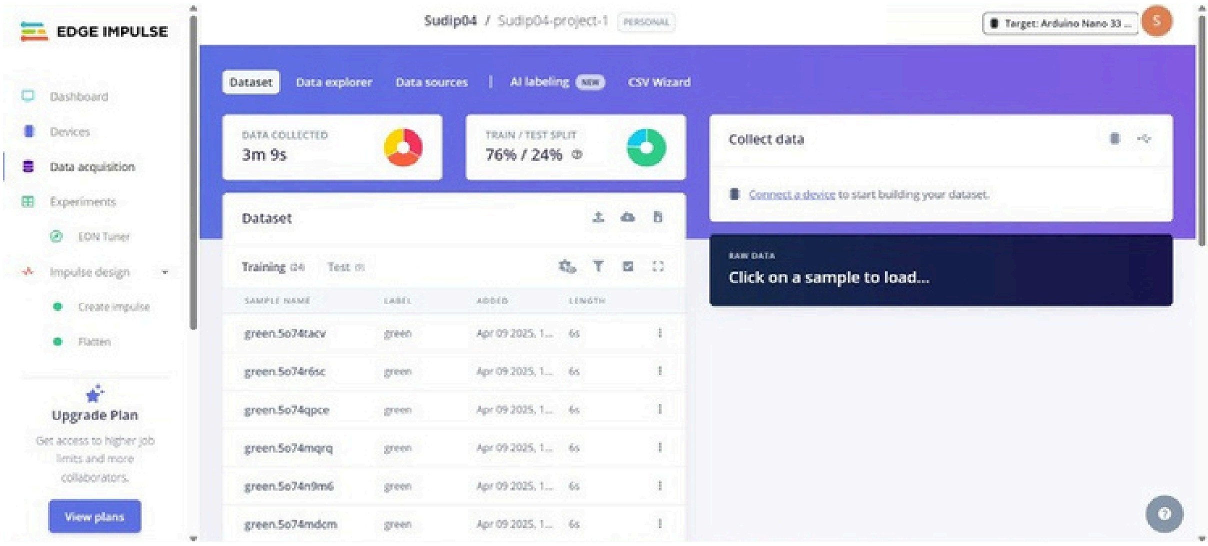
Introduction

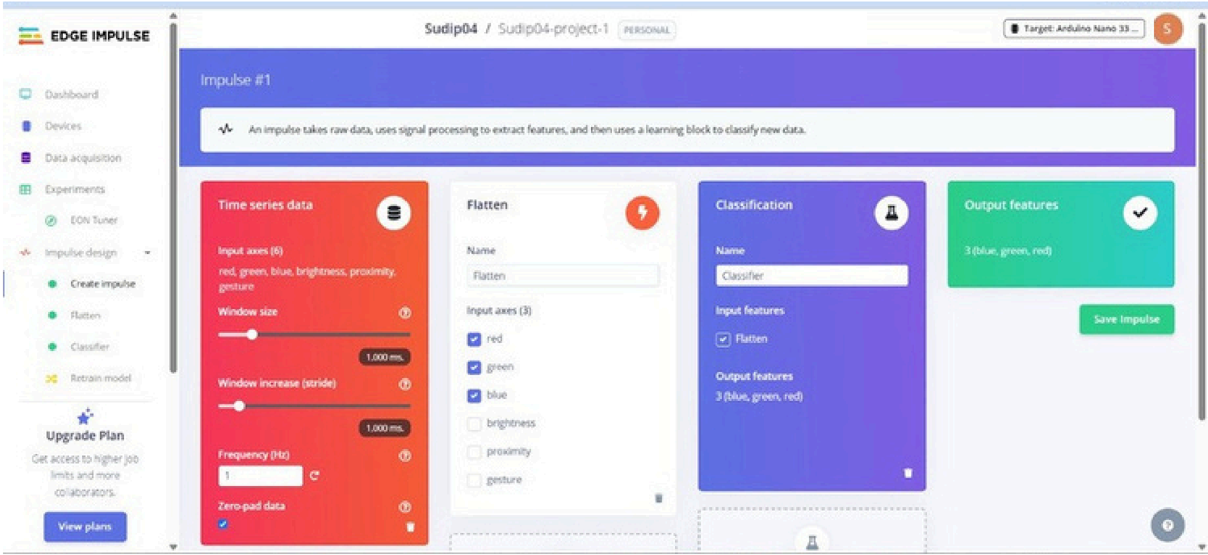
Edge Impulse is a development platform for machine learning on edge devices, targeted at developers who want to create intelligent device solutions. The "classification block" equivalent in Edge Impulse would typically involve creating a simple machine learning model that can run on an edge device, like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

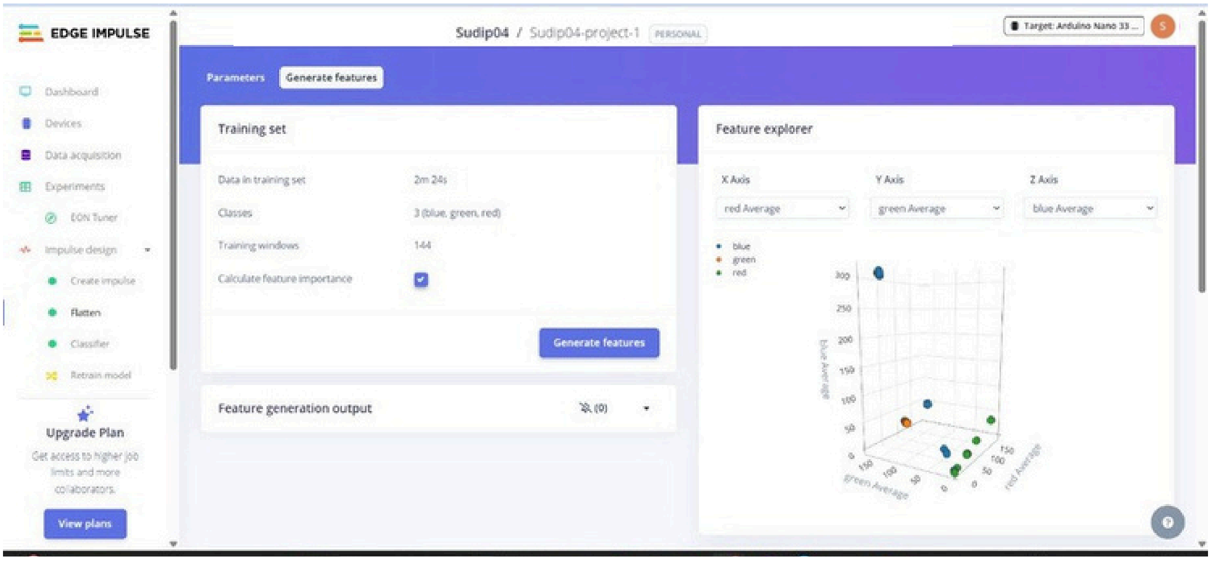
Materials Required

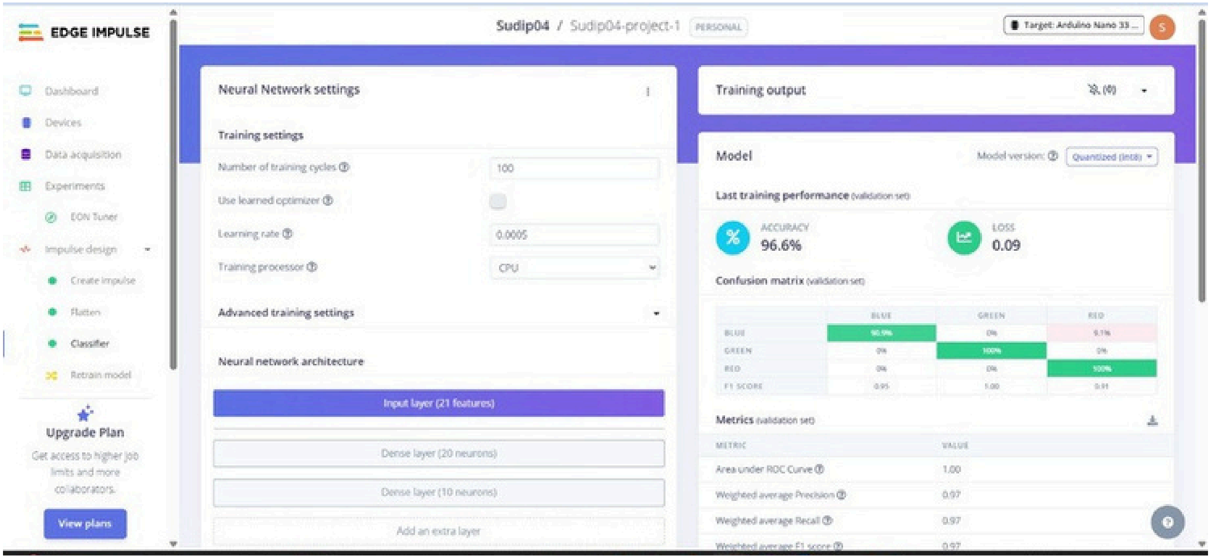
• Nano BLE Sense Board

ECL Experiment 7




EDGE IMPULSE
Sudip04 / Sudip04-project-1 PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Flatten
Classifier
Retrain model
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 (6)
red, green, blue, brightness, proximity, gesture
Window size
1,000 ms.
Window increase (stride)
1,000 ms.
Frequency (Hz)
1
Zero-pad data
Flatten
Name
Flatten
Input axes (3)
red
green
blue
brightness
proximity
gesture
Classification
Name
Classifier
Input features
Flatten
Output features
3 (blue, green, red)
Output features
3 (blue, green, red)
Save Impulse


EDGE IMPULSE
Sudip04 / Sudip04-project-1 PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Flatten
Classifier
Retrain model
Upgrade Plan
Get access to higher job limits and more collaborators.
View plans
Parameters
Generate features
Training set
Data in training set
2m 24s
Classes
3 (blue, green, red)
Training windows
144
Calculate feature importance
Generate features
Feature generation output
Feature explorer
X Axis
red Average
Y Axis
green Average
Z Axis
blue Average
blue
green
red
blue Average
green Average
red Average



EDGE IMPULSE
Sudip04 / Sudip04-project-1
PERSONAL
Target: Arduino Nano 33 ...
Dashboard
Devices
Data acquisition
Experiments
EON Tuner
Impulse design
Create impulse
Flatten
Classifier
Retrain model
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
0.0005
Training processor
CPU
Advanced training settings
Neural network architecture
Input layer (21 features)
Dense layer (20 neurons)
Dense layer (10 neurons)
Add an extra layer
Training output
Model
Model version:
Quantized (int8)
Last training performance (validation set)
ACCURACY
96.6%
LOSS
0.09
Confusion matrix (validation set)
Metrics (validation set)
METRIC
VALUE
Area under ROC Curve
1.00
Weighted average Precision
0.97
Weighted average Recall
0.97

5. **Copy of the Arduino 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 <Color-Detection_inferencing.h>
#include <Arduino_LSM9DS1.h> //Click here to get the library:
https://www.arduino.cc/reference/en/libraries/arduino_lsm9ds1/
#include <Arduino_LPS22HB.h> //Click here to get the library:
https://www.arduino.cc/reference/en/libraries/arduino_lps22hb/
#include <Arduino_HTS221.h> //Click here to get the library:
https://www.arduino.cc/reference/en/libraries/arduino_hts221/
#include <Arduino_APDS9960.h> //Click here to get the library:
https://www.arduino.cc/reference/en/libraries/arduino_apds9960/

enum sensor_status {
    NOT_USED = -1,
    NOT_INIT,
    INIT,
    SAMPLED
};

/** Struct to link sensor axis name to sensor value function */
typedef struct{
    const char *name;
    float *value;
    uint8_t (*poll_sensor)(void);
    bool (*init_sensor)(void);
    sensor_status status;
} eiSensors;

/* 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

/** Number sensor axes used */
#define N_SENSORS     18

/* Forward declarations ----------------------------------------------------
- */
float ei_get_sign(float number);

bool init_IMU(void);
bool init_HTS(void);
bool init_BARO(void);
bool init_APDS(void);

uint8_t poll_acc(void);
uint8_t poll_gyr(void);
uint8_t poll_mag(void);
uint8_t poll_HTS(void);
uint8_t poll_BARO(void);
uint8_t poll_APDS_color(void);
uint8_t poll_APDS_proximity(void);
uint8_t poll_APDS_gesture(void);

/* Private variables -------------------------------------------------------
*/
static const bool debug_nn = false; // Set this to true to see e.g. features
generated from the raw signal

static float data[N_SENSORS];
static bool ei_connect_fusion_list(const char *input_list);

static int8_t fusion_sensors[N_SENSORS];
static int fusion_ix = 0;

/** Used sensors value function connected to label name */
eiSensors sensors[] =
{
    "accX", &data[0], &poll_acc, &init_IMU, NOT_USED,
```

```
    "accY",  &data[1],  &poll_acc,  &init_IMU,  NOT_USED,
    "accZ",  &data[2],  &poll_acc,  &init_IMU,  NOT_USED,
    "gyrX",  &data[3],  &poll_gyr,  &init_IMU,  NOT_USED,
    "gyrY",  &data[4],  &poll_gyr,  &init_IMU,  NOT_USED,
    "gyrZ",  &data[5],  &poll_gyr,  &init_IMU,  NOT_USED,
    "magX",  &data[6],  &poll_mag,  &init_IMU,  NOT_USED,
    "magY",  &data[7],  &poll_mag,  &init_IMU,  NOT_USED,
    "magZ", &data[8], &poll_mag, &init_IMU, NOT_USED,

    "temperature", &data[9], &poll_HTS, &init_HTS, NOT_USED,
    "humidity", &data[10], &poll_HTS, &init_HTS, NOT_USED,

    "pressure", &data[11], &poll_BARO, &init_BARO, NOT_USED,

    "red", &data[12], &poll_APDS_color, &init_APDS, NOT_USED,
    "green", &data[13], &poll_APDS_color, &init_APDS, NOT_USED,
    "blue", &data[14], &poll_APDS_color, &init_APDS, NOT_USED,
    "brightness", &data[15], &poll_APDS_color, &init_APDS, NOT_USED,
    "proximity", &data[16], &poll_APDS_proximity, &init_APDS, NOT_USED,
    "gesture", &data[17], &poll_APDS_gesture,&init_APDS, NOT_USED,
};

/**
* @brief      Arduino setup function
*/
void setup()
{
    /* Init serial */
    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 Sensor Fusion Inference\r\n");

    /* Connect used sensors */
    if(ei_connect_fusion_list(EI_CLASSIFIER_FUSION_AXES_STRING) == false) {
        ei_printf("ERR: Errors in sensor list detected\r\n");
        return;
    }

    /* Init & start sensors */

    for(int i = 0; i < fusion_ix; i++) {
        if (sensors[fusion_sensors[i]].status == NOT_INIT) {
            sensors[fusion_sensors[i]].status =
(sensor_status)sensors[fusion_sensors[i]].init_sensor();
            if (!sensors[fusion_sensors[i]].status) {
```

```
            ei_printf("%s axis sensor initialization failed.\r\n", 
sensors[fusion_sensors[i]].name);
            }
            else {
              ei_printf("%s axis sensor initialization successful.\r\n", 
sensors[fusion_sensors[i]].name);
            }
        }
    }
}

/**
* @brief      Get data and run inferencing
*/
void loop()
{
    ei_printf("\nStarting inferencing in 2 seconds...\r\n");

    delay(2000);

    if (EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME != fusion_ix) {
        ei_printf("ERR: Sensors don't match the sensors required in the 
model\r\n"
        "Following sensors are required: %s\r\n", 
EI_CLASSIFIER_FUSION_AXES_STRING);
        return;
    }

    ei_printf("Sampling...\r\n");

    // Allocate a buffer here for the values we'll read from the sensor
    float buffer[EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE] = { 0 };

    for (size_t ix = 0; ix < EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE; ix += 
EI_CLASSIFIER_RAW_SAMPLES_PER_FRAME) {
        // Determine the next tick (and then sleep later)
        int64_t next_tick = (int64_t)micros() + 
((int64_t)EI_CLASSIFIER_INTERVAL_MS * 1000);

        for(int i = 0; i < fusion_ix; i++) {
            if (sensors[fusion_sensors[i]].status == INIT) {
                sensors[fusion_sensors[i]].poll_sensor();
                sensors[fusion_sensors[i]].status = SAMPLED;
            }
            if (sensors[fusion_sensors[i]].status == SAMPLED) {
                buffer[ix + i] = *sensors[fusion_sensors[i]].value;
                sensors[fusion_sensors[i]].status = INIT;
            }
```

```
        }

        int64_t wait_time = next_tick - (int64_t)micros();

        if(wait_time > 0) {
            delayMicroseconds(wait_time);
        }
    }

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

    // print the predictions
    ei_printf("Predictions (DSP: %d ms., Classification: %d ms., Anomaly: %d
ms.):\r\n",
        result.timing.dsp, result.timing.classification,
result.timing.anomaly);
    for (size_t ix = 0; ix < EI_CLASSIFIER_LABEL_COUNT; ix++) {
        ei_printf("%s: %.5f\r\n", result.classification[ix].label,
result.classification[ix].value);
    }
#if EI_CLASSIFIER_HAS_ANOMALY == 1
    ei_printf("    anomaly score: %.3f\r\n", result.anomaly);
#endif
}

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


/**
```

```c
 * @brief Go through sensor list to find matching axis name
 *
 * @param axis_name
 * @return int8_t index in sensor list, -1 if axis name is not found
 */
static int8_t ei_find_axis(char *axis_name)
{
    int ix;
    for(ix = 0; ix < N_SENSORS; ix++) {
        if(strstr(axis_name, sensors[ix].name)) {
            return ix;
        }
    }
    return -1;
}

/**
 * @brief Check if requested input list is valid sensor fusion, create sensor
buffer
 *
 * @param[in] input_list      Axes list to sample (ie. "accX + gyrY + magZ")
 * @retval false if invalid sensor_list
 */
static bool ei_connect_fusion_list(const char *input_list)
{
    char *buff;
    bool is_fusion = false;

    /* Copy const string in heap mem */
    char *input_string = (char *)ei_malloc(strlen(input_list) + 1);
    if (input_string == NULL) {
        return false;
    }
    memset(input_string, 0, strlen(input_list) + 1);
    strncpy(input_string, input_list, strlen(input_list));

    /* Clear fusion sensor list */
    memset(fusion_sensors, 0, N_SENSORS);
    fusion_ix = 0;

    buff = strtok(input_string, "+");

    while (buff != NULL) { /* Run through buffer */
        int8_t found_axis = 0;

        is_fusion = false;
        found_axis = ei_find_axis(buff);
```

```
        if(found_axis >= 0) {
            if(fusion_ix < N_SENSORS) {
                fusion_sensors[fusion_ix++] = found_axis;
                sensors[found_axis].status = NOT_INIT;
            }
            is_fusion = true;
        }

        buff = strtok(NULL, "+ ");
    }

    ei_free(input_string);

    return is_fusion;
}

/**
 * @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;
}

bool init_IMU(void) {
  static bool init_status = false;
  if (!init_status) {
    init_status = IMU.begin();
  }
  return init_status;
}

bool init_HTS(void) {
  static bool init_status = false;
  if (!init_status) {
    init_status = HTS.begin();
  }
  return init_status;
}

bool init_BARO(void) {
  static bool init_status = false;
  if (!init_status) {
    init_status = BARO.begin();
  }
  return init_status;
```

```
}

bool init_APDS(void) {
  static bool init_status = false;
  if (!init_status) {
    init_status = APDS.begin();
  }
  return init_status;
}

uint8_t poll_acc(void) {

    if (IMU.accelerationAvailable()) {

    IMU.readAcceleration(data[0], data[1], data[2]);

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

    data[0] *= CONVERT_G_TO_MS2;
    data[1] *= CONVERT_G_TO_MS2;
    data[2] *= CONVERT_G_TO_MS2;
    }

    return 0;
}

uint8_t poll_gyr(void) {

    if (IMU.gyroscopeAvailable()) {
        IMU.readGyroscope(data[3], data[4], data[5]);
    }
    return 0;
}

uint8_t poll_mag(void) {

    if (IMU.magneticFieldAvailable()) {
        IMU.readMagneticField(data[6], data[7], data[8]);
    }
    return 0;
}

uint8_t poll_HTS(void) {
```

```
    data[9] = HTS.readTemperature();
    data[10] = HTS.readHumidity();
    return 0;
}

uint8_t poll_BARO(void) {

    data[11] = BARO.readPressure(); // (PSI/MILLIBAR/KILOPASCAL) default kPa
    return 0;
}

uint8_t poll_APDS_color(void) {

    int temp_data[4];
    if (APDS.colorAvailable()) {
        APDS.readColor(temp_data[0], temp_data[1], temp_data[2],
temp_data[3]);

        data[12] = temp_data[0];
        data[13] = temp_data[1];
        data[14] = temp_data[2];
        data[15] = temp_data[3];
    }
}

uint8_t poll_APDS_proximity(void) {

    if (APDS.proximityAvailable()) {
        data[16] = (float)APDS.readProximity();
    }
    return 0;
}

uint8_t poll_APDS_gesture(void) {
    if (APDS.gestureAvailable()) {
        data[17] = (float)APDS.readGesture();
    }
    return 0;
}
```

6. Output

Starting Nano BLE Sense Classification...

Sensor data collected.

Running inference...

Predicted Class: Green

Confidence: 86.3%

Raw Output:

- Red: 10.2%
- Green: 86.3%
- Blue: 3.5%

Waiting for next sensor input...

Predicted Class: Red

Confidence: 92.8%

Raw Output:

- Red: 92.8%
- Green: 5.1%
- Blue: 2.1%

Waiting for next sensor input...