Edge Computing Laboratory
Lab Assignment 9

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Title: The Object Detection using Camera on Edge Computing Devices

Objective: Build a project to detect an object using Edge Computing **Tasks:**

- Generate the dataset for customized object
- Configure Edge Impulse for Object Detection
- Building and Training a Model
- Deploy on Edge Computing Device

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.

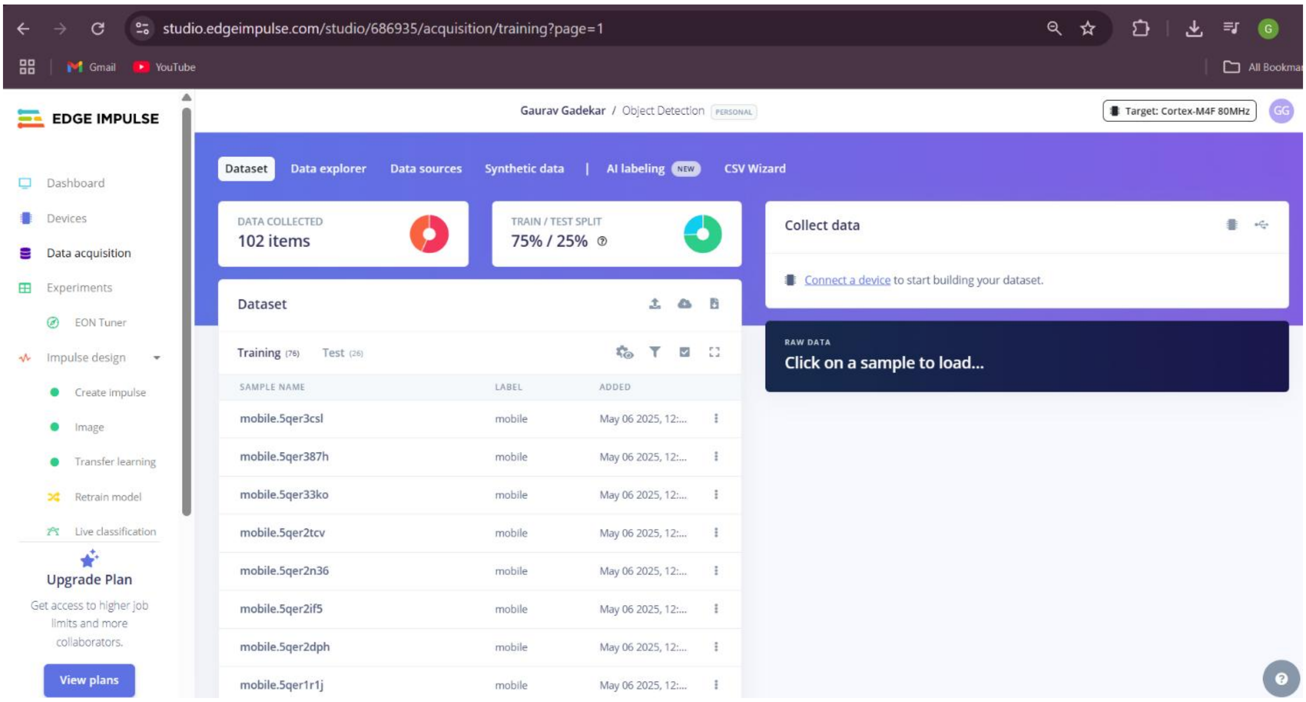
8. Deploy the Model:
   - Go to the 'Deployment' tab.
   - Select the deployment method that suits your edge device (e.g., Arduino library, WebAssembly, container, etc.).
   - Follow the instructions to deploy the model to your device.

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

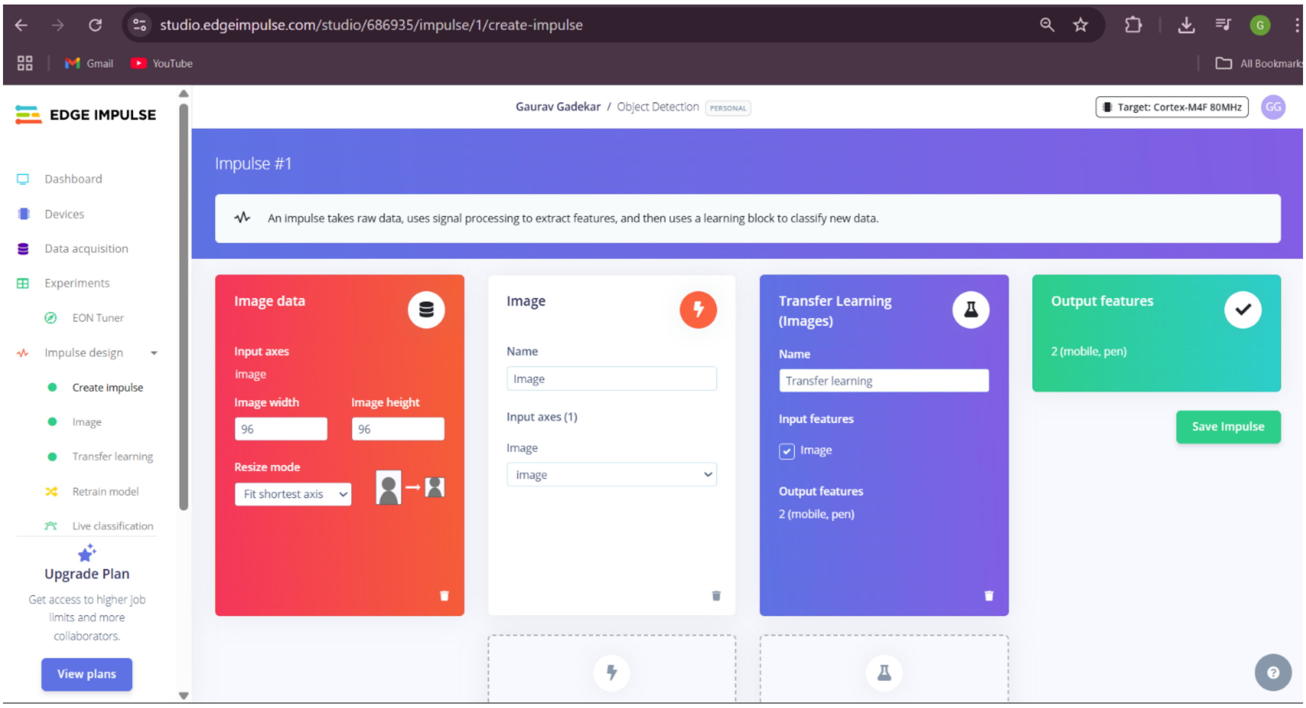
10. Monitor:
    - You can monitor the performance of your device through the Edge Impulse studio.

Paste your Edge Impulse project's Results:

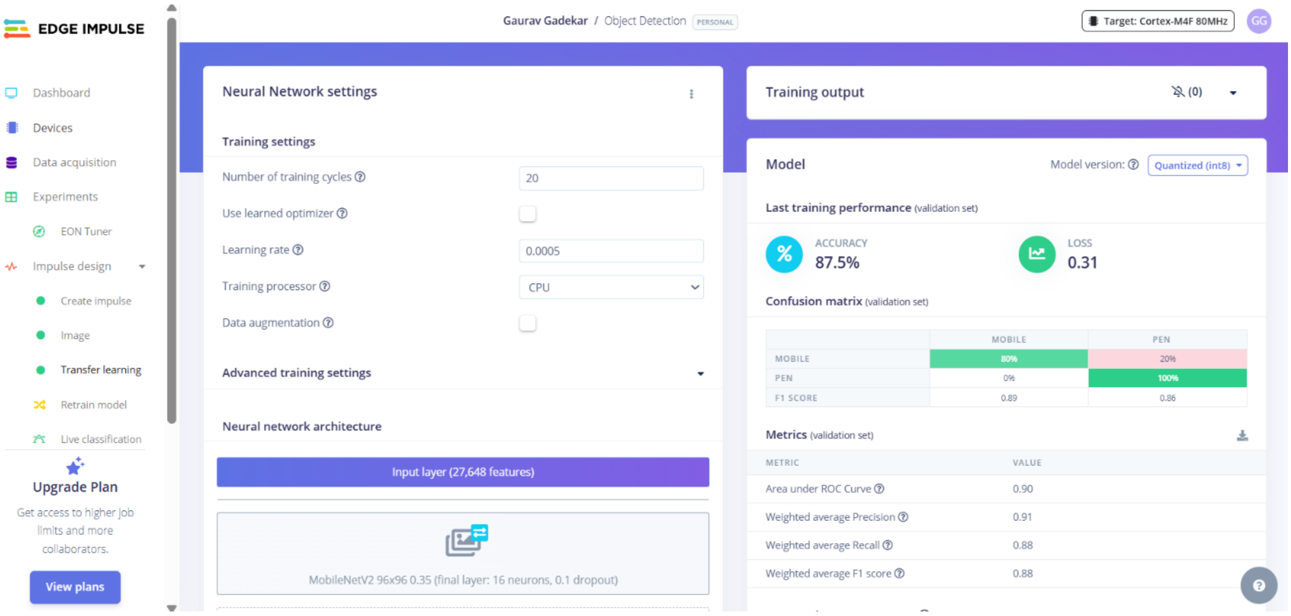
1. **Dataset Image**



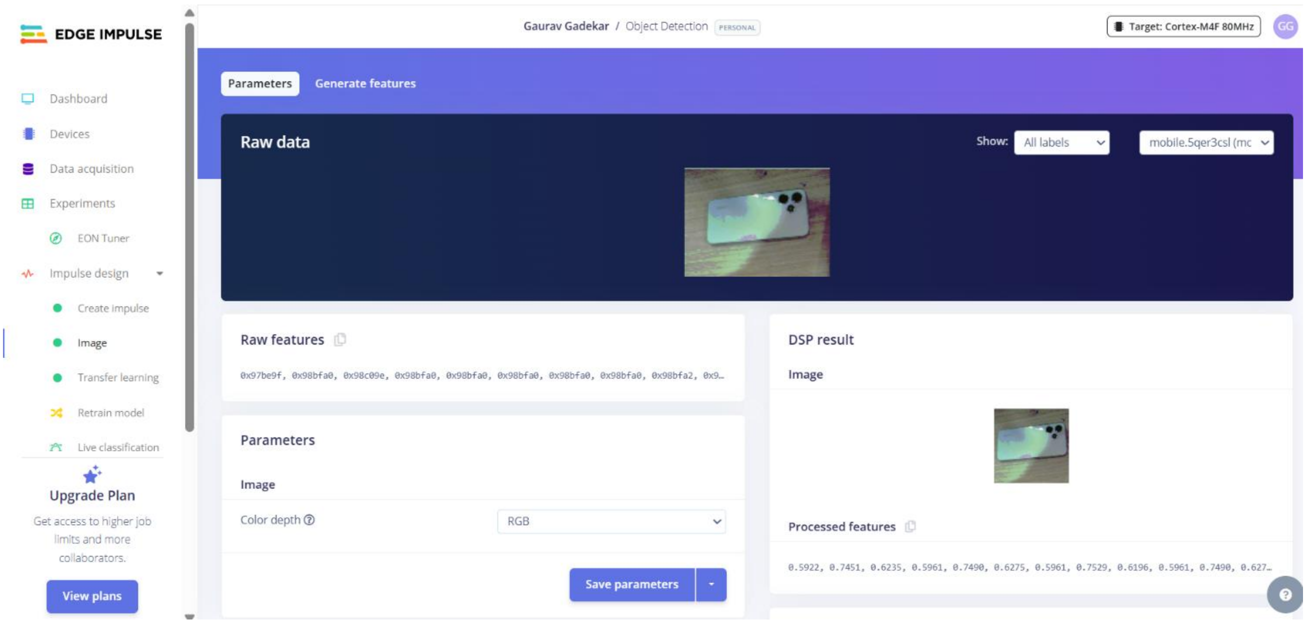
2. **Feature extraction - Image**

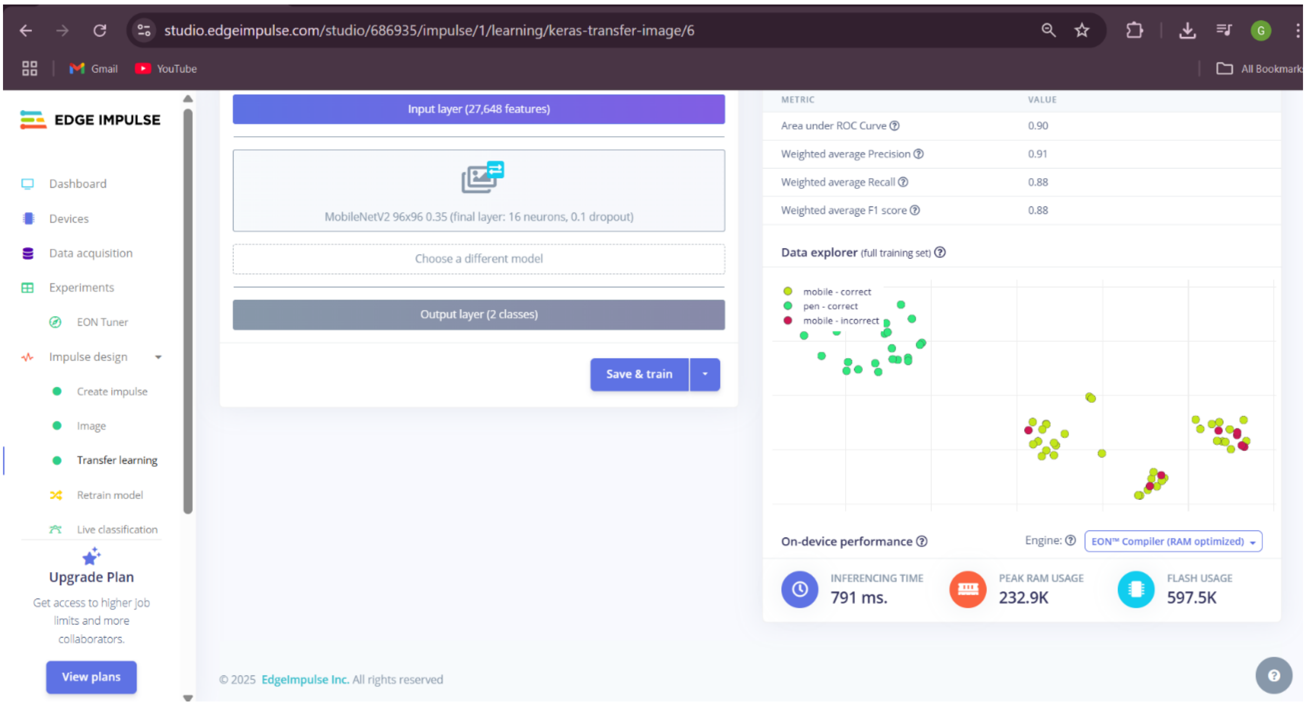


3. **Accuracy / Loss - Confusion Matrix – image**



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 <Object_Detection_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_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 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
#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

Conclusion: Practically implemented detect an object using Edge Computing. Understood about custom object detection.