Edge Computing Lab

Class: TY-AIEC

School of Computing, MIT Art Design Technology University

Academic Year: 2024-25

Experiment No. 10

Introduction
Study of Transfer Learning (Images) on Edge Computing Devices

Objective: Build a project to apply Transfer Learning of MobileNetV1 & V2 architectures trained on an ImageNet dataset

Tasks:

- Understand Transfer learning
- Understanding of MobileNetV1 & V2 Architectures
- Configure Edge Impulse for Object Detection
- Apply a pre-trained network for you to fine-tune your specific application
- Building and Training a Model
- Deploy on Edge Computing Devices

Introduction

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

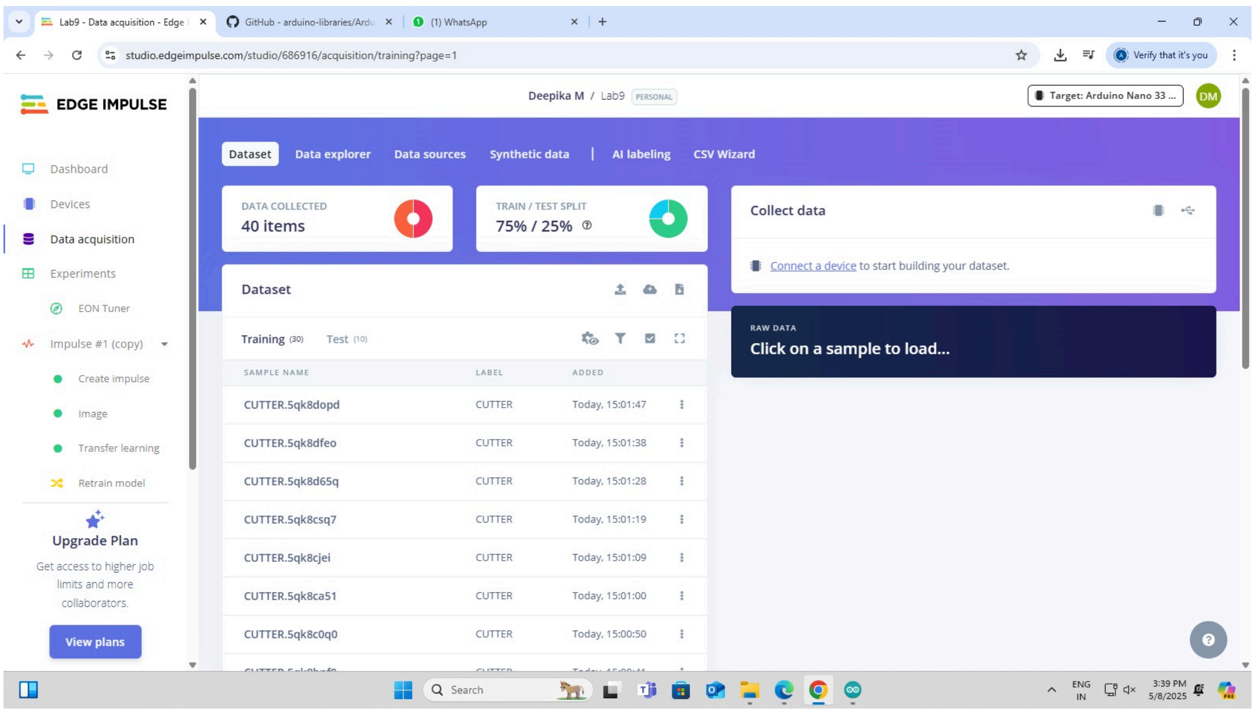
9. Run Inference:

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

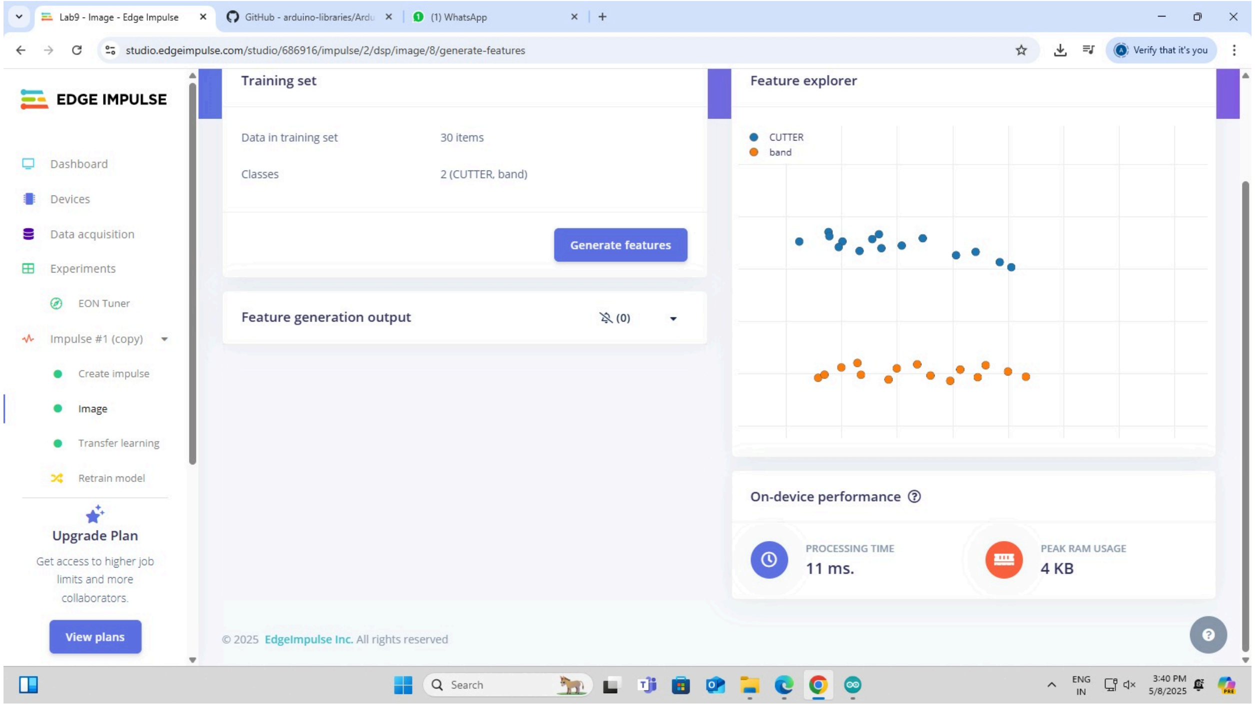
10. Monitor:

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

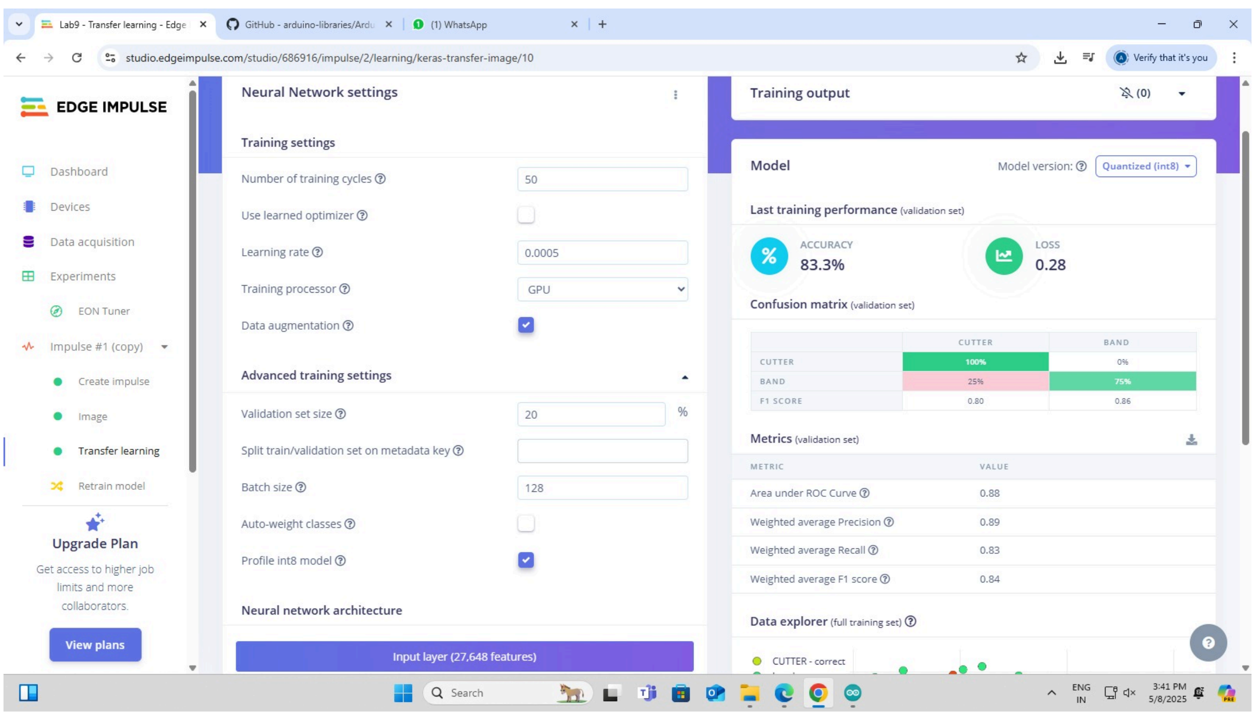
1) Dataset Image



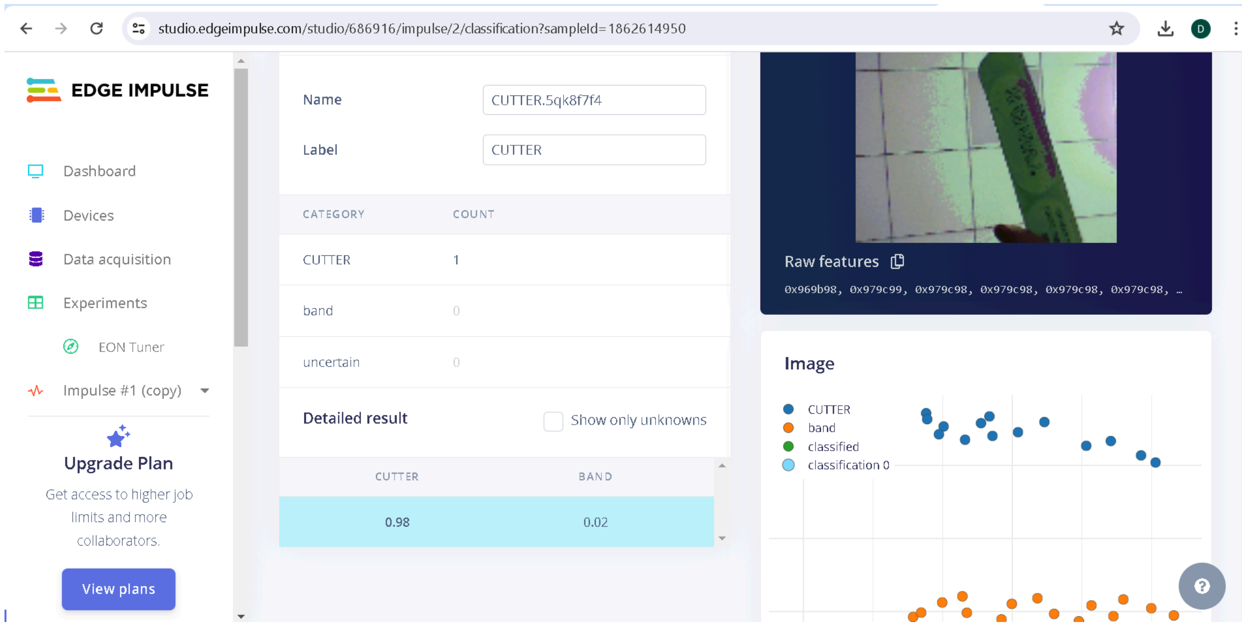
2) Feature extraction - Image



3) Accuracy / Loss - Confusion Matrix – image



4) Validation Result – Image



5) Copy the code of Arduino Sketch

```
/* Edge Impulse ingestion SDK

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 *

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 *

 */
```

```
/* Includes
---------------------------------------------------------------- */

#include <Lab9_inferencing.h>

#include <Arduino_OV767X.h> //Click here to get the library:
https://www.arduino.cc/reference/en/libraries/arduino_ov767x/


#include <stdint.h>

#include <stdlib.h>


/* Constant variables
------------------------------------------------------- */

#define EI_CAMERA_RAW_FRAME_BUFFER_COLS     160

#define EI_CAMERA_RAW_FRAME_BUFFER_ROWS     120


#define DWORD_ALIGN_PTR(a)   ((a & 0x3) ?(((uintptr_t)a + 0x4) &
~(uintptr_t)0x3) : a)


/*

 ** 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_vers
ion>/`.

 **

 ** 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.
 */

/* Edge Impulse
------------------------------------------------------------- */
class OV7675 : public OV767X {
    public:
        int begin(int resolution, int format, int fps);
        void readFrame(void* buffer);

    private:
        int vsyncPin;
        int hrefPin;
        int pclkPin;
        int xclkPin;

        volatile uint32_t* vsyncPort;
        uint32_t vsyncMask;
        volatile uint32_t* hrefPort;
        uint32_t hrefMask;
        volatile uint32_t* pclkPort;
        uint32_t pclkMask;

        uint16_t width;
        uint16_t height;
        uint8_t bytes_per_pixel;
```

```
        uint16_t bytes_per_row;
        uint8_t buf_rows;
        uint16_t buf_size;
        uint8_t resize_height;
        uint8_t *raw_buf;
        void *buf_mem;
        uint8_t *intrp_buf;
        uint8_t *buf_limit;

        void readBuf();
        int allocate_scratch_buffs();
        int deallocate_scratch_buffs();
};

typedef struct {
    size_t width;
    size_t height;
} ei_device_resize_resolutions_t;

/**
 * @brief      Check if new serial data is available
 *
 * @return     Returns number of available bytes
 */
int ei_get_serial_available(void) {
    return Serial.available();
}
```

```
/**
 * @brief      Get next available byte
 *
 * @return     byte
 */
char ei_get_serial_byte(void) {
    return Serial.read();
}

/* Private variables
------------------------------------------------------- */
static OV7675 Cam;
static bool is_initialised = false;

/*
** @brief points to the output of the capture
*/
static uint8_t *ei_camera_capture_out = NULL;
uint32_t resize_col_sz;
uint32_t resize_row_sz;
bool do_resize = false;
bool do_crop = false;

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

/* Function definitions
------------------------------------------------------- */
bool ei_camera_init(void);
```

```
void ei_camera_deinit(void);

bool ei_camera_capture(uint32_t img_width, uint32_t img_height,
uint8_t *out_buf) ;

int calculate_resize_dimensions(uint32_t out_width, uint32_t
out_height, uint32_t *resize_col_sz, uint32_t *resize_row_sz, bool
*do_resize);

void resizeImage(int srcWidth, int srcHeight, uint8_t *srcImage, int
dstWidth, int dstHeight, uint8_t *dstImage, int iBpp);

void cropImage(int srcWidth, int srcHeight, uint8_t *srcImage, int
startX, int startY, int dstWidth, int dstHeight, uint8_t *dstImage,
int iBpp);


/**

* @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("\tImage resolution: %dx%d\n",
EI_CLASSIFIER_INPUT_WIDTH, EI_CLASSIFIER_INPUT_HEIGHT);

    ei_printf("\tFrame size: %d\n",
EI_CLASSIFIER_DSP_INPUT_FRAME_SIZE);
```

```
    ei_printf("\tNo. of classes: %d\n",
sizeof(ei_classifier_inferencing_categories) /
sizeof(ei_classifier_inferencing_categories[0]));
}


/**
* @brief      Get data and run inferencing
*
* @param[in]  debug  Get debug info if true
*/
void loop()
{
    bool stop_inferencing = false;

    while(stop_inferencing == false) {
        ei_printf("\nStarting inferencing in 2 seconds...\n");

        // instead of wait_ms, we'll wait on the signal, this allows
threads to cancel us...
        if (ei_sleep(2000) != EI_IMPULSE_OK) {
            break;
        }

        ei_printf("Taking photo...\n");

        if (ei_camera_init() == false) {
            ei_printf("ERR: Failed to initialize image sensor\r\n");
            break;
        }
```

```
        // choose resize dimensions
        uint32_t resize_col_sz;
        uint32_t resize_row_sz;
        bool do_resize = false;
        int res =
calculate_resize_dimensions(EI_CLASSIFIER_INPUT_WIDTH,
EI_CLASSIFIER_INPUT_HEIGHT, &resize_col_sz, &resize_row_sz,
&do_resize);
        if (res) {
            ei_printf("ERR: Failed to calculate resize dimensions
(%d)\r\n", res);
            break;
        }

        void *snapshot_mem = NULL;
        uint8_t *snapshot_buf = NULL;
        snapshot_mem = ei_malloc(resize_col_sz*resize_row_sz*2);
        if(snapshot_mem == NULL) {
            ei_printf("failed to create snapshot_mem\r\n");
            break;
        }
        snapshot_buf = (uint8_t
*)DWORD_ALIGN_PTR((uintptr_t)snapshot_mem);

        if (ei_camera_capture(EI_CLASSIFIER_INPUT_WIDTH,
EI_CLASSIFIER_INPUT_HEIGHT, snapshot_buf) == false) {
            ei_printf("Failed to capture image\r\n");
            if (snapshot_mem) ei_free(snapshot_mem);
            break;
        }
```

```
        ei::signal_t signal;
        signal.total_length = EI_CLASSIFIER_INPUT_WIDTH *
EI_CLASSIFIER_INPUT_HEIGHT;
        signal.get_data = &ei_camera_cutout_get_data;

        // run the impulse: DSP, neural network and the Anomaly
algorithm
        ei_impulse_result_t result = { 0 };

        EI_IMPULSE_ERROR ei_error = run_classifier(&signal, &result,
debug_nn);
        if (ei_error != EI_IMPULSE_OK) {
            ei_printf("Failed to run impulse (%d)\n", ei_error);
            ei_free(snapshot_mem);
            break;
        }

        // print the predictions
        ei_printf("Predictions (DSP: %d ms., Classification: %d ms.,
Anomaly: %d ms.): \n",
                  result.timing.dsp, result.timing.classification,
result.timing.anomaly);
#if EI_CLASSIFIER_OBJECT_DETECTION == 1
        ei_printf("Object detection bounding boxes:\r\n");
        for (uint32_t i = 0; i < result.bounding_boxes_count; i++) {
            ei_impulse_result_bounding_box_t bb =
result.bounding_boxes[i];
            if (bb.value == 0) {
                continue;
            }
```

```
            ei_printf("  %s (%f) [ x: %u, y: %u, width: %u, height: %u ]\r\n",
                        bb.label,
                        bb.value,
                        bb.x,
                        bb.y,
                        bb.width,
                        bb.height);
        }

    // Print the prediction results (classification)
#else
        ei_printf("Predictions:\r\n");
        for (uint16_t i = 0; i < EI_CLASSIFIER_LABEL_COUNT; i++) {
            ei_printf("  %s: ", ei_classifier_inferencing_categories[i]);
            ei_printf("%.5f\r\n", result.classification[i].value);
        }
#endif

    // Print anomaly result (if it exists)
#if EI_CLASSIFIER_HAS_ANOMALY
        ei_printf("Anomaly prediction: %.3f\r\n", result.anomaly);
#endif

#if EI_CLASSIFIER_HAS_VISUAL_ANOMALY
        ei_printf("Visual anomalies:\r\n");
        for (uint32_t i = 0; i < result.visual_ad_count; i++) {
```

```
            ei_impulse_result_bounding_box_t bb =
result.visual_ad_grid_cells[i];

            if (bb.value == 0) {

                continue;

            }

            ei_printf("  %s (%f) [ x: %u, y: %u, width: %u, height:
%u ]\r\n",

                    bb.label,

                    bb.value,

                    bb.x,

                    bb.y,

                    bb.width,

                    bb.height);

        }

#endif


        while (ei_get_serial_available() > 0) {

            if (ei_get_serial_byte() == 'b') {

                ei_printf("Inferencing stopped by user\r\n");

                stop_inferencing = true;

            }

        }

        if (snapshot_mem) ei_free(snapshot_mem);

    }

    ei_camera_deinit();

}


/**

 * @brief      Determine whether to resize and to which dimension
```

```
 *
 * @param[in]  out_width     width of output image
 * @param[in]  out_height    height of output image
 * @param[out] resize_col_sz       pointer to frame buffer's
column/width value
 * @param[out] resize_row_sz       pointer to frame buffer's
rows/height value
 * @param[out] do_resize     returns whether to resize (or not)
 *
 */
int calculate_resize_dimensions(uint32_t out_width, uint32_t
out_height, uint32_t *resize_col_sz, uint32_t *resize_row_sz, bool
*do_resize)
{
    size_t list_size = 2;
    const ei_device_resize_resolutions_t list[list_size] = {
{42,32}, {128,96} };

    // (default) conditions
    *resize_col_sz = EI_CAMERA_RAW_FRAME_BUFFER_COLS;
    *resize_row_sz = EI_CAMERA_RAW_FRAME_BUFFER_ROWS;
    *do_resize = false;

    for (size_t ix = 0; ix < list_size; ix++) {
        if ((out_width <= list[ix].width) && (out_height <=
list[ix].height)) {
            *resize_col_sz = list[ix].width;
            *resize_row_sz = list[ix].height;
            *do_resize = true;
            break;
        }
```

```
    }

    return 0;
}

/**
 * @brief   Setup image sensor & start streaming
 *
 * @retval  false if initialisation failed
 */
bool ei_camera_init(void) {
    if (is_initialised) return true;

    if (!Cam.begin(QQVGA, RGB565, 1)) { // VGA downsampled to QQVGA
(OV7675)
        ei_printf("ERR: Failed to initialize camera\r\n");
        return false;
    }
    is_initialised = true;

    return true;
}

/**
 * @brief      Stop streaming of sensor data
 */
void ei_camera_deinit(void) {
    if (is_initialised) {
        Cam.end();
```

```
        is_initialised = false;
    }
}


/**
 * @brief      Capture, rescale and crop image
 *
 * @param[in]  img_width     width of output image
 * @param[in]  img_height    height of output image
 * @param[in]  out_buf       pointer to store output image, NULL may
be used
 *                           when full resolution is expected.
 *
 * @retval     false if not initialised, image captured, rescaled or
cropped failed
 *
 */
bool ei_camera_capture(uint32_t img_width, uint32_t img_height,
uint8_t *out_buf)
{
    if (!is_initialised) {
        ei_printf("ERR: Camera is not initialized\r\n");
        return false;
    }

    if (!out_buf) {
        ei_printf("ERR: invalid parameters\r\n");
        return false;
    }
```

```
    // choose resize dimensions
    int res = calculate_resize_dimensions(img_width, img_height,
&resize_col_sz, &resize_row_sz, &do_resize);
    if (res) {
        ei_printf("ERR: Failed to calculate resize dimensions
(%d)\r\n", res);
        return false;
    }

    if ((img_width != resize_col_sz)
        || (img_height != resize_row_sz)) {
        do_crop = true;
    }

    Cam.readFrame(out_buf); // captures image and resizes

    if (do_crop) {
        uint32_t crop_col_sz;
        uint32_t crop_row_sz;
        uint32_t crop_col_start;
        uint32_t crop_row_start;
        crop_row_start = (resize_row_sz - img_height) / 2;
        crop_col_start = (resize_col_sz - img_width) / 2;
        crop_col_sz = img_width;
        crop_row_sz = img_height;

        //ei_printf("crop cols: %d, rows: %d\r\n",
crop_col_sz,crop_row_sz);
```

```
        cropImage(resize_col_sz, resize_row_sz,
                out_buf,
                crop_col_start, crop_row_start,
                crop_col_sz, crop_row_sz,
                out_buf,
                16);
    }

    // The following variables should always be assigned
    // if this routine is to return true
    // cutout values
    //ei_camera_snapshot_is_resized = do_resize;
    //ei_camera_snapshot_is_cropped = do_crop;
    ei_camera_capture_out = out_buf;

    return true;
}

/**
 * @brief      Convert RGB565 raw camera buffer to RGB888
 *
 * @param[in]   offset       pixel offset of raw buffer
 * @param[in]   length       number of pixels to convert
 * @param[out]  out_buf      pointer to store output image
 */
int ei_camera_cutout_get_data(size_t offset, size_t length, float
*out_ptr) {
    size_t pixel_ix = offset * 2;
    size_t bytes_left = length;
```

```
    size_t out_ptr_ix = 0;

    // read byte for byte
    while (bytes_left != 0) {
        // grab the value and convert to r/g/b
        uint16_t pixel = (ei_camera_capture_out[pixel_ix] << 8) |
ei_camera_capture_out[pixel_ix+1];
        uint8_t r, g, b;
        r = ((pixel >> 11) & 0x1f) << 3;
        g = ((pixel >> 5) & 0x3f) << 2;
        b = (pixel & 0x1f) << 3;

        // then convert to out_ptr format
        float pixel_f = (r << 16) + (g << 8) + b;
        out_ptr[out_ptr_ix] = pixel_f;

        // and go to the next pixel
        out_ptr_ix++;
        pixel_ix+=2;
        bytes_left--;
    }

    // and done!
    return 0;
}

// This include file works in the Arduino environment
// to define the Cortex-M intrinsics
#ifdef __ARM_FEATURE_SIMD32
```

```c
#include <device.h>
#endif
// This needs to be < 16 or it won't fit. Cortex-M4 only has SIMD for signed multiplies
#define FRAC_BITS 14
#define FRAC_VAL (1<<FRAC_BITS)
#define FRAC_MASK (FRAC_VAL - 1)
//
// Resize
//
// Assumes that the destination buffer is dword-aligned
// Can be used to resize the image smaller or larger
// If resizing much smaller than 1/3 size, then a more rubust algorithm should average all of the pixels
// This algorithm uses bilinear interpolation - averages a 2x2 region to generate each new pixel
//
// Optimized for 32-bit MCUs
// supports 8 and 16-bit pixels
void resizeImage(int srcWidth, int srcHeight, uint8_t *srcImage, int dstWidth, int dstHeight, uint8_t *dstImage, int iBpp)
{
    uint32_t src_x_accum, src_y_accum; // accumulators and fractions for scaling the image
    uint32_t x_frac, nx_frac, y_frac, ny_frac;
    int x, y, ty, tx;

    if (iBpp != 8 && iBpp != 16)
        return;
    src_y_accum = FRAC_VAL/2; // start at 1/2 pixel in to account for integer downsampling which might miss pixels
```

```
    const uint32_t src_x_frac = (srcWidth * FRAC_VAL) / dstWidth;

    const uint32_t src_y_frac = (srcHeight * FRAC_VAL) / dstHeight;

    const uint32_t r_mask = 0xf800f800;

    const uint32_t g_mask = 0x07e007e0;

    const uint32_t b_mask = 0x001f001f;

    uint8_t *s, *d;

    uint16_t *s16, *d16;

    uint32_t x_frac2, y_frac2; // for 16-bit SIMD

    for (y=0; y < dstHeight; y++) {

        ty = src_y_accum >> FRAC_BITS; // src y

        y_frac = src_y_accum & FRAC_MASK;

        src_y_accum += src_y_frac;

        ny_frac = FRAC_VAL - y_frac; // y fraction and 1.0 - y
fraction

        y_frac2 = ny_frac | (y_frac << 16); // for M4/M4 SIMD

        s = &srcImage[ty * srcWidth];

        s16 = (uint16_t *)&srcImage[ty * srcWidth * 2];

        d = &dstImage[y * dstWidth];

        d16 = (uint16_t *)&dstImage[y * dstWidth * 2];

        src_x_accum = FRAC_VAL/2; // start at 1/2 pixel in to
account for integer downsampling which might miss pixels

        if (iBpp == 8) {

        for (x=0; x < dstWidth; x++) {

            uint32_t tx, p00,p01,p10,p11;

            tx = src_x_accum >> FRAC_BITS;

            x_frac = src_x_accum & FRAC_MASK;

            nx_frac = FRAC_VAL - x_frac; // x fraction and 1.0 - x
fraction

            x_frac2 = nx_frac | (x_frac << 16);
```

```
            src_x_accum += src_x_frac;

            p00 = s[tx]; p10 = s[tx+1];

            p01 = s[tx+srcWidth]; p11 = s[tx+srcWidth+1];

    #ifdef __ARM_FEATURE_SIMD32

            p00 = __SMLAD(p00 | (p10<<16), x_frac2, FRAC_VAL/2) >>
FRAC_BITS; // top line

            p01 = __SMLAD(p01 | (p11<<16), x_frac2, FRAC_VAL/2) >>
FRAC_BITS; // bottom line

            p00 = __SMLAD(p00 | (p01<<16), y_frac2, FRAC_VAL/2) >>
FRAC_BITS; // combine

    #else // generic C code

            p00 = ((p00 * nx_frac) + (p10 * x_frac) + FRAC_VAL/2) >>
FRAC_BITS; // top line

            p01 = ((p01 * nx_frac) + (p11 * x_frac) + FRAC_VAL/2) >>
FRAC_BITS; // bottom line

            p00 = ((p00 * ny_frac) + (p01 * y_frac) + FRAC_VAL/2) >>
FRAC_BITS; // combine top + bottom

    #endif // Cortex-M4/M7

            *d++ = (uint8_t)p00; // store new pixel

        } // for x

        } // 8-bpp

        else

        { // RGB565

        for (x=0; x < dstWidth; x++) {

            uint32_t tx, p00,p01,p10,p11;

            uint32_t r00, r01, r10, r11, g00, g01, g10, g11, b00,
b01, b10, b11;

            tx = src_x_accum >> FRAC_BITS;

            x_frac = src_x_accum & FRAC_MASK;

            nx_frac = FRAC_VAL - x_frac; // x fraction and 1.0 - x
fraction
```

```
            x_frac2 = nx_frac | (x_frac << 16);

            src_x_accum += src_x_frac;

            p00 = __builtin_bswap16(s16[tx]); p10 =
__builtin_bswap16(s16[tx+1]);

            p01 = __builtin_bswap16(s16[tx+srcWidth]); p11 =
__builtin_bswap16(s16[tx+srcWidth+1]);

    #ifdef __ARM_FEATURE_SIMD32

            {

            p00 |= (p10 << 16);

            p01 |= (p11 << 16);

            r00 = (p00 & r_mask) >> 1; g00 = p00 & g_mask; b00 = p00
& b_mask;

            r01 = (p01 & r_mask) >> 1; g01 = p01 & g_mask; b01 = p01
& b_mask;

            r00 = __SMLAD(r00, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
top line

            r01 = __SMLAD(r01, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
bottom line

            r00 = __SMLAD(r00 | (r01<<16), y_frac2, FRAC_VAL/2) >>
FRAC_BITS; // combine

            g00 = __SMLAD(g00, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
top line

            g01 = __SMLAD(g01, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
bottom line

            g00 = __SMLAD(g00 | (g01<<16), y_frac2, FRAC_VAL/2) >>
FRAC_BITS; // combine

            b00 = __SMLAD(b00, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
top line

            b01 = __SMLAD(b01, x_frac2, FRAC_VAL/2) >> FRAC_BITS; //
bottom line

            b00 = __SMLAD(b00 | (b01<<16), y_frac2, FRAC_VAL/2) >>
FRAC_BITS; // combine

            }
```

```
    #else // generic C code
            {
            r00 = (p00 & r_mask) >> 1; g00 = p00 & g_mask; b00 = p00 & b_mask;
            r10 = (p10 & r_mask) >> 1; g10 = p10 & g_mask; b10 = p10 & b_mask;
            r01 = (p01 & r_mask) >> 1; g01 = p01 & g_mask; b01 = p01 & b_mask;
            r11 = (p11 & r_mask) >> 1; g11 = p11 & g_mask; b11 = p11 & b_mask;
            r00 = ((r00 * nx_frac) + (r10 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // top line
            r01 = ((r01 * nx_frac) + (r11 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // bottom line
            r00 = ((r00 * ny_frac) + (r01 * y_frac) + FRAC_VAL/2) >> FRAC_BITS; // combine top + bottom
            g00 = ((g00 * nx_frac) + (g10 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // top line
            g01 = ((g01 * nx_frac) + (g11 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // bottom line
            g00 = ((g00 * ny_frac) + (g01 * y_frac) + FRAC_VAL/2) >> FRAC_BITS; // combine top + bottom
            b00 = ((b00 * nx_frac) + (b10 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // top line
            b01 = ((b01 * nx_frac) + (b11 * x_frac) + FRAC_VAL/2) >> FRAC_BITS; // bottom line
            b00 = ((b00 * ny_frac) + (b01 * y_frac) + FRAC_VAL/2) >> FRAC_BITS; // combine top + bottom
            }
    #endif // Cortex-M4/M7
            r00 = (r00 << 1) & r_mask;
            g00 = g00 & g_mask;
            b00 = b00 & b_mask;
```

```
            p00 = (r00 | g00 | b00); // re-combine color components
            *d16++ = (uint16_t)__builtin_bswap16(p00); // store new pixel
        } // for x
        } // 16-bpp
    } // for y
} /* resizeImage() */
//
// Crop
//
// Assumes that the destination buffer is dword-aligned
// optimized for 32-bit MCUs
// Supports 8 and 16-bit pixels
//
void cropImage(int srcWidth, int srcHeight, uint8_t *srcImage, int startX, int startY, int dstWidth, int dstHeight, uint8_t *dstImage, int iBpp)
{
    uint32_t *s32, *d32;
    int x, y;

    if (startX < 0 || startX >= srcWidth || startY < 0 || startY >= srcHeight || (startX + dstWidth) > srcWidth || (startY + dstHeight) > srcHeight)
       return; // invalid parameters
    if (iBpp != 8 && iBpp != 16)
       return;

    if (iBpp == 8) {
      uint8_t *s, *d;
```

```
      for (y=0; y<dstHeight; y++) {
        s = &srcImage[srcWidth * (y + startY) + startX];
        d = &dstImage[(dstWidth * y)];
        x = 0;
        if ((intptr_t)s & 3 || (intptr_t)d & 3) { // either src or dst pointer is not aligned
          for (; x<dstWidth; x++) {
            *d++ = *s++; // have to do it byte-by-byte
          }
        } else {
          // move 4 bytes at a time if aligned or alignment not enforced
          s32 = (uint32_t *)s;
          d32 = (uint32_t *)d;
          for (; x<dstWidth-3; x+= 4) {
            *d32++ = *s32++;
          }
          // any remaining stragglers?
          s = (uint8_t *)s32;
          d = (uint8_t *)d32;
          for (; x<dstWidth; x++) {
            *d++ = *s++;
          }
        }
      } // for y
    } // 8-bpp
    else
    {
      uint16_t *s, *d;
```

```
      for (y=0; y<dstHeight; y++) {

        s = (uint16_t *)&srcImage[2 * srcWidth * (y + startY) +
startX * 2];

        d = (uint16_t *)&dstImage[(dstWidth * y * 2)];

        x = 0;

        if ((intptr_t)s & 2 || (intptr_t)d & 2) { // either src or
dst pointer is not aligned

          for (; x<dstWidth; x++) {

            *d++ = *s++; // have to do it 16-bits at a time

          }

        } else {

          // move 4 bytes at a time if aligned or alignment no
enforced

          s32 = (uint32_t *)s;

          d32 = (uint32_t *)d;

          for (; x<dstWidth-1; x+= 2) { // we can move 2 pixels at a
time

            *d32++ = *s32++;

          }

          // any remaining stragglers?

          s = (uint16_t *)s32;

          d = (uint16_t *)d32;

          for (; x<dstWidth; x++) {

            *d++ = *s++;

          }

        }

      } // for y

    } // 16-bpp case

} /* cropImage() */
```

```
#if !defined(EI_CLASSIFIER_SENSOR) || EI_CLASSIFIER_SENSOR !=
EI_CLASSIFIER_SENSOR_CAMERA

#error "Invalid model for current sensor"

#endif


// OV767X camera library override

#include <Arduino.h>

#include <Wire.h>


#define digitalPinToBitMask(P) (1 << (digitalPinToPinName(P) % 32))

#define portInputRegister(P) ((P == 0) ? &NRF_P0->IN : &NRF_P1->IN)


//

// OV7675::begin()

//

// Extends the OV767X library function. Some private variables are
needed

// to use the OV7675::readFrame function.

//

int OV7675::begin(int resolution, int format, int fps)

{

    pinMode(OV7670_VSYNC, INPUT);

    pinMode(OV7670_HREF, INPUT);

    pinMode(OV7670_PLK, INPUT);

    pinMode(OV7670_XCLK, OUTPUT);


    vsyncPort = portInputRegister(digitalPinToPort(OV7670_VSYNC));

    vsyncMask = digitalPinToBitMask(OV7670_VSYNC);

    hrefPort = portInputRegister(digitalPinToPort(OV7670_HREF));
```

```
    hrefMask = digitalPinToBitMask(OV7670_HREF);

    pclkPort = portInputRegister(digitalPinToPort(OV7670_PLK));

    pclkMask = digitalPinToBitMask(OV7670_PLK);


    // init driver to use full image sensor size

    bool ret = OV767X::begin(VGA, format, fps);

    width = OV767X::width(); // full sensor width

    height = OV767X::height(); // full sensor height

    bytes_per_pixel = OV767X::bytesPerPixel();

    bytes_per_row = width * bytes_per_pixel; // each pixel is 2
bytes

    resize_height = 2;


    buf_mem = NULL;

    raw_buf = NULL;

    intrp_buf = NULL;

    //allocate_scratch_buffs();


    return ret;

} /* OV7675::begin() */


int OV7675::allocate_scratch_buffs()

{

    //ei_printf("allocating buffers..\r\n");

    buf_rows = height / resize_row_sz * resize_height;

    buf_size = bytes_per_row * buf_rows;


    buf_mem = ei_malloc(buf_size);

    if(buf_mem == NULL) {
```

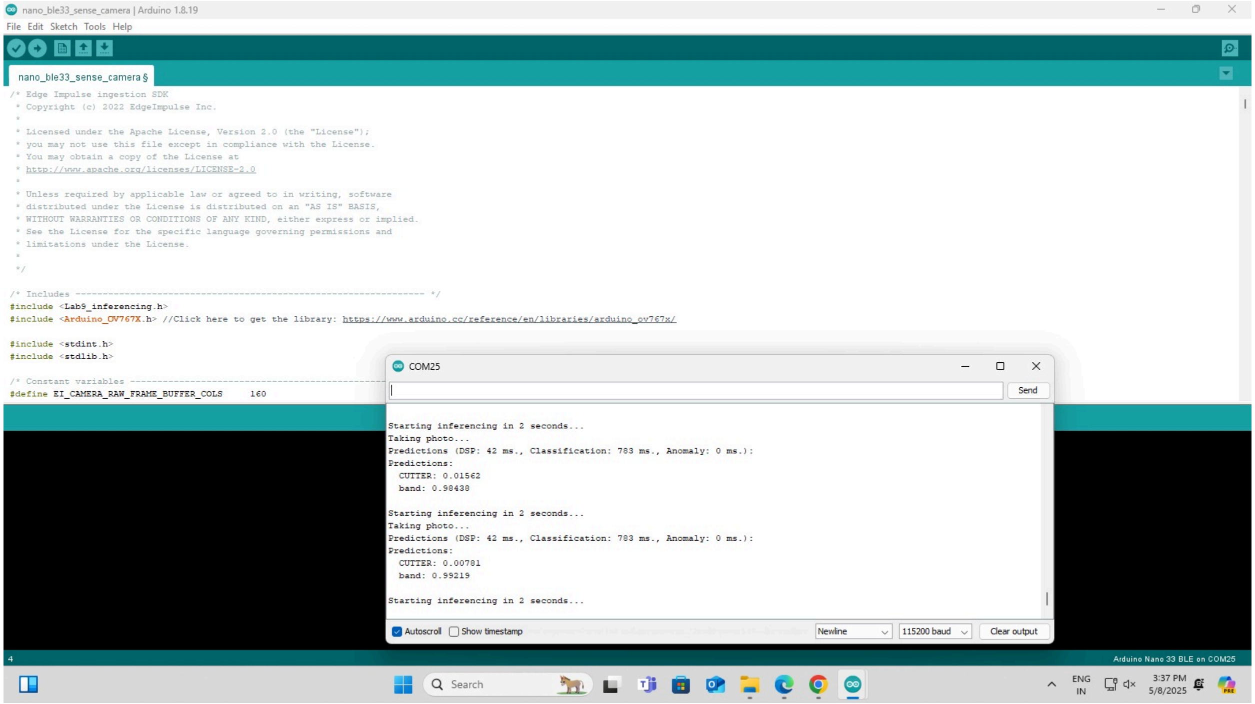
```
        ei_printf("failed to create buf_mem\r\n");

        return false;

    }

    raw_buf = (uint8_t *)DWORD_ALIGN_PTR((uintptr_t)buf_mem);


    //ei_printf("allocating buffers OK\r\n");

    return 0;

}


int OV7675::deallocate_scratch_buffs()

{

    //ei_printf("deallocating buffers...\r\n");

    ei_free(buf_mem);

    buf_mem = NULL;


    //ei_printf("deallocating buffers OK\r\n");

    return 0;

}


//

// OV7675::readFrame()

//

// Overrides the OV767X library function. Fixes the camera output to
be

// a far more desirable image. This image utilizes the full sensor
size

// and has the correct aspect ratio. Since there is limited memory
on the

// Nano we bring in only part of the entire sensor at a time and
then
```

```
// interpolate to a lower resolution.

//

void OV7675::readFrame(void* buffer)

{

    allocate_scratch_buffs();


    uint8_t* out = (uint8_t*)buffer;

    noInterrupts();


    // Falling edge indicates start of frame

    while ((*vsyncPort & vsyncMask) == 0); // wait for HIGH

    while ((*vsyncPort & vsyncMask) != 0); // wait for LOW


    int out_row = 0;

    for (int raw_height = 0; raw_height < height; raw_height +=
buf_rows) {

        // read in 640xbuf_rows buffer to work with

        readBuf();


        resizeImage(width, buf_rows,

                    raw_buf,

                    resize_col_sz, resize_height,

                    &(out[out_row]),

                    16);


        out_row += resize_col_sz * resize_height * bytes_per_pixel;
/* resize_col_sz * 2 * 2 */

    }

```

```
    interrupts();


    deallocate_scratch_buffs();

} /* OV7675::readFrame() */


//

// OV7675::readBuf()

//

// Extends the OV767X library function. Reads buf_rows VGA rows from
the

// image sensor.

//

void OV7675::readBuf()

{

    int offset = 0;


    uint32_t ulPin = 33; // P1.xx set of GPIO is in 'pin' 32 and
above

    NRF_GPIO_Type * port;


    port = nrf_gpio_pin_port_decode(&ulPin);


    for (int i = 0; i < buf_rows; i++) {

        // rising edge indicates start of line

        while ((*hrefPort & hrefMask) == 0); // wait for HIGH


        for (int col = 0; col < bytes_per_row; col++) {

            // rising edges clock each data byte

            while ((*pclkPort & pclkMask) != 0); // wait for LOW
```

```
            uint32_t in = port->IN; // read all bits in parallel

            in >>= 2; // place bits 0 and 1 at the "bottom" of the 
register
            in &= 0x3f03; // isolate the 8 bits we care about
            in |= (in >> 6); // combine the upper 6 and lower 2 bits

            raw_buf[offset++] = in;

            while ((*pclkPort & pclkMask) == 0); // wait for HIGH
        }

        while ((*hrefPort & hrefMask) != 0); // wait for LOW
    }
} /* OV7675::readBuf() */
```

6) Screen shot of Arduino Terminal - Result


nano_ble33_sense_camera | Arduino 1.8.19
File Edit Sketch Tools Help
nano_ble33_sense_camera §
/* Edge Impulse ingestion SDK
* Copyright (c) 2022 EdgeImpulse Inc.
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* 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 <Lab9_inferencing.h>
#include <Arduino_OV767X.h> //Click here to get the library: https://www.arduino.cc/reference/en/libraries/arduino_ov767x/
#include <stdint.h>
#include <stdlib.h>
/* Constant variables
#define EI_CAMERA_RAW_FRAME_BUFFER_COLS 160
COM25
Send
Starting inferencing in 2 seconds...
Taking photo...
Predictions (DSP: 42 ms., Classification: 783 ms., Anomaly: 0 ms.):
Predictions:
CUTTER: 0.01562
band: 0.98438
Starting inferencing in 2 seconds...
Taking photo...
Predictions (DSP: 42 ms., Classification: 783 ms., Anomaly: 0 ms.):
Predictions:
CUTTER: 0.00781
band: 0.99219
Starting inferencing in 2 seconds...
Autoscroll
Show timestamp
Newline
115200 baud
Clear output
Arduino Nano 33 BLE on COM25
Search
ENG
IN
3:37 PM
5/8/2025