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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:

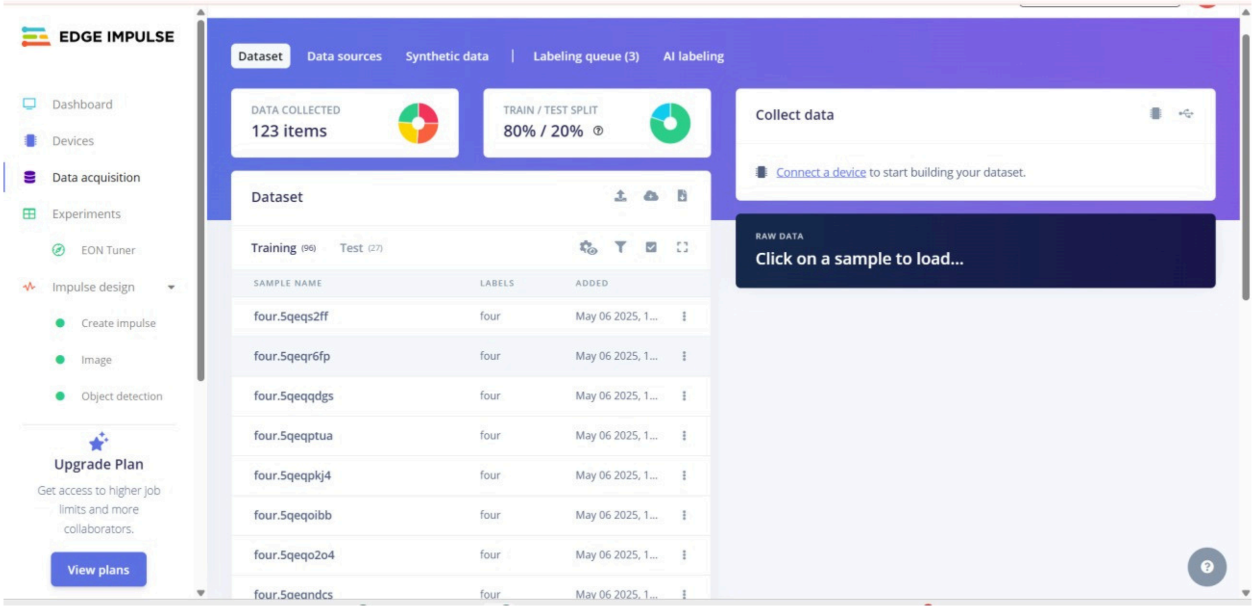
 With the model deployed, run inference on the edge device to see it classifying data in real-time.

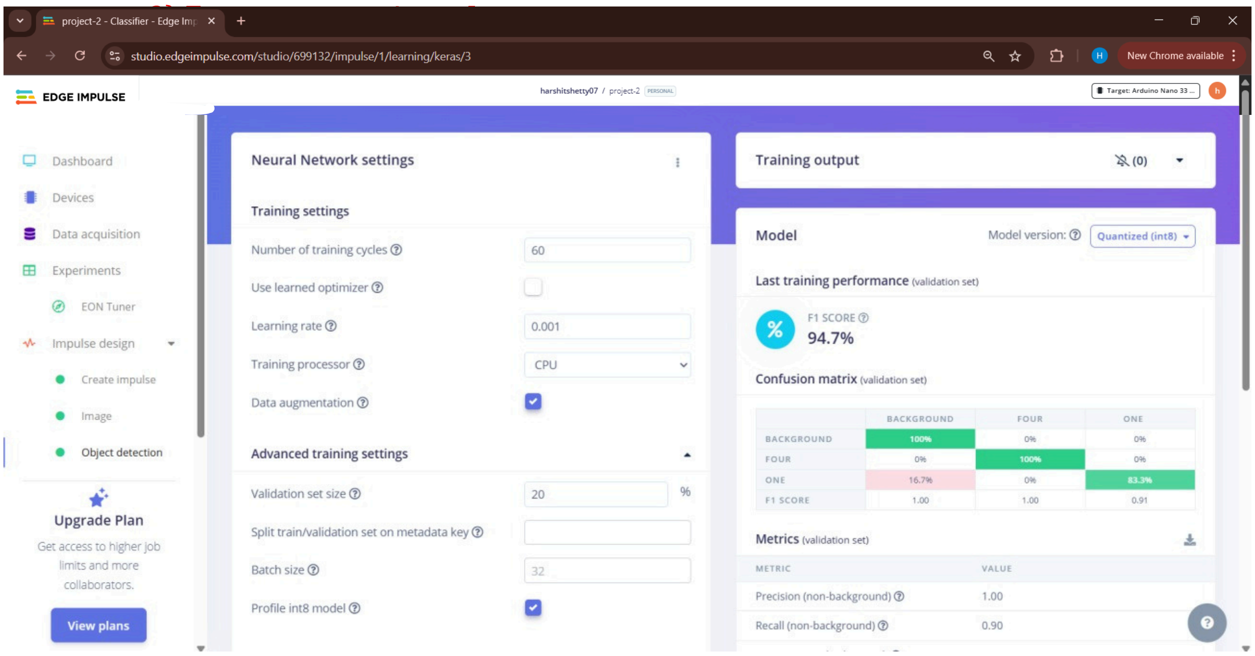
10. Monitor:

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

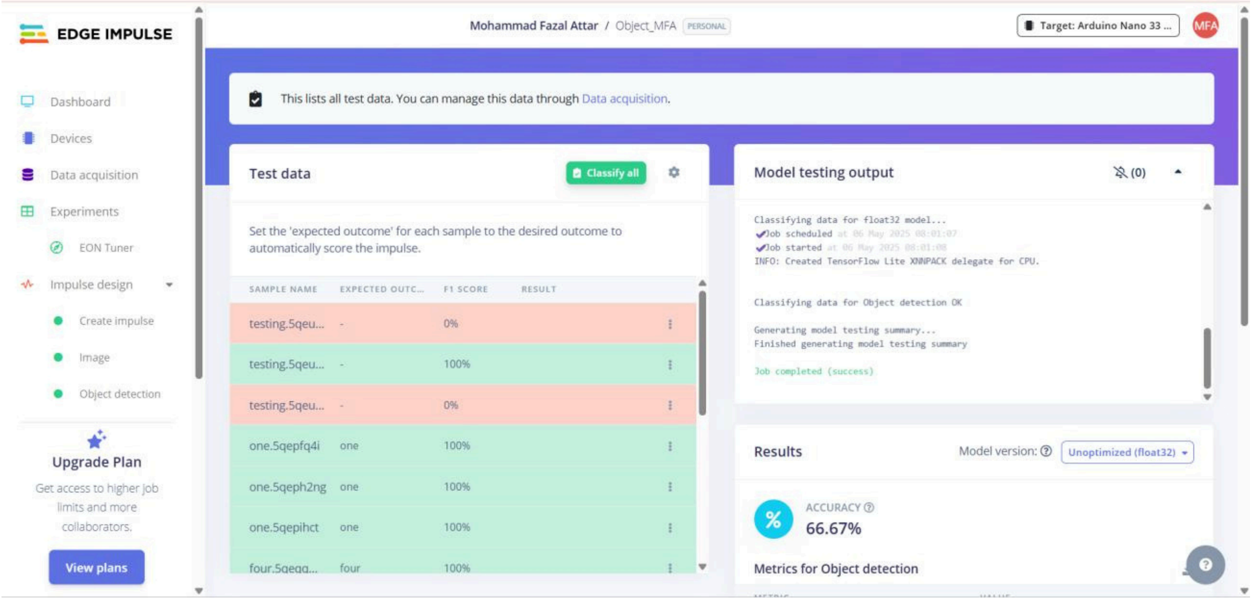
Paste your Edge Impulse project's Results:

1) Dataset Image

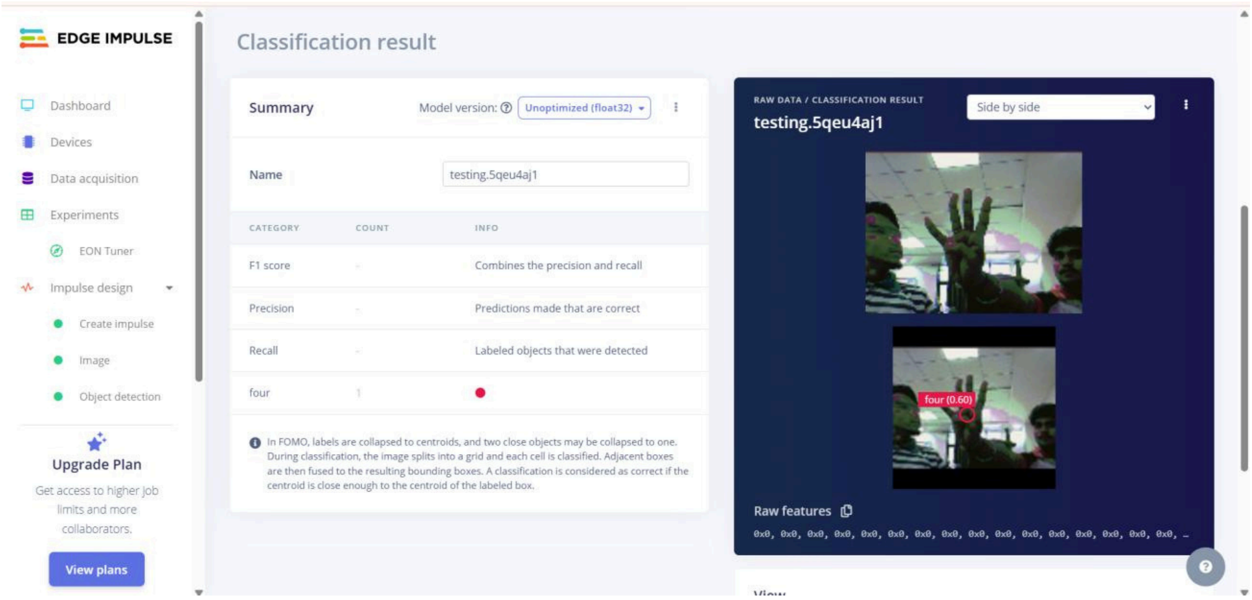




3) Accuracy / Loss - Confusion Matrix – image



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 <Image_MFA_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     120
#define EI_CAMERA_RAW_FRAME_BUFFER_ROWS     96

#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_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.
 */

/* 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 OV767X 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_cate
gories) /
sizeof(ei_classifier_inferencing_cate
gories[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_CLASSI
FIER_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_INPU
T_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_boundin
g_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_boundin
g_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("Inferencin
g 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
#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(OV
7670_VSYNC));
    vsyncMask =
digitalPinToBitMask(OV7670_VSYNC);
    hrefPort =
portInputRegister(digitalPinToPort(OV
7670_HREF));
    hrefMask =
digitalPinToBitMask(OV7670_HREF);
    pclkPort =
portInputRegister(digitalPinToPort(OV
7670_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