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ENPM701 Assignment 4

Robotic Control Command Identification

Assignment #4

Reading Direction from Green Arrow in an image/sign and analyzing raspberry pi camera performance over time

Question #2

# SODAR: Reading distance from Ultrasonic sensor

```python
import numpy as np
import cv2
import imutils
import RPi.GPIO as gpio
import time
import os

# Define pin allocations
trig = 16
echo = 18

def distance():
    gpio.setmode(gpio.BOARD)
    gpio.setup(trig, gpio.OUT)
    gpio.setup(echo, gpio.IN)

    # Ensure output has no value
    gpio.output(trig, False)
    time.sleep(0.01)

    # Generate trigger pulse
    gpio.output(trig, True)
    time.sleep(0.00001)
    gpio.output(trig, False)

    # Generate echo time signal
    while gpio.input(echo) == 0:
        pulse_start = time.time()
    while gpio.input(echo) == 1:
        pulse_end = time.time()

    pulse_duration = pulse_end - pulse_start

    # Convert time to distance
    distance = pulse_duration * 17150
    distance = round(distance, 2)

    # Cleanup gpio pins & return distance estimate
    gpio.cleanup()
    return distance

if __name__ == "__main__":

    # Record image using Raspistill
    name = "lecture4inclass.jpg"
    os.system('raspistill -w 640 -h 480 -o /home/pi/ENPM701-class-files/' + name)

    print("Hi!")
    print("Ultrasonic sensor will print 10 successive range estimates per 1Hz")

    img = cv2.imread('lecture4inclass.jpg')
    img = imutils.resize(img, width=400)

    # show image
#     cv2.imshow("Ultrasonic on image", img)
#     cv2.waitKey(0)

    # Start printing range values
    start = time.time()
    idx = 1
    measurements = []

    while idx <= 10:

        if (round((time.time() - start), 2) == 1):
            dist = distance()
            print ("Counter: ", idx, "| Distance: ", dist, " cm")
            idx += 1
            start = time.time()
            measurements.append(dist)

    # Take the average of the measurements
    ave = round(np.average(measurements), 2)
```

```python
# Choose font style and color
font = cv2.FONT_HERSHEY_COMPLEX_SMALL
red = (0, 0, 255)

# Append measurement on image
cv2.putText(img, str(ave)+" cm", (100, 200), font, 1, red, 2)

# show image
cv2.imshow("Ultrasonic on image", img)


# Save appended image
cv2.imwrite('lecture4inclass_US_txt.jpg', img)

print("Done")
cv2.waitKey(0)

cv2.destroyAllWindows()
```

Output:

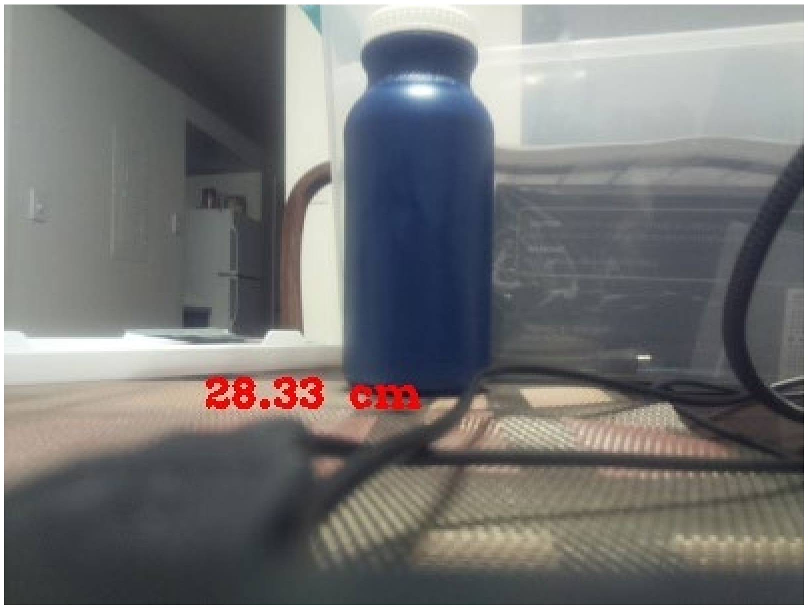


Fig-1: 0.5m water bottle distance measured using Pi Camera

Question #3

# Detect arrow from picture and read its direction

First Part: HSV Masking and Direction Detection

```python
import cv2
import os
import imutils
import numpy as np
import matplotlib.pyplot as plt

def img_masking(gnArrow):

    # Save the shape of the image array
    (height, width, c)  = gnArrow.shape
    # Convert image from BGR to HSV space
    gnArrowHSV = cv2.cvtColor(gnArrow, cv2.COLOR_BGR2HSV)

    # Display HSV converted image
    cv2.imwrite("grnArrowHSV.png", gnArrowHSV)

    # HSV bounds
    minHSV = np.array([49, 103, 61])
    maxHSV = np.array([93, 255, 248])

    # Create a function that will search through every
    # pixel and mask

    # Need cv2.inRange() or custom function for HSV masking
    maskHSV = cv2.inRange(gnArrowHSV, minHSV, maxHSV)

    cv2.imwrite("gnArrow_MaskOnlyHSV.png",maskHSV)

    # Read all three differnet pictures for ease of display
    grn_HSV = cv2.imread("grnArrowHSV.png")
    grn_Mask = cv2.imread("gnArrow_MaskOnlyHSV.png")

    # Now stack images horizontally for ease of display
    grn_all = np.hstack([gnArrow,grn_HSV,grn_Mask])

    return maskHSV, grn_all

def blur_img(maskHSV):

    blurred = cv2.GaussianBlur(maskHSV,(11,11), 0)
    return blurred

def corner_detect(img,orig_img):

    # Detect corners from image
    corners = cv2.goodFeaturesToTrack(img,5,0.01,10)
    corners = np.int0(corners)

    # Create a list to store the x,y location of points
    pts_loc = []

    # identify location of corners in image
    for i in corners:
        # Extract x,y coordinate of points
        x,y = i.ravel()
        # Draw circle of corners on image
        cv2.circle(img,(x,y),3,255,-1)
        cv2.circle(orig_img,(x,y),3,(255,0,0),-1)
        # Store image coordinate of corners in a list
        pts_loc.append([x,y])

    # Create a column vector from pts list
    pts_loc = np.array(pts_loc)

    return img, pts_loc, orig_img

def def_det(pt_list):

    # Extract x,y points from pt_list
    x = pt_list[:,0]
    y = pt_list[:,1]

    # Determine the min and max width & height values
    # of the points, as if to drow rectangle around arrow
    x_min = x.min()
    y_min = y.min()

    x_max = x.max()
    y_max = y.max()

    # Store height of bounding box
    vert_dst = y_max - y_min

    # Store width of bounding box
```

```python
    horz_dst = x_max - x_min

    # Compute and store half dimensions of
    # box, will come later when determining
    # arrow direction
    y_half = vert_dst/2 + y_min
    x_half = horz_dst/2 + x_min

    # Initializing the direction of the arrow
    direction = ""

    # Initialize counter to track the number of
    # points below the half vertical distance.
    count = 0

    # When the arrow vertical (up/down) or (left/right)
    if vert_dst > horz_dst:

        # Since the head has 3 corners identified,
        # if the arrow is pointing up (noting origin of image
        # is at the left top corner), there will be three
        # points below the middle of the arrow vertically

        # loop through all vertical points of corner ordered
        # points
        for i in y:
            if (i < y_half):
                count+=1
        # Determine direction
        if count >= 3:
            direction = "Up"
        else:
            direction = "Down"

    else:
        # Similar to above if logic

        # Since the head has 3 corners identified,
        # if the arrow is pointing left (noting origin of image
        # is at the left top corner), there will be three
        # points to the left of the middle of the arrow horizontally

        # loop through all vertical points of corner ordered
        # points
        for i in x:
            if (i < x_half):
                count+=1
        # Determine direction
        if count >= 3:
            direction = "Left"
        else:
            direction = "Right"

    return direction

def img_dir_txt(img,img_crn,direction):

    (cx,cy) = (img.shape[1]/4.5, img.shape[0]/8)
    # Drawing white background
    cv2.rectangle(img,(0,0),(int(cx),int(cy)),(255,255,255),-1)
    # Placing text over white background
    font = cv2.FONT_HERSHEY_COMPLEX_SMALL
    green = (0,255,0)
    cv2.putText(img,direction,(0,int(cy/2)),font,2,green,2)

    return img

def main():

    print("Arrow detection program started!")

    # Read an image from library
    gnArrow = cv2.imread("greenArrow01.png")

    # Apply HSV masking to image read
    img_msk, grn_all = img_masking(gnArrow)

    # Apply Gaussian bluring on image
    img_blurred = blur_img(img_msk)
    cv2.imwrite("arw_blur.png",img_blurred)
    # Detect corners from image
    img_crnr, pts_loc, org_img = corner_detect(img_blurred,gnArrow)
    cv2.imwrite("arw_crnr_det.png",img_crnr)

    # Identify direction of arrow
    direction = def_det(pts_loc)
    print("The arrow is pointing " + direction)

    # Display original image, corner, and text together
    fin_img = img_dir_txt(org_img,img_crnr,direction)
    # Read masked images for display purposes
    blur = cv2.imread("arw_blur.png")
    img_crnr = cv2.imread("arw_crnr_det.png")

    # Stack the arrow detection steps
    arr_det = np.hstack([blur,img_crnr,fin_img])
    # Stack the whole process from original to final
    fin_disp = np.vstack([grn_all,arr_det])

    # Display full output of process
    cv2.imshow("Green Arrow Masked",fin_disp)
    cv2.imwrite("gnArrow_det_full.png",fin_disp)
    cv2.waitKey(0)
    cv2.destroyAllWindows()

if __name__ == "__main__":
    main()
```

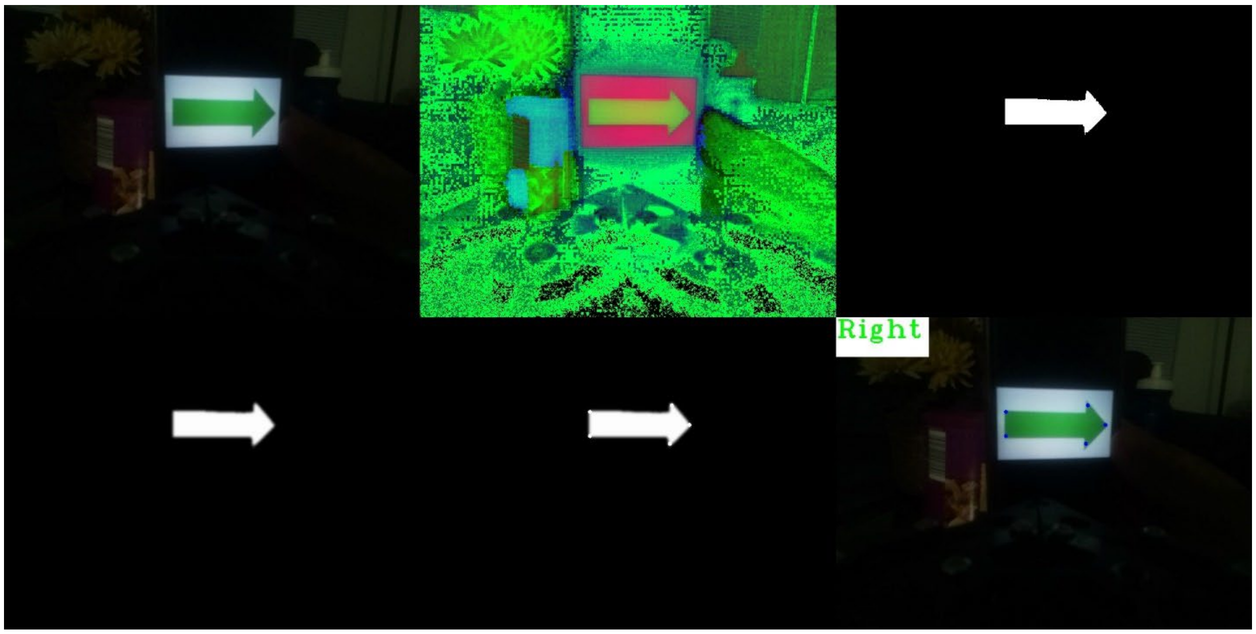


Fig-2: Original image (top left), Converted to HSV scale (top middle), HSV Masking (top right), Application of Gaussian Blur (bottom left), Shi-Tomasi Corner Detection (bottom middle), Arrow Direction Detection Full (bottom right)

Second Part: Application of Arrow Detection to Live Video Stream

```python
import cv2
import os
import imutils
import numpy as np
import matplotlib.pyplot as plot
from picamera.array import PiRGBArray
from picamera import PiCamera
import time
from datetime import datetime

def img_mask_blur(img):

    # Save the shape of the image array
    (height, width, c)  = img.shape

    # Convert image from BGR to HSV space
    imgHSV = cv2.cvtColor(img, cv2.COLOR_BGR2HSV)

    # HSV bounds
    minHSV = np.array([49, 103, 61])
    maxHSV = np.array([93, 255, 248])

    # Create a function that will search through every
    # pixel and mask

    # Need cv2.inRange() or custom function for HSV masking
    maskHSV = cv2.inRange(imgHSV, minHSV, maxHSV)
    # Apply Gaussian blur
    blurred = cv2.GaussianBlur(maskHSV,(11,11), 0)

    return blurred

def corner_detect(img,orig_img):

    # Detect corners from image
    corners = cv2.goodFeaturesToTrack(img,5,0.01,10)

    # Check if there are corners
    if corners is None:
        return orig_img, []
    else:
        corners = np.int0(corners)
    # Create a list to store the x,y location of points
    pts_loc = []

    # identify location of corners in image
    for i in corners:
        # Extract x,y coordinate of points
        x,y = i.ravel()
        # Draw circle of corners on image
        cv2.circle(orig_img,(x,y),3,(255,0,0),-1)
        # Store image coordinate of corners in a list
        pts_loc.append([x,y])

    # Create a column vector from pts list
    pts_loc = np.array(pts_loc)

    return orig_img, pts_loc

def def_det(img,pt_list):

    # Extract x,y points from pt_list
    x = pt_list[:,0]
    y = pt_list[:,1]

    # Determine the min and max width & height values
    # of the points, as if to drow rectangle around arrow
    x_min = x.min()
    y_min = y.min()

    x_max = x.max()
    y_max = y.max()

    # Store height of bounding box
    vert_dst = y_max - y_min

    # Store width of bounding box
    horz_dst = x_max - x_min

    # Compute and store half dimensions of
    # box, will come later when determining
    # arrow direction
    y_half = vert_dst/2 + y_min
    x_half = horz_dst/2 + x_min

    # Find the percentage difference between vertical
    # and horizonal max separtaion distances of points
    ver_pnt = 100 * (vert_dst/(vert_dst+horz_dst))
    hor_pnt = 100 * (horz_dst/(vert_dst+horz_dst))

    # Initializing the direction of the arrow
    direction = ""

    # Initialize color to display direction on
    # image frame
    color = (0,0,0)

    # Initialize counter to track the number of
    # points below the half vertical distance.
    count = 0

    # When the arrow vertical (up/down) or (left/right)
    if (vert_dst > horz_dst) and (ver_pnt > 60):

        # Since the head has 3 corners identified,
        # if the arrow is pointing up (noting origin of image
        # is at the left top corner), there will be three
        # points below the middle of the arrow vertically

        # loop through all vertical points of corner ordered
        # points
        for i in y:
            if (i < y_half):
                count+=1
        # Determine direction
        if count > 2:
            direction = "Up"
            # default color
        else:
            direction = "Down"
            color = (0,0,255)

    elif (horz_dst > vert_dst) and (hor_pnt > 60):
        # Similar to above if logic

        # Since the head has 3 corners identified,
         # if the arrow is pointing left (noting origin of image
        # is at the left top corner), there will be three
        # points to the left of the middle of the arrow horizontally

        # loop through all vertical points of corner ordered
        # points
```

```python
        for i in x:
            if (i < x_half):
                count+=1
        # Determine direction
        if count > 2:
            direction = "Left"
            color = (255,0,0)
        else:
            direction = "Right"
            color = (0,255,0)

    else:
        direction = "---"
        color = (10,10,10)

    return direction, color

def img_dir_txt(img,direction,color):

    # Place direction text on image
    (cx,cy) = (img.shape[1]/4.5, img.shape[0]/8)
    # Drawing white background
    cv2.rectangle(img,(0,0),(int(cx),int(cy)),(255,255,255),-1)
    # Placing text over white background
    font = cv2.FONT_HERSHEY_COMPLEX_SMALL
    # Print direction of arrow on image
    cv2.putText(img,direction,(0,int(cy/2)),font,2,color,2)

    return img

def main():

    # Purpose: Continuosly locate and identify green light from video feed
    # Pull in code from Assignment 2 and adjust
    # initialize the Raspberry Pi camera
    camera = PiCamera()
    camera.resolution = (640, 480)
    camera.framerate = 25
    rawCapture = PiRGBArray(camera, size=(640,480))

    # Pull in code from steps 1 and 2
    # allow the camera to warmup
    time.sleep(0.1)

    # Initialize time count for iteration
    start = time.time()

    # create object to read camera
    video = cv2.VideoCapture(0)

    if (video.isOpened() == False):
        print("Error reading video")

    # define the codec and create VideoWriter object
    fourcc = cv2.VideoWriter_fourcc(*'XVID')
    out = cv2.VideoWriter('videonameNew.avi', fourcc, 3, (640, 480))

    # Initialize performance collection variables
    # (total number of frames, duration of each iteration )
    frm_cnt = 0
    duration = 0

    # Open .txt file to save data
    f = open('hw4data.txt','a')

    # keep looping
    for frame in camera.capture_continuous(rawCapture, format="bgr",
use_video_port=False):
        # Record iteration start time
        startR = datetime.now() #.microsecond / 1000000
        # grab the current frame
        image = frame.array
        # Flig image vertically and horizontally
        # to accomodate for pi camera mount
        image = cv2.flip(image, -1)
        # Apply HSV masking and Gaussian Blur to image read
        img_blurred = img_mask_blur(image)
        # Detect corners from image
        image, pts_loc = corner_detect(img_blurred,image)
        # Go to the next iteration if on arrow detected
        if len(pts_loc) == 0:
            # show the frame to our screen
            cv2.imshow("No Arrow Detection", image)
        else:
            # Identify direction of arrow
            direction, color = def_det(image,pts_loc)
            # Image of direction detected
            image = img_dir_txt(image,direction,color)
            # show the frame to our screen
            cv2.imshow("Direction Arrow Detection", image)
        key = cv2.waitKey(1) & 0xFF
        # write frame into file
        out.write(image)

        frm_cnt += 1

        # clear the stream in preparation for the next frame
        rawCapture.truncate(0)
        duration = time.time() - start

        # End time count for iteration
        stopR = datetime.now()

        now = stopR - startR

        outstring = str(now.total_seconds()) + '\n'
        f.write(outstring)
        print(now)

        # press the 'q' key to stop the video stream
        if (key == ord("q") or (duration >= 40)) and (frm_cnt > 110):
            break

    # Release video capture and video object
    video.release()
    out.release()

    # Close all windows
    cv2.destroyAllWindows()

if __name__ == "__main__":
    main()
```

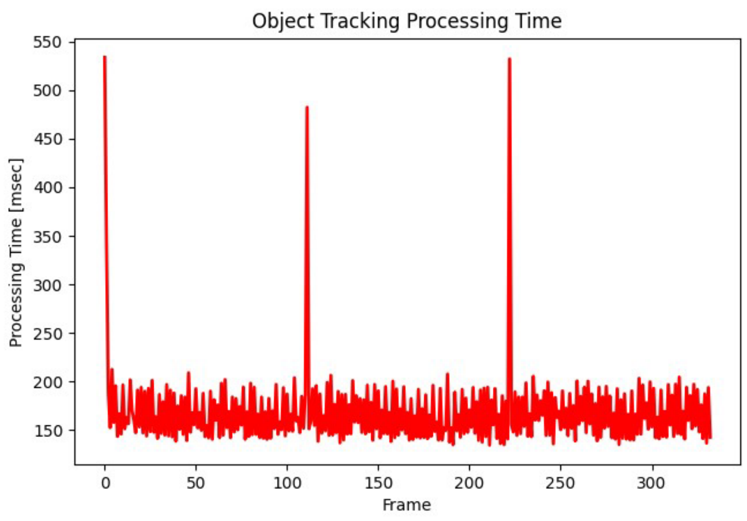
Video Demonstration: https://youtu.be/bDCpjN02aJo

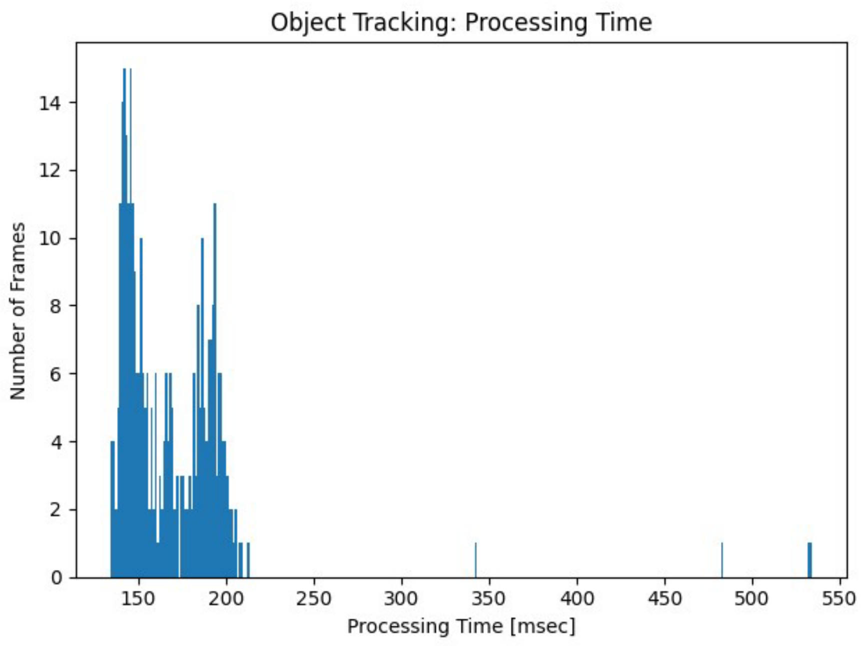
Third Phase – Arrow Detection Performance Time

```
import numpy as np
import matplotlib.pyplot as plt


# 1) Load imu data as string
picamdata = np.genfromtxt("hw4data.txt", dtype=str)

# Obtain shape of data/array
```

```python
size = picamdata.shape

# Extract raw data and convert to milliseconds for better resolution
perf = picamdata[:].astype(np.float64) * 1000

# Create horizontal x axis for plot
x = np.linspace(0,size[0],num=size[0],endpoint=False,dtype=int)

# Plot perf angle with respect to horizontal step 0 - imusize
fig, ax1 = plt.subplots()
ax1.plot(x,perf,ls='solid', color='red',linewidth=2, label='picam-img-det-raw-
data')

# 3) Label the axes, title, legend
ax1.set(title="Object Tracking Processing Time",
        ylabel="Processing Time [msec]",
        xlabel="Frame")
plt.show()
fig.savefig('obj_trck_prcs_time.png')
plt.close()

# Plot histogram of data
num_bins = size[0]
fig, ax = plt.subplots()

# the histogram of the data
# n, bins, patches = ax.hist(perf,num_bins, density=True)
ax.hist(perf,bins=num_bins)
ax.set_xlabel('Processing Time [msec]')
ax.set_ylabel('Number of Frames')
ax.set_title('Object Tracking: Processing Time')

# Tweak spacing to prevent clipping of ylabel
fig.tight_layout()
plt.show()
fig.savefig('hist-obj_trck_prcs_time.png')
plt.close()
```

Plots from Performance Time analysis





PiCamera Performance Discussion

It is apparent from the plots generated that the piCamera performance is heavily affected at the start of the program execution which is evident by the amount of time it takes to loop through a single iteration in order to perform the required task (in this case detecting edges of a masked image of green light). However, as the video frame iteration continues its performance improves gradually and, thus, begins to perform decently.

Therefore, one can learn from this exercise that he or she should disregard the results from the first few seconds, due to abundance of caution in ensuring a stable result from his or her algorithm being executed. As a result, “warming up” the PiCamera for few seconds seems to be the optimal decision to undertake when using this device along with the Raspberry Pi.