Edge Computing Lab

Class: TY-AIEC

School of Computing, MIT Art Design Technology University

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Experiment No. 7

TASHU DHOTE

TY AIEC

2223307

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

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:

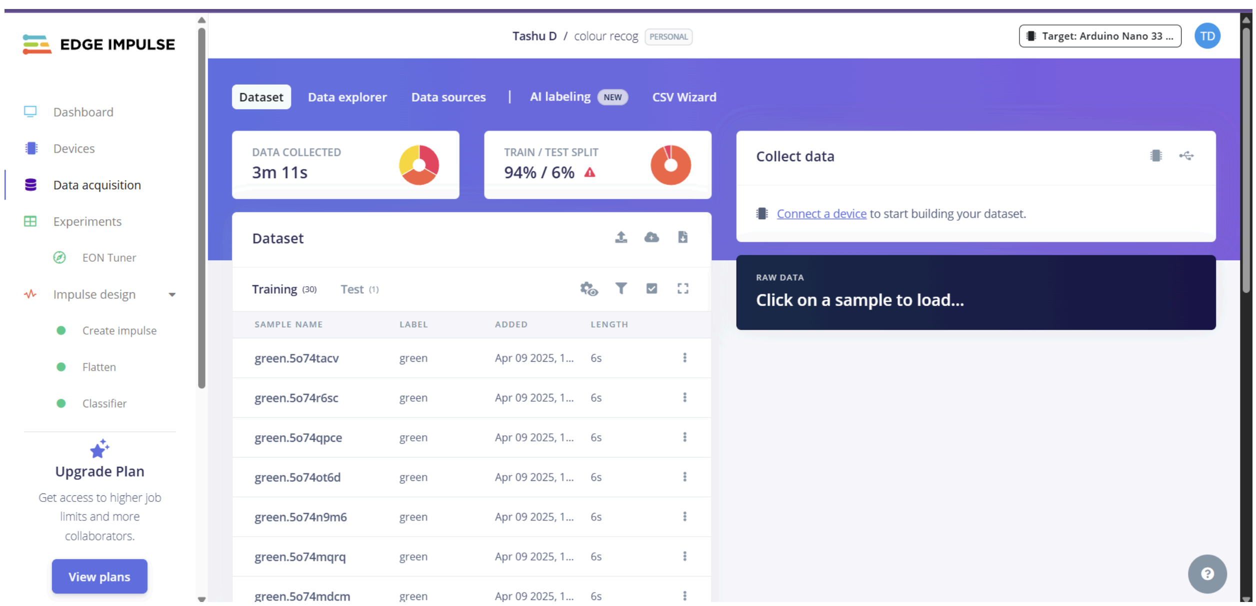
- With the model deployed, run inference on the edge device to see it classifying data in real-time.

10. Monitor:

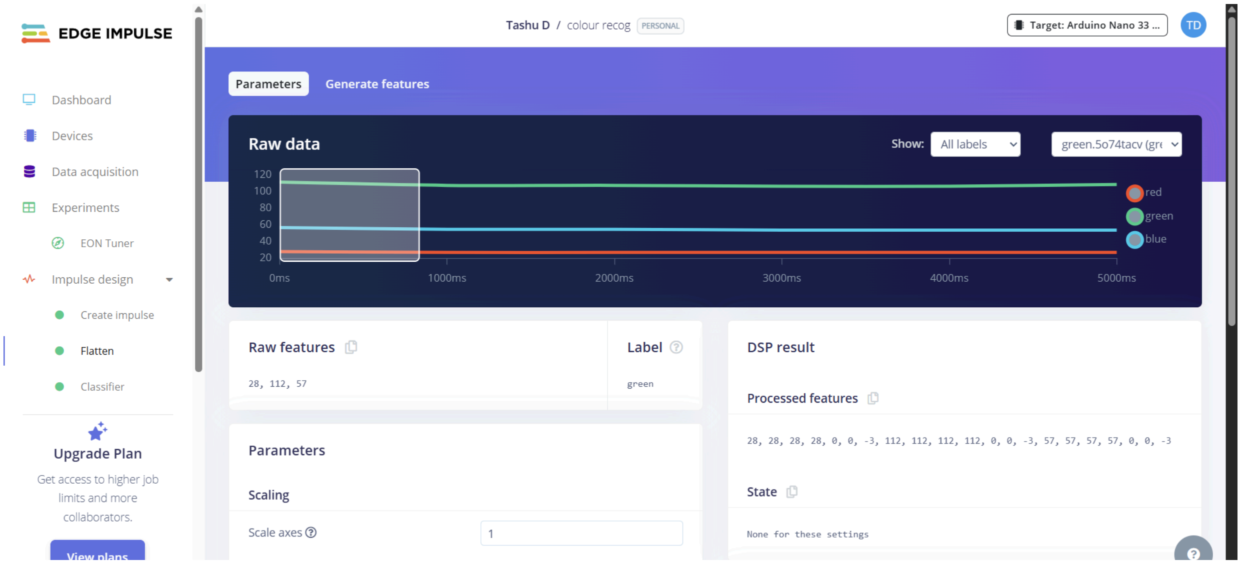
- You can monitor the performance of your device through the Edge Impulse studio.

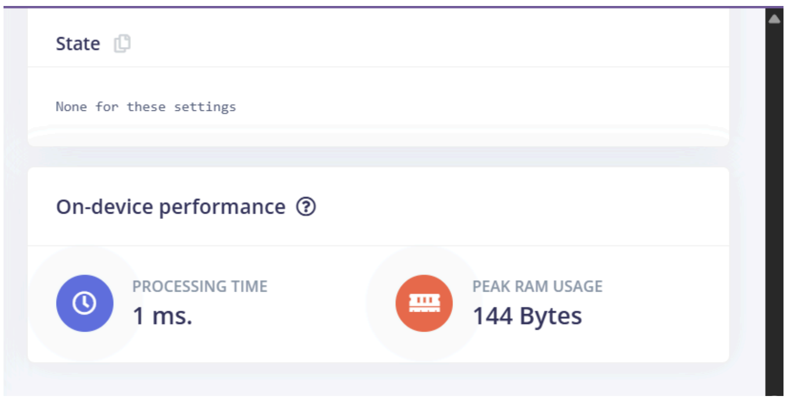
Paste your Edge Impulse project's Results:

1) Dataset Image

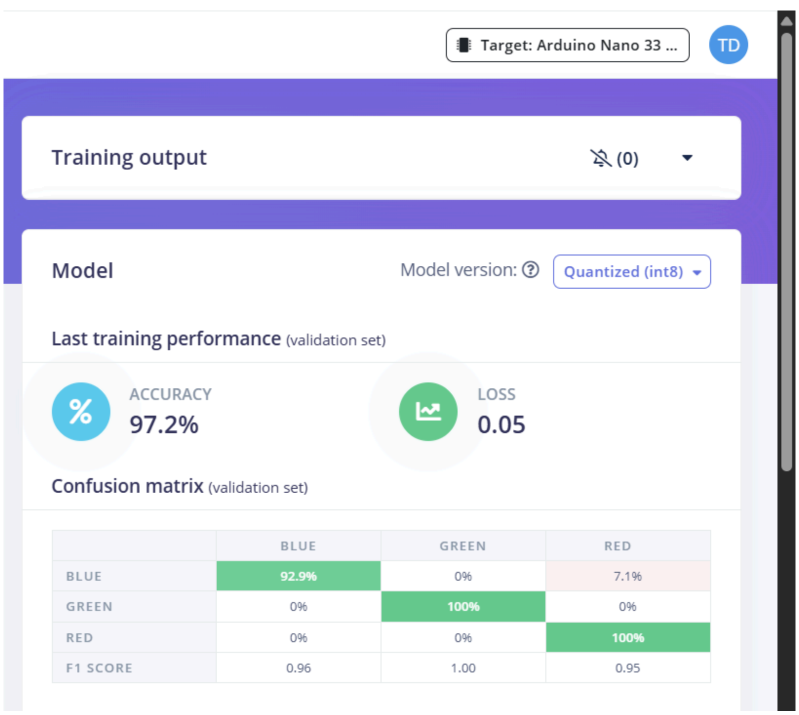


2) Feature extraction - Image

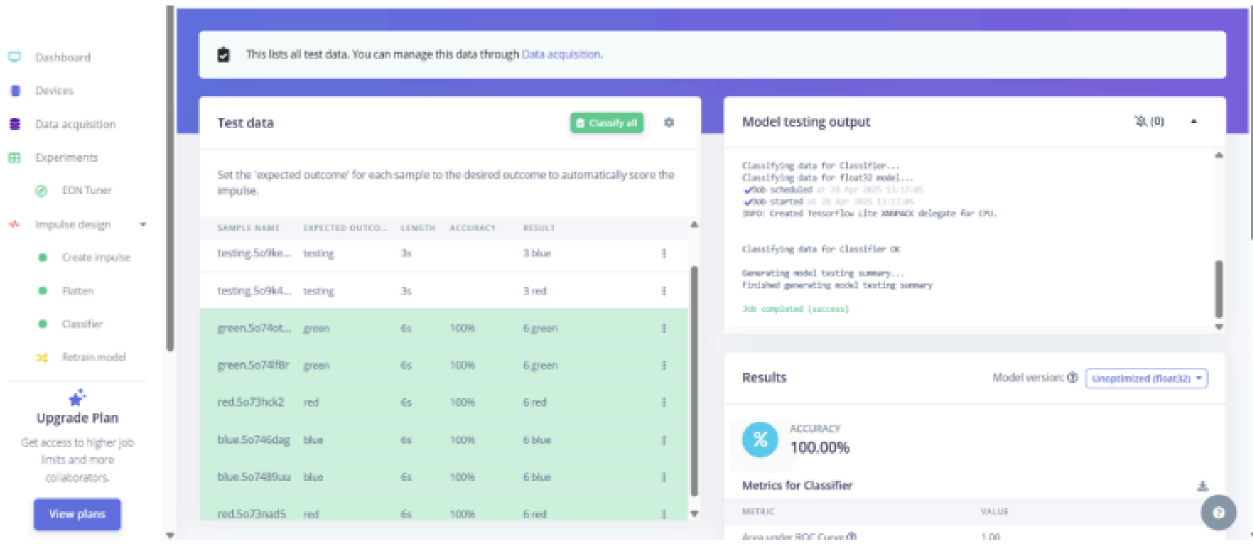




3) Accuracy / Loss - Confusion Matrix – image



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 <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) Screen shot of Arduino Terminal - Result

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...