Sistem automat de procesare de imagini pentru recunoașterea video a semnelor de circulație sau a culorilor de la semafor, folosind Raspberry PI și o cameră video atașată

Proiect - Sisteme Incorporate - 2023/2024

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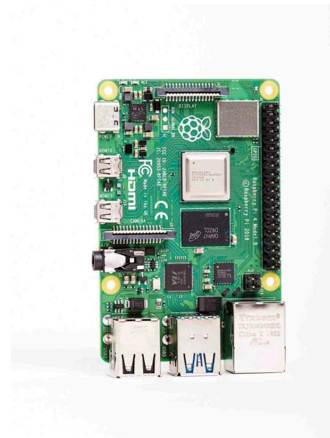
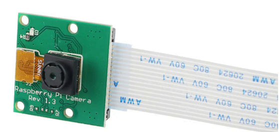
Cuprins

Descrierea lucrării



Echipamente utilizate:

- Raspberry Pi 4B cu specificațiile:
  - Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.8GHz
  - 4GB LPDDR4-3200 SDRAM
  - 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE
  - Gigabit Ethernet
  - 2 USB 3.0 and 2 USB 2.0 ports
  - 40-pin GPIO header, backward compatible
  - 2 micro-HDMI ports, supporting 4K displays
  - USB-C for power supply



- Raspberry Pi Camera 1.3 cu specificațiile:
  - 5 MP OmniVision OV5647 sensor
  - 1080p30, 720p60 and 640 × 480p60/90 video modes
  - Comunicare prin CSI (Camera Serial Interface)

Mod de lucru:

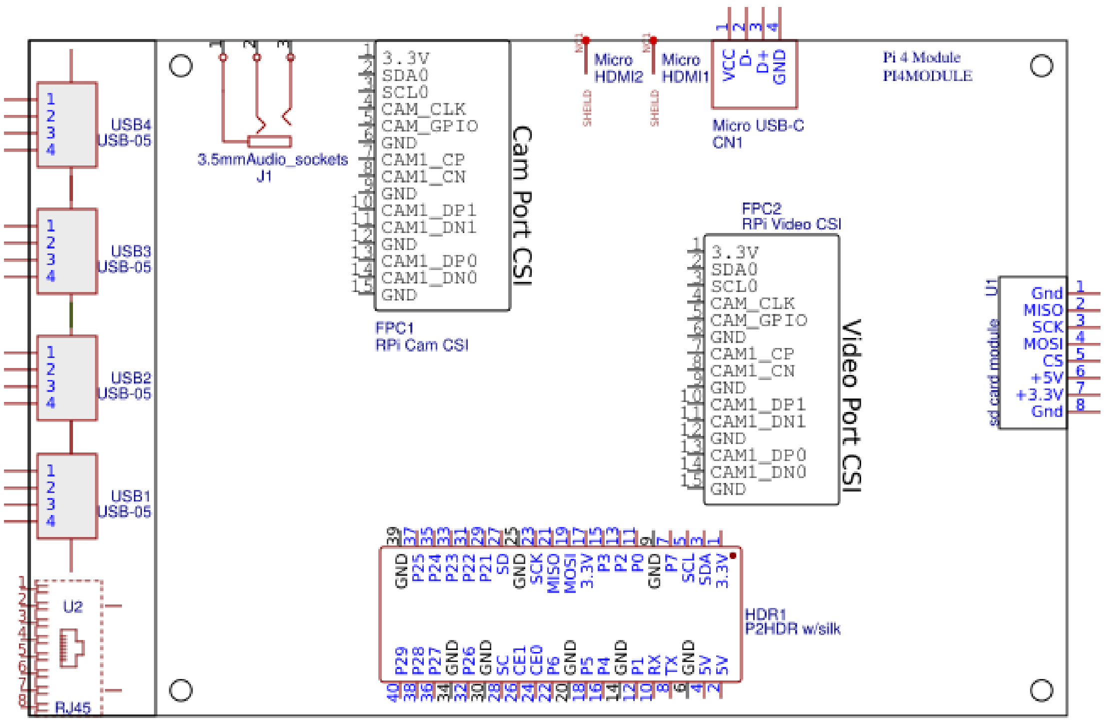
Am utilizat modelul *ssd-mobilenet-v2-fpnlite-320*, disponibil în Tensorflow 2 Model Zoo. Acesta a fost antrenat pentru 40000 de iterații cu un batch size de 16 imagini, pe un dataset realizat de noi. Am ales acest model datorită performanței cu care rulează pe Raspberry Pi, spre deosebire de alte modele care necesită mai multe resurse.

Dataset-ul cuprinde aproximativ 300 de imagini cu indicatoare rutiere de 3 tipuri: Cedează trecerea, Oprirea interzisă și Trecere de pietoni. Imaginile au fost preluate de pe Google Maps Street View și au fost etichetate manual, una câte una, utilizând programul open-source *LabelImg*.

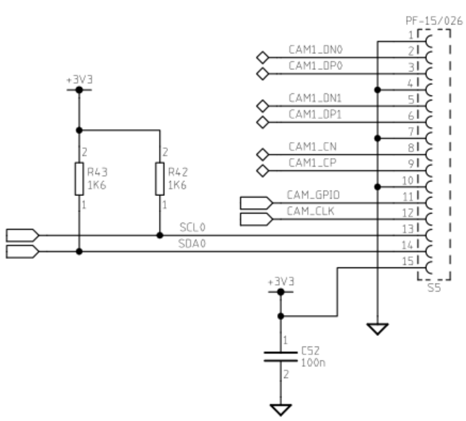
Antrenarea finală a modelului a fost realizată folosind backend-ul Google Compute Engine cu GPU-ul T4, în Google Collab Pro și a durat aproximativ 4 ore. După antrenare, modelul a fost convertit la formatul *tensorflow-lite* și cuantizat, convertind weight-urile din numere în virgulă flotantă pe 32 de biți în numere întregi pe 8 biți. Această conversie a avut ca scop creșterea performanței în schimbul unei reduceri minore (în acest caz) a acurateții de detecție.

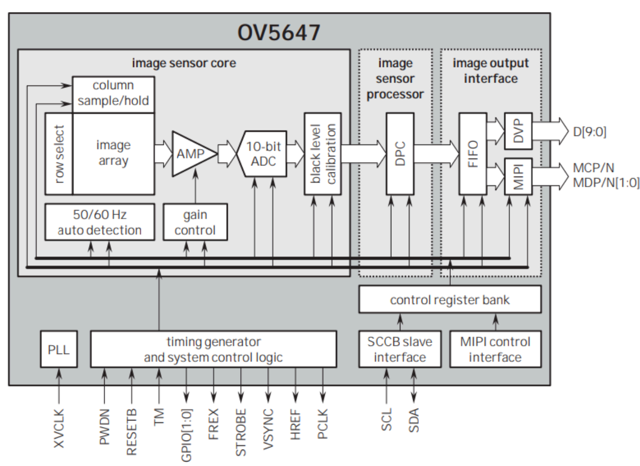
Sistemul final rulează prin execuția unui script Python pe Raspberry Pi, care utilizează un API de nivel înalt pentru comunicarea cu camera video.

Hardware



Schemă conectori Raspberry PI





Schema internă conector CSI

Diagramă bloc OV5647

Software

Script Python pentru detecție în timp real utilizând camera conectată la Raspberry Pi:

```
# Import packages
import os
import argparse
import cv2
import numpy as np
import sys
import time
from threading import Thread
import importlib.util

# Define VideoStream class to handle streaming of video from webcam in separate processing
thread
# Source - Adrian Rosebrock, PyImageSearch:
https://www.pyimagesearch.com/2015/12/28/increasing-raspberry-pi-fps-with-python-and-opencv/
class VideoStream:
    """Camera object that controls video streaming from the Picamera"""
    def __init__(self,resolution=(640,480),framerate=30):
        # Initialize the PiCamera and the camera image stream
        self.stream = cv2.VideoCapture(0)
        ret = self.stream.set(cv2.CAP_PROP_FOURCC, cv2.VideoWriter_fourcc(*'MJPG'))
        ret = self.stream.set(3,resolution[0])
        ret = self.stream.set(4,resolution[1])

        # Read first frame from the stream
        (self.grabbed, self.frame) = self.stream.read()

       # Variable to control when the camera is stopped
        self.stopped = False

    def start(self):
       # Start the thread that reads frames from the video stream
        Thread(target=self.update,args=()).start()
        return self

    def update(self):
        # Keep looping indefinitely until the thread is stopped
        while True:
            # If the camera is stopped, stop the thread
            if self.stopped:
                # Close camera resources
                self.stream.release()
                return

            # Otherwise, grab the next frame from the stream
            (self.grabbed, self.frame) = self.stream.read()
```

```
    def read(self):
        # Return the most recent frame
        return self.frame

    def stop(self):
        # Indicate that the camera and thread should be stopped
        self.stopped = True

# Define and parse input arguments
parser = argparse.ArgumentParser()
parser.add_argument('--modeldir', help='Folder the .tflite file is located in',
                    required=True)
parser.add_argument('--graph', help='Name of the .tflite file, if different than
detect.tflite',
                    default='detect.tflite')
parser.add_argument('--labels', help='Name of the labelmap file, if different than
labelmap.txt',
                    default='labelmap.txt')
parser.add_argument('--threshold', help='Minimum confidence threshold for displaying
detected objects',
                    default=0.5)
parser.add_argument('--resolution', help='Desired webcam resolution in WxH. If the webcam
does not support the resolution entered, errors may occur.',
                    default='1280x720')
parser.add_argument('--edgetpu', help='Use Coral Edge TPU Accelerator to speed up
detection',
                    action='store_true')

args = parser.parse_args()

MODEL_NAME = args.modeldir
GRAPH_NAME = args.graph
LABELMAP_NAME = args.labels
min_conf_threshold = float(args.threshold)
resW, resH = args.resolution.split('x')
imW, imH = int(resW), int(resH)
use_TPU = args.edgetpu

# Import TensorFlow libraries
# If tflite_runtime is installed, import interpreter from tflite_runtime, else import from
regular tensorflow
# If using Coral Edge TPU, import the load_delegate library
pkg = importlib.util.find_spec('tflite_runtime')
if pkg:
    from tflite_runtime.interpreter import Interpreter
    if use_TPU:
        from tflite_runtime.interpreter import load_delegate
else:
    from tensorflow.lite.python.interpreter import Interpreter
    if use_TPU:
        from tensorflow.lite.python.interpreter import load_delegate
```

```python
# If using Edge TPU, assign filename for Edge TPU model
if use_TPU:
    # If user has specified the name of the .tflite file, use that name, otherwise use
default 'edgetpu.tflite'
    if (GRAPH_NAME == 'detect.tflite'):
        GRAPH_NAME = 'edgetpu.tflite'

# Get path to current working directory
CWD_PATH = os.getcwd()

# Path to .tflite file, which contains the model that is used for object detection
PATH_TO_CKPT = os.path.join(CWD_PATH,MODEL_NAME,GRAPH_NAME)

# Path to label map file
PATH_TO_LABELS = os.path.join(CWD_PATH,MODEL_NAME,LABELMAP_NAME)

# Load the label map
with open(PATH_TO_LABELS, 'r') as f:
    labels = [line.strip() for line in f.readlines()]

# Have to do a weird fix for label map if using the COCO "starter model" from
# https://www.tensorflow.org/lite/models/object_detection/overview
# First label is '???', which has to be removed.
if labels[0] == '???':
    del(labels[0])

# Load the Tensorflow Lite model.
# If using Edge TPU, use special load_delegate argument
if use_TPU:
    interpreter = Interpreter(model_path=PATH_TO_CKPT,
                              experimental_delegates=[load_delegate('libedgetpu.so.1.0')])
    print(PATH_TO_CKPT)
else:
    interpreter = Interpreter(model_path=PATH_TO_CKPT)

interpreter.allocate_tensors()

# Get model details
input_details = interpreter.get_input_details()
output_details = interpreter.get_output_details()
height = input_details[0]['shape'][1]
width = input_details[0]['shape'][2]

floating_model = (input_details[0]['dtype'] == np.float32)

input_mean = 127.5
input_std = 127.5

# Check output layer name to determine if this model was created with TF2 or TF1,
# because outputs are ordered differently for TF2 and TF1 models
outname = output_details[0]['name']
```

```python
if ('StatefulPartitionedCall' in outname): # This is a TF2 model
    boxes_idx, classes_idx, scores_idx = 1, 3, 0
else: # This is a TF1 model
    boxes_idx, classes_idx, scores_idx = 0, 1, 2

# Initialize frame rate calculation
frame_rate_calc = 1
freq = cv2.getTickFrequency()

# Initialize video stream
videostream = VideoStream(resolution=(imW,imH),framerate=30).start()
time.sleep(1)

#for frame1 in camera.capture_continuous(rawCapture, format="bgr",use_video_port=True):
while True:

    # Start timer (for calculating frame rate)
    t1 = cv2.getTickCount()

    # Grab frame from video stream
    frame1 = videostream.read()

    # Acquire frame and resize to expected shape [1xHxWx3]
    frame = frame1.copy()
    frame_rgb = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
    frame_resized = cv2.resize(frame_rgb, (width, height))
    input_data = np.expand_dims(frame_resized, axis=0)

    # Normalize pixel values if using a floating model (i.e. if model is non-quantized)
    if floating_model:
        input_data = (np.float32(input_data) - input_mean) / input_std

    # Perform the actual detection by running the model with the image as input
    interpreter.set_tensor(input_details[0]['index'],input_data)
    interpreter.invoke()

    # Retrieve detection results
    boxes = interpreter.get_tensor(output_details[boxes_idx]['index'])[0] # Bounding box
coordinates of detected objects
    classes = interpreter.get_tensor(output_details[classes_idx]['index'])[0] # Class index
of detected objects
    scores = interpreter.get_tensor(output_details[scores_idx]['index'])[0] # Confidence of
detected objects

    # Loop over all detections and draw detection box if confidence is above minimum
threshold
    for i in range(len(scores)):
        if ((scores[i] > min_conf_threshold) and (scores[i] <= 1.0)):

            # Get bounding box coordinates and draw box
            # Interpreter can return coordinates that are outside of image dimensions, need
to force them to be within image using max() and min()
```

```
            ymin = int(max(1,(boxes[i][0] * imH)))
            xmin = int(max(1,(boxes[i][1] * imW)))
            ymax = int(min(imH,(boxes[i][2] * imH)))
            xmax = int(min(imW,(boxes[i][3] * imW)))

            cv2.rectangle(frame, (xmin,ymin), (xmax,ymax), (10, 255, 0), 2)

            # Draw label
            object_name = labels[int(classes[i])] # Look up object name from "labels" array
using class index
            label = '%s: %d%%' % (object_name, int(scores[i]*100)) # Example: 'person: 72%'
            labelSize, baseLine = cv2.getTextSize(label, cv2.FONT_HERSHEY_SIMPLEX, 0.7, 2) #
Get font size
            label_ymin = max(ymin, labelSize[1] + 10) # Make sure not to draw label too
close to top of window
            cv2.rectangle(frame, (xmin, label_ymin-labelSize[1]-10), (xmin+labelSize[0],
label_ymin+baseLine-10), (255, 255, 255), cv2.FILLED) # Draw white box to put label text in
            cv2.putText(frame, label, (xmin, label_ymin-7), cv2.FONT_HERSHEY_SIMPLEX, 0.7,
(0, 0, 0), 2) # Draw label text

    # Draw framerate in corner of frame
    cv2.putText(frame,'FPS:
{0:.2f}'.format(frame_rate_calc),(30,50),cv2.FONT_HERSHEY_SIMPLEX,1,(255,255,0),2,cv2.LINE_A
A)

    # All the results have been drawn on the frame, so it's time to display it.
    cv2.imshow('Object detector', frame)

    # Calculate framerate
    t2 = cv2.getTickCount()
    time1 = (t2-t1)/freq
    frame_rate_calc= 1/time1

    # Press 'q' to quit
    if cv2.waitKey(1) == ord('q'):
        break

# Clean up
cv2.destroyAllWindows()
videostream.stop()
```

Bibliografie

1. Tool etichetare imagini:
   https://github.com/HumanSignal/labelImg

2. Tensorflow2 Detection Model Zoo:
   https://github.com/tensorflow/models/blob/master/research/object_detection/g3doc/tf2_detection_zoo.md

3. Notebook antrenare model:
   https://colab.research.google.com/github/EdjeElectronics/TensorFlow-Lite-Object-Detection-on-Android-and-Raspberry-Pi/blob/master/Train_TFLite2_Object_Detction_Model.ipynb#scrollTo=GSJ2wgGCixy2

4. Deployment pe RaspberryPi:
   https://github.com/EdjeElectronics/TensorFlow-Lite-Object-Detection-on-Android-and-Raspberry-Pi/blob/master/deploy_guides/Raspberry_Pi_Guide.md

5. Datasheet OV5647:
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6. Documentație oficială cameră video:
   https://www.raspberrypi.com/documentation/accessories/camera.html

7. Scheme Raspberry Pi:
   https://easyeda.com/modules/RASPBERRY-PI-4-MODEL-B-SCHEMATIC_0b85e106e09b4eb982fa59dc1bbc4dde