

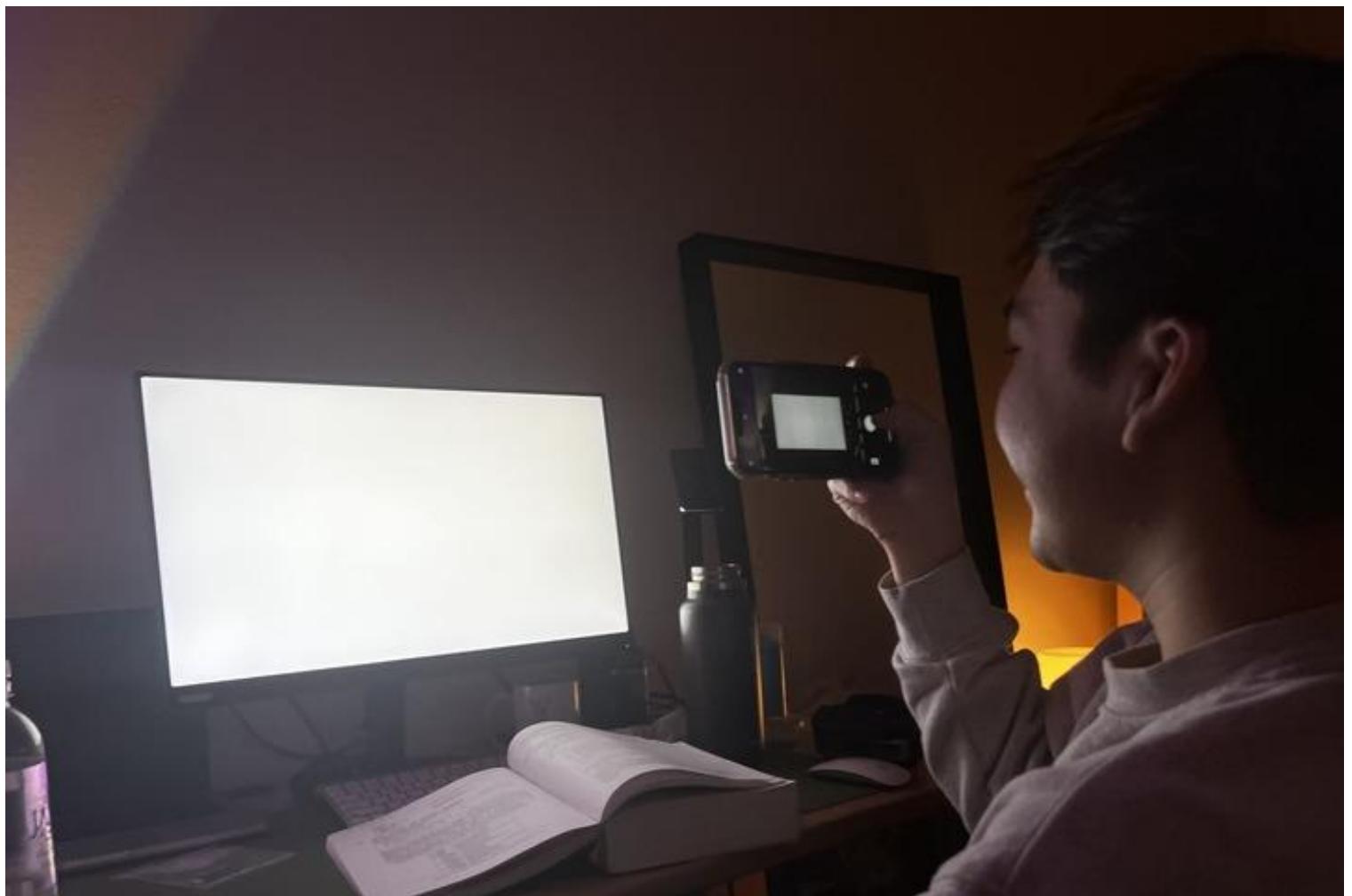
COMS W4735: Assignment 1

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DELIVERABLES FOR STEP 1

How you captured the imagery: camera, lighting, objects, background.

I decided to use a backlighting situation because that way, I could consistently eliminate shadows from the surface of the hand. I pulled up [this website](#) on my laptop, went to a dark room, and took a picture using my iPhone of my hand using the screen as the backdrop. Later on in the project, I used my friend's monitor as the background.



Your environment: hardware, OS, language, packages.

I'm running Windows 11 on a Surface Book 3. I installed opencv-contrib-python and numpy. I'm also using Caer.

Your library: how many images, the format they are stored in/what they were intended to capture

I took a photo of each position (palm, splay, and fist) in each location, not including the edge cases. See the zip folder to view the images. This is how I defined each shape:

splay: a hand with all the fingers spread apart, palm facing the computer screen.

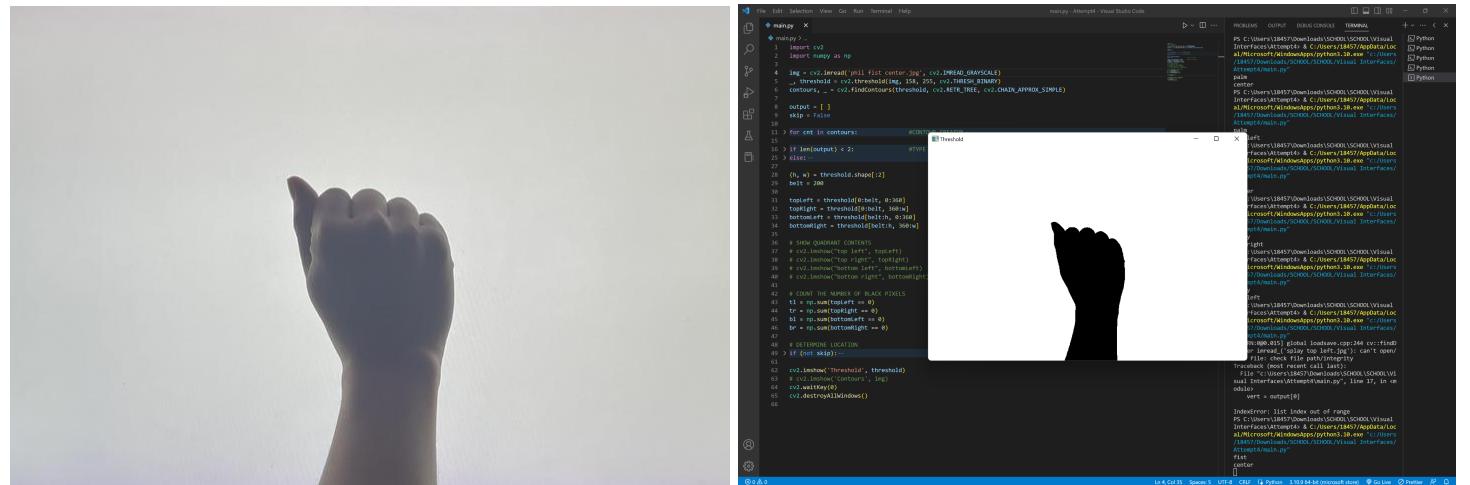
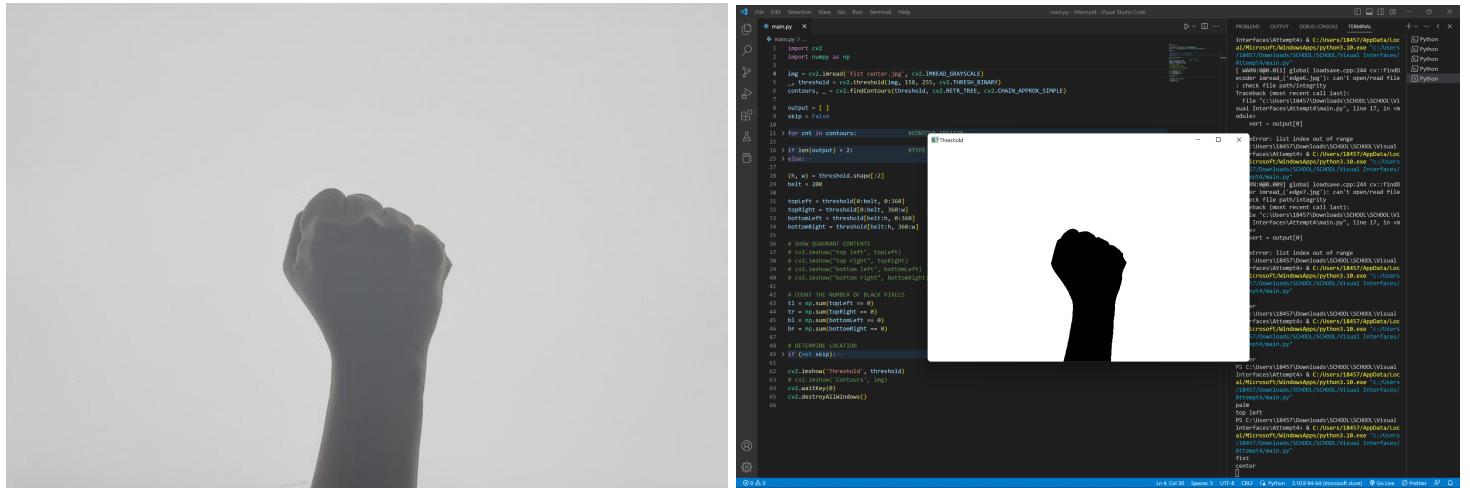
fist: hand with all the fingers curled up into a fist, with the fingers and thumb facing the computer screen. The thumb is tucked in.

palm: a hand with the fingers touching each other. It so happens that I and many others have a ring finger that is bent slightly between the second and third knuckle, thus creating a sliver of backlit light to seep through. This is actually the crux of defining a palm in my code, as I explain in its comments.

I stored these photos as 720x480 px .jpg files locally on my computer.

DELIVERABLES FOR STEP 2

Two images of a centered fist that are accurately recognized and labeled as “fist, center” (true positive)



Two images of a cornered splay that are accurately recognized and labeled as “splay, upper right” [or some other corner] (true positive)

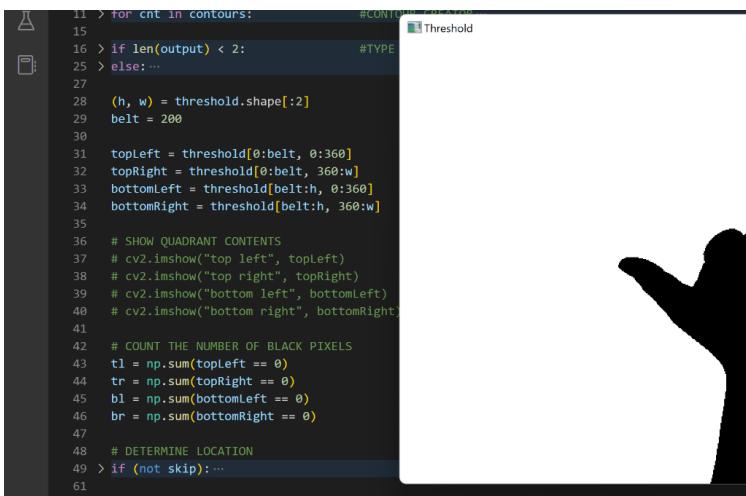




```
 1 import cv2
 2 import numpy as np
 3
 4 img = cv2.imread("play_top_right.jpg", cv2.IMREAD_GRAYSCALE)
 5 threshold = cv2.threshold(img, 150, 255, cv2.THRESH_BINARY)
 6 contours, hierarchy = cv2.findContours(threshold, cv2.RETR_TREE, cv2.CHAIN_APPROX_SIMPLE)
 7
 8 output = []
 9 skip = False
10
11 for cont in contours:
12     if len(output) > 2:
13         break
14     else:
15         (x, y) = cont[0]
16         w = x[0] - x[1]
17         h = y[0] - y[1]
18
19         topleft = threshold[y[0], x[0]:x[1]]
20         toptight = threshold[y[0], x[0]:x[1]+w]
21         bottomleft = threshold[y[1], x[0]:x[1]+w]
22         bottomtight = threshold[y[1], x[0]:x[1]]
23
24         if w < 200 and h < 200:
25             if np.sum(topleft) == 0:
26                 output.append(cont)
27             if np.sum(toptight) == 0:
28                 output.append(cont)
29             if np.sum(bottomleft) == 0:
30                 output.append(cont)
31             if np.sum(bottomtight) == 0:
32                 output.append(cont)
33
34 # SHOW SUBQUADRANT CONTENTS
35 # cv2.imshow("top left", topleft)
36 # cv2.imshow("top right", topright)
37 # cv2.imshow("bottom left", bottomleft)
38 # cv2.imshow("bottom right", bottomtight)
39
40 # COUNT THE NUMBER OF BLACK PIXELS
41 t1 = np.sum(topleft) == 0
42 t2 = np.sum(topright) == 0
43 b1 = np.sum(bottomleft) == 0
44 b2 = np.sum(bottomtight) == 0
45
46 # DETERMINE LOCATION
47 if not skip:
48
49 #cv2.imshow("threshold", threshold)
50 #cv2.imshow("contours", contours)
51 cv2.waitKey(0)
52 cv2.destroyAllWindows()
```

DELIVERABLES FOR STEP 3

One image of a centered fist that is not recognized as “fist, center” (false negative)



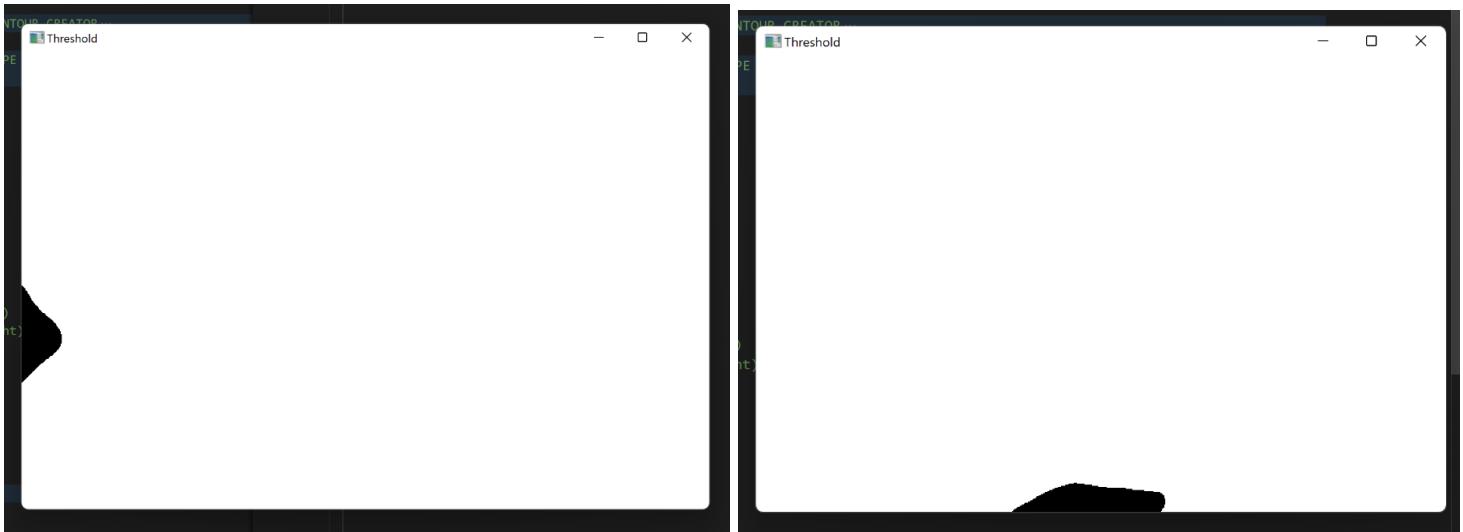
```
palm
top left
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\V
isual Interfaces\Attempt4> & C:/Users/18457
/AppData/Local/Microsoft/WindowsApps/python
3.10.exe "c:/Users/18457/Downloads/SCHOOL/S
CHOOL/Visual Interfaces/Attempt4/main.py"
palm
top left
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\V
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/AppData/Local/Microsoft/WindowsApps/python
3.10.exe "c:/Users/18457/Downloads/SCHOOL/S
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palm
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isual Interfaces\Attempt4> & C:/Users/18457
/AppData/Local/Microsoft/WindowsApps/python
3.10.exe "c:/Users/18457/Downloads/SCHOOL/S
CHOOL/Visual Interfaces/Attempt4/main.py"
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top left
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\V
isual Interfaces\Attempt4> & C:/Users/18457
/AppData/Local/Microsoft/WindowsApps/python
3.10.exe "c:/Users/18457/Downloads/SCHOOL/S
CHOOL/Visual Interfaces/Attempt4/main.py"
splay
top right
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\V
```

output: palm, bottom left. It triggered the line `elif (bl and not tl)` before it hit the `elif (br and not tr)` line in the location classification block, so while it crossed into both the bottom left and right quadrants, it got classified as bottom left.

One image that is incorrectly recognized as “fist, center” (false positive)

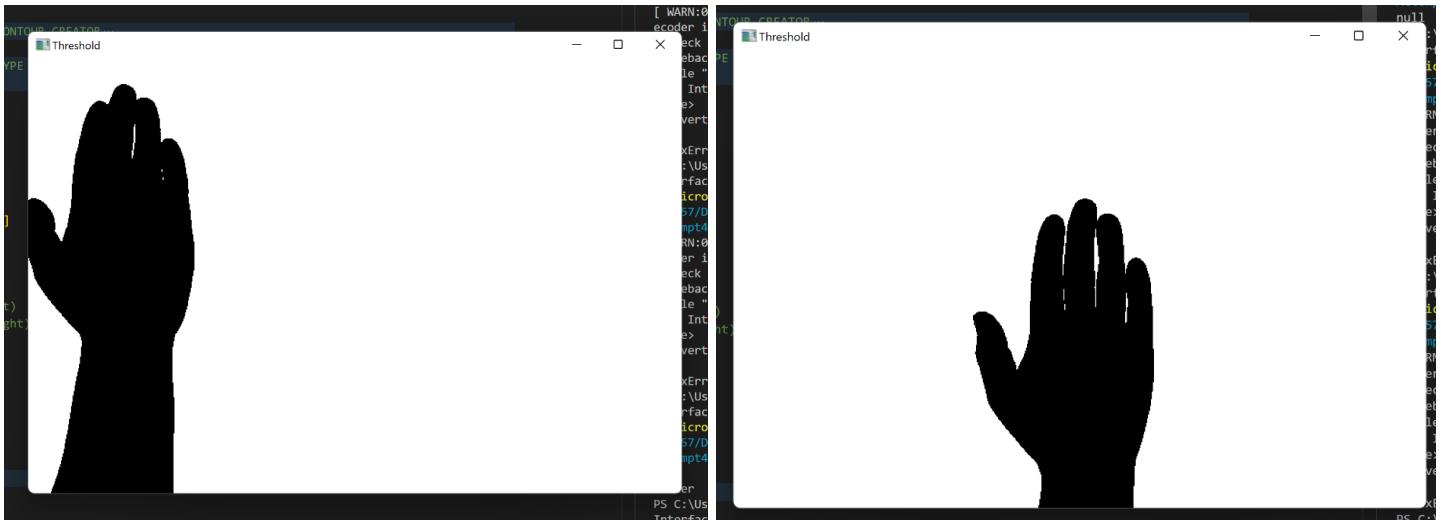
```

11 > for cnt in contours: #CONTOUR CREATOR
12
13 > if len(output) < 2: #TYPE
14 > else: ...
15
16     (h, w) = threshold.shape[:2]
17     belt = 200
18
19     topLeft = threshold[0:belt, 0:360]
20     topRight = threshold[0:belt, 360:w]
21     bottomLeft = threshold[belt:h, 0:360]
22     bottomRight = threshold[belt:h, 360:w]
23
24     # SHOW QUADRANT CONTENTS
25     # cv2.imshow("top left", topLeft)
26     # cv2.imshow("top right", topRight)
27     # cv2.imshow("bottom left", bottomLeft)
28     # cv2.imshow("bottom right", bottomRight)
29
30     # COUNT THE NUMBER OF BLACK PIXELS
31     tl = np.sum(topLeft == 0)
32     tr = np.sum(topRight == 0)
33     bl = np.sum(bottomLeft == 0)
34     br = np.sum(bottomRight == 0)
35
36     # DETERMINE LOCATION
37     #if (tl > 0 and tr > 0 and bl > 0 and br > 0):
38     #    print("center")
39     #else:
40     #    print("fist")
41
42     # DETERMINE LOCATION
43     #if (tl > 0 and tr > 0 and bl > 0 and br > 0):
44     #    print("center")
45     #else:
46     #    print("fist")
47
48     # DETERMINE LOCATION
49     > if (not skip): ...
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```



output: null, null. They're both very small portions of the hand that are off the edge of the screen.

Two images of a palm that are correctly recognized as “palm”. (true positive)



output: palm top left, and palm center, respectively.

One image of a palm that is incorrectly recognized as “fist” (false negative)

```
10
11 > for cnt in contours:           #CONTOUR DETECTION
12
13 > if len(output) < 2:           #TYPE
14 > else:...
15
16 (h, w) = threshold.shape[:2]
17 belt = 200
18
19 topLeft = threshold[0:belt, 0:360]
20 topRight = threshold[0:belt, 360:w]
21 bottomLeft = threshold[belt:h, 0:360]
22 bottomRight = threshold[belt:h, 360:w]
23
24 # SHOW QUADRANT CONTENTS
25 # cv2.imshow("top left", topLeft)
26 # cv2.imshow("top right", topRight)
27 # cv2.imshow("bottom left", bottomLeft)
28 # cv2.imshow("bottom right", bottomRight)
29
30 # COUNT THE NUMBER OF BLACK PIXELS
31 tl = np.sum(topLeft == 0)
32 tr = np.sum(topRight == 0)
33 bl = np.sum(bottomLeft == 0)
34 br = np.sum(bottomRight == 0)
35
36 # DETERMINE LOCATION
37 > if (not skip):...
38
39 > print("Threshold")
```



```
vert = output[0]

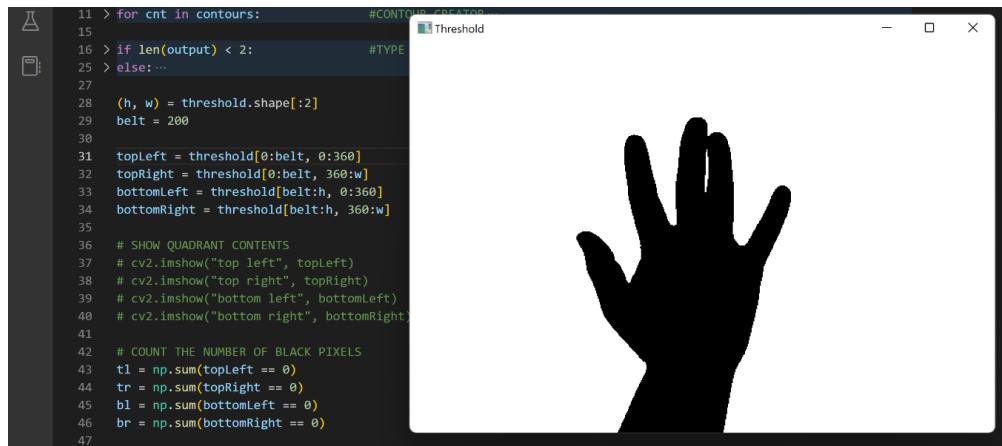
xError: list index out of range
:Users\18457\Downloads\SCHOOL\SCHOOL\Visual
Interfaces\Attempt4> & C:/Users/18457/AppData/Loc
Microsoft/WindowsApps/python3.10.exe "c:/Users
57/Downloads/SCHOOL/SCHOOL/Visual Interfaces/
mp4/main.py"

:Users\18457\Downloads\SCHOOL\SCHOOL\Visual
Interfaces\Attempt4> & C:/Users/18457/AppData/Loc
Microsoft/WindowsApps/python3.10.exe "c:/Users
57/Downloads/SCHOOL/SCHOOL/Visual Interfaces/
mp4/main.py"
RN:@@.011] global loadsave.cpp:244 cv::findD
er imread_('edge6.jpg'): can't open/read file
check file path/integrity
eback (most recent call last):
le "c:\Users\18457\Downloads\SCHOOL\SCHOOL\Vi
l Interfaces\Attempt4\main.py", line 17, in <m
e>
vert = output[0]

xError: list index out of range
:Users\18457\Downloads\SCHOOL\SCHOOL\Visual
Interfaces\Attempt4> & C:/Users/18457/AppData/Loc
Microsoft/WindowsApps/python3.10.exe "c:/Users
57/Downloads/SCHOOL/SCHOOL/Visual Interfaces/
mp4/main.py"
RN:@@.009] global loadsave.cpp:244 cv::findD
er imread_('edge7.jpg'): can't open/read file
check file path/integrity
Traceback (most recent call last):
```

output: fist, center. It's a palm that's angled towards the screen.

One image of “splay” that is incorrectly recognized as “palm” (false positive)



The screenshot shows a Python code editor with several tabs open. The main tab contains the following code:

```
11 > for cnt in contours: #CONTOUR CREATOR
12
13 >     if len(output) < 2: #TYPE
14 >         else: ...
15
16 >         (h, w) = threshold.shape[::2]
17 >         belt = 200
18
19 >         topLeft = threshold[0:belt, 0:360]
20 >         topRight = threshold[0:belt, 360:w]
21 >         bottomLeft = threshold[belt:h, 0:360]
22 >         bottomRight = threshold[belt:h, 360:w]
23
24 >         # SHOW QUADRANT CONTENTS
25 >         # cv2.imshow("top left", topLeft)
26 >         # cv2.imshow("top right", topRight)
27 >         # cv2.imshow("bottom left", bottomLeft)
28 >         # cv2.imshow("bottom right", bottomRight)
29
30 >         # COUNT THE NUMBER OF BLACK PIXELS
31 >         tl = np.sum(topLeft == 0)
32 >         tr = np.sum(topRight == 0)
33 >         bl = np.sum(bottomLeft == 0)
34 >         br = np.sum(bottomRight == 0)
35
36 >         # output: palm, center. The gap between the middle two fingers causes it to be labeled as a palm because that gap creates a new shape in the field, which
37 >         # distinguishes a palm, rather than the entire hand registering as a single continuous shape as in a "splay".
38
39 >         if tl > tr & tl > bl & tl > br:
40 >             output.append('palm')
41 >             center = 'center'
42 >         elif tl < tr & tl < bl & tl < br:
43 >             output.append('fist')
44 >             center = 'center'
45 >         elif tl == tr & tl == bl & tl == br:
46 >             output.append('center')
47 >
```

To the right of the code is a thresholded image of a hand, showing a dark silhouette against a white background.

On the far right, there is a terminal window showing command-line output:

```
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\Visual Interfaces\Attempt4> & C:/Users/18457/AppData/Local/Microsoft/WindowsApps/python3.10.exe "c:/Users/18457/Downloads/SCHOOL/SCHOOL/Visual Interfaces/Attempt4/main.py"
[ WARN:0@0.015] global loadsSave.cpp:244 cv::findDecoder imread_('splay top left.jpg'): can't open/read file: check file path/integrity
Traceback (most recent call last):
  File "c:/Users/18457/Downloads/SCHOOL/SCHOOL/Visual Interfaces/Attempt4/main.py", line 17, in <module>
    vert = output[0]

IndexError: list index out of range
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\Visual Interfaces\Attempt4> & C:/Users/18457/AppData/Local/Microsoft/WindowsApps/python3.10.exe "c:/Users/18457/Downloads/SCHOOL/SCHOOL/Visual Interfaces/Attempt4/main.py"
fist
center
PS C:\Users\18457\Downloads\SCHOOL\SCHOOL\Visual Interfaces\Attempt4> & C:/Users/18457/AppData/Local/Microsoft/WindowsApps/python3.10.exe "c:/Users/18457/Downloads/SCHOOL/SCHOOL/Visual Interfaces/Attempt4/main.py"
```

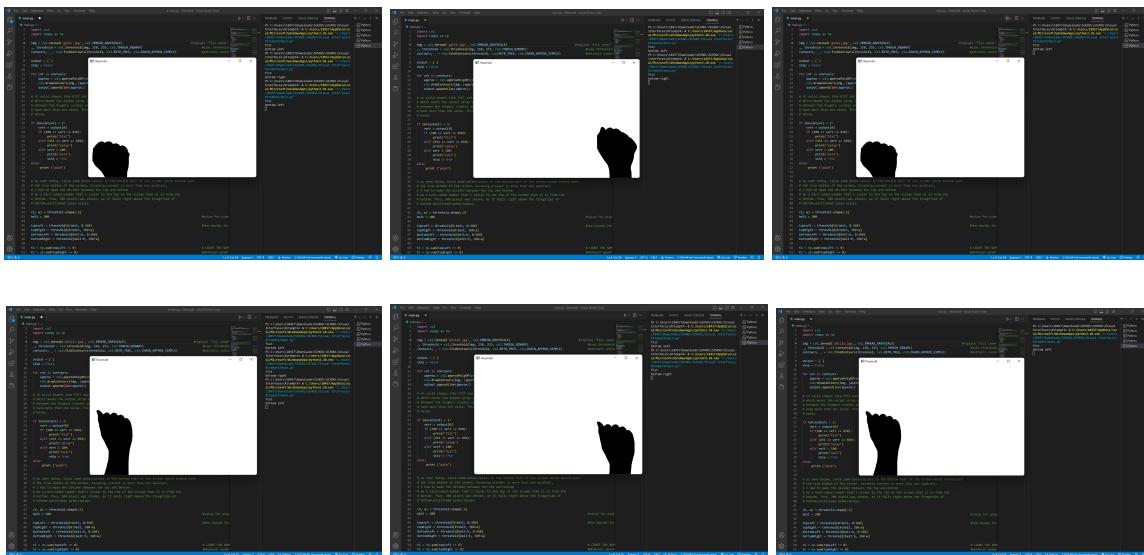
output: palm, center. The gap between the middle two fingers causes it to be labeled as a palm because that gap creates a new shape in the field, which distinguishes a palm, rather than the entire hand registering as a single continuous shape as in a “splay”.

DELIVERABLES FOR STEP 4

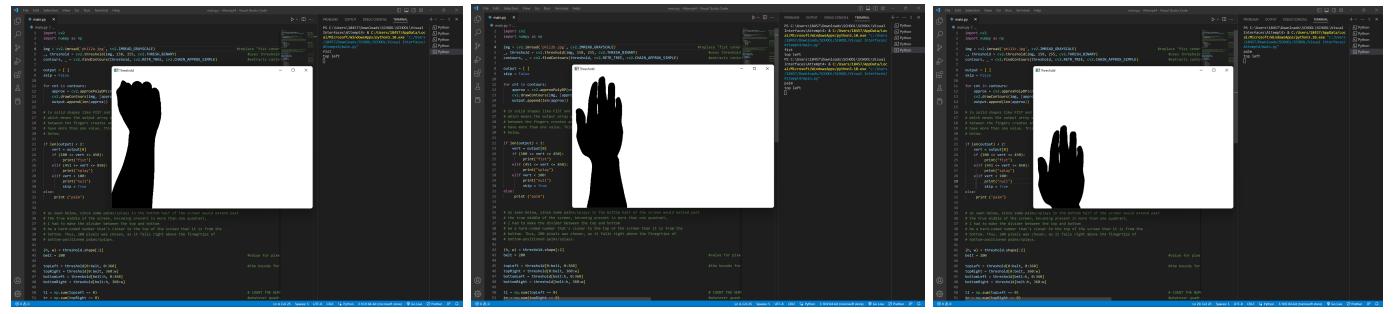
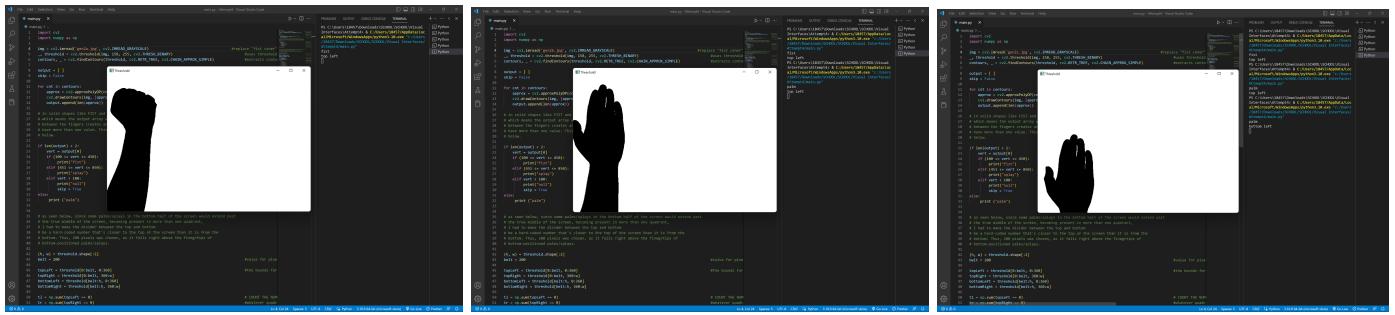
Explain how you determined the three sequences.

All of the shapes are equally perceivable by the code, so I think the hard part is placement. The shapes that trip up the location code are the ones that don’t clearly populate the top two quadrants; smaller shapes like the fist might not make it up past the “belt” dividing the top and bottom of the screen if the user doesn’t place their fist in the very corner.

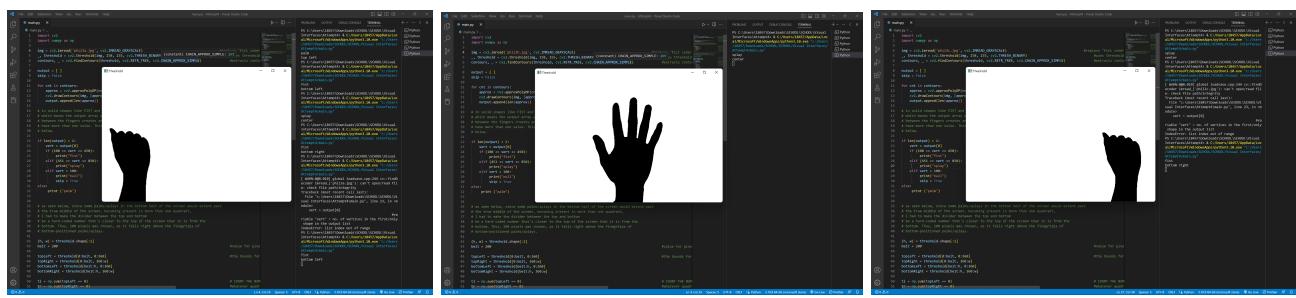
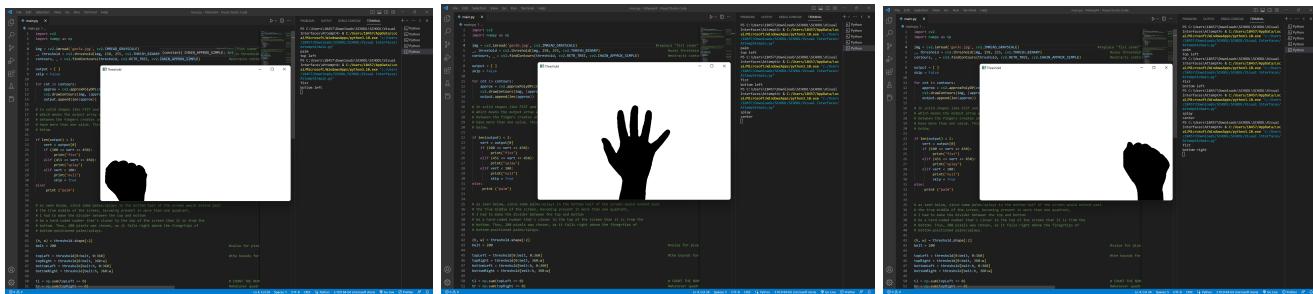
1. Easy: The absolute easiest sequence would only involve the bottom corners because they’re the most generous regions in the frame as I’ve coded it. *Fist Bottom Left, Fist Bottom Right, Fist Bottom Left*.



2. Hard: going off what I mentioned above, the hardest sequence would involve a fist in a top-right corner. Also, to make it worse, it would involve a palm from a user with little to no bend in their ring finger (thus eliminating the glimpse of white pixels between the fingers of a closed palm that generate the only type of data that can classify input as a palm). *Fist Top Left, Palm Top Left, Palm Bottom Left.*



3. Good: A good sequence would involve the bottom two corners and a large center figure, since the bottom two corners are always stimulated and a large center figure would guarantee all four quadrants have input (which is the trigger, in the code, for considering something to be in the “center”). *Fist Bottom Left, Splay Center, Fist Bottom Right.*



Report on your system's overall success rate in terms of accuracy.

All outputs were 100% accurate. I apologize that the images are so small, but you may be able to see the output in the terminal to the right of the photo.

Report any feedback from your friend about the system: ease of use, confusability of “what”, and of “where”, and any other comments that could be used to improve the system.

My friend found that when asked to cling to a white computer screen in a dark room with an open hand, it felt like a poetic moment between man and machine. Other than that, because of the very limited factors in image production (lights off, white screen on, hand on screen in one of five locations in one of three hand positions), my friend expressed no confusion.

Once the project as a whole was explained, the instructions became more clear, so if I were to conduct this on a mass-scale, I would definitely include a project summary before I asked for anyone to do anything else.

Given your experiences, summarize how you would approach System 2.0: what you would keep, what you would change, etc.

In System 2.0, I'd come up with a different way of classifying a palm. It's reliant on that finger-bend. If not for that anatomical anomaly, I honestly would not know how to classify a palm. I'd need more time to figure out a completely different classification mechanism that may have to drift away from counting the contours of present shapes.

I would keep, however, the backlit photography setup. It eliminates the hassle of color and shadow. No matter the skintone, the hand will be a dark, monotone figure, and the screen will be a consistent white. Also, there is no need for any control over ambient lighting, thus limiting the factors I have to worry about when setting the photography scene up. I pull up the white screen and turn off the room lights. Done. I must, however, acknowledge that depending on the brightness of the screen, light will crawl up the sides of the hands and illuminate certain contours that create speckles of white within the shape of the hand, which blow the whole “monotone dark shape” thing. I was able to lower the brightness of my friend's monitor so this effect would lessen, but it's definitely not something I could ignore when producing the photos or processing them.

Please note that the prof is not responsible for any impact of your system on your friendship.

I was able to preserve my friendship with Phillip, the namesake for some of the files I've submitted, while using his time, patience, hand, and desktop monitor throughout this project.