EN2550: Assignment 03 on Object Counting on a Conveyor Belt

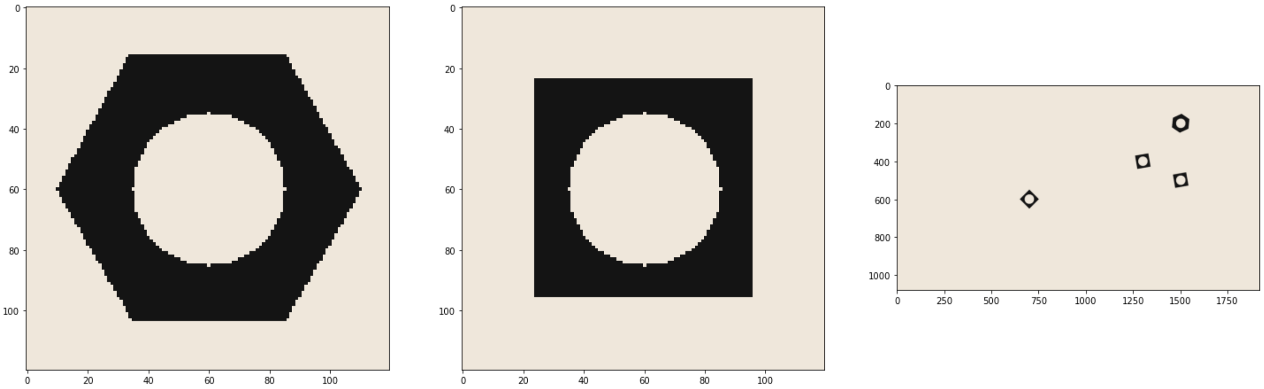
Connected Component Analysis

In this part, we will generate an indexed image representing connected components in `conveyor_f101.png` image. Notice that, as there are three square nuts and one hexagonal nut in the image, there will be five connected components (backgound will be assigned the label 0).

1. Open the `hexnut_template.png`, `squarenut_template.png` and `conveyor_f100.png` and display. This is done for you.

In [ ]:

```
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt

hexnut_template = cv.imread('hexnut_template.png', cv.IMREAD_COLOR)
squarenut_template =  cv.imread('squarenut_template.png', cv.IMREAD_COLOR)
conveyor_f100 =  cv.imread('conveyor_f100.png', cv.IMREAD_COLOR)

fig, ax = plt. subplots(1,3, figsize = (25,10))
ax[0].imshow(cv.cvtColor(hexnut_template, cv.COLOR_RGB2BGR))
ax[1].imshow(cv.cvtColor(squarenut_template, cv.COLOR_RGB2BGR))
ax[2].imshow(cv.cvtColor(conveyor_f100, cv.COLOR_RGB2BGR))
plt.show()
```



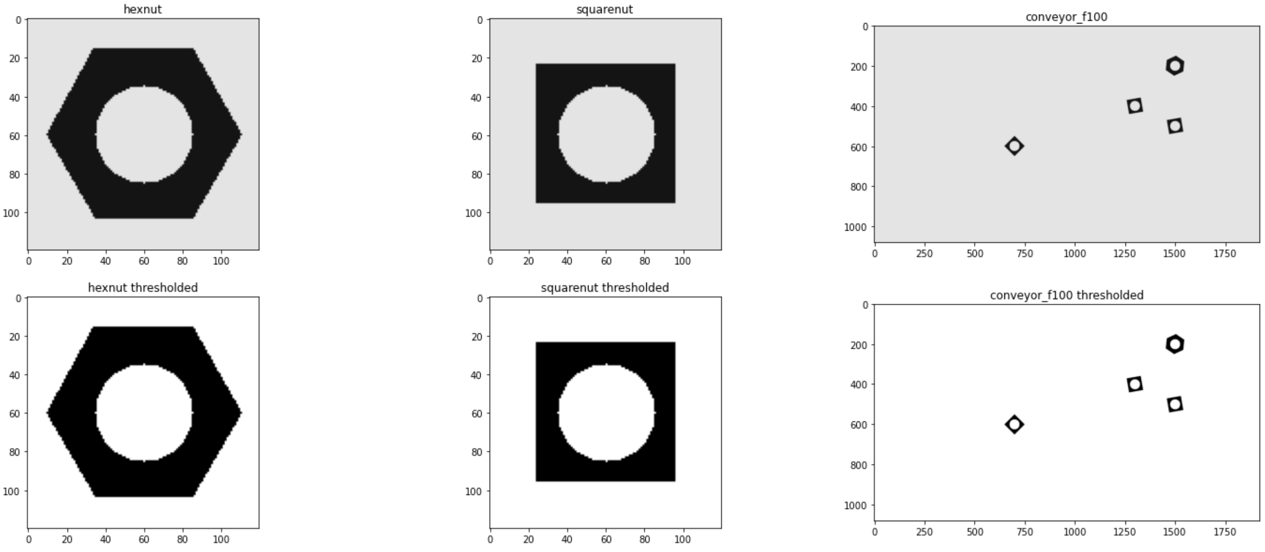
1. Convert the images to grayscale and apply Otsu's thresholding to obtain the binarized image. Do this for both the templates and belt images. See https://docs.opencv.org/master/d7/d4d/tutorial_py_thresholding.html for a guide. State the threshold value (automatically) selected in the operation. Display the output images.

In [ ]:

```
hexnut_gray = cv.cvtColor(hexnut_template, cv.COLOR_RGB2GRAY)
squarenut_gray = cv.cvtColor(squarenut_template, cv.COLOR_RGB2GRAY)
conveyor100_gray = cv.cvtColor(conveyor_f100, cv.COLOR_RGB2GRAY)

#Otsu's thresholding
ret1,th1 = cv.threshold(hexnut_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
```

```
ret2,th2 = cv.threshold(squarenut_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
ret3,th3 = cv.threshold(conveyor100_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)

images = [[hexnut_gray, th1],[squarenut_gray,th2],[conveyor100_gray,th3]]
titles = [['hexnut', 'hexnut thresholded'],['squarenut', 'squarenut thresholded'], ['co

fig, ax = plt. subplots(2,3, figsize = (25,10))
for i in range(2):
    ax[i][0].imshow(cv.cvtColor(images[0][i] , cv.COLOR_GRAY2BGR))
    ax[i][1].imshow(cv.cvtColor(images[1][i] , cv.COLOR_GRAY2BGR))
    ax[i][2].imshow(cv.cvtColor(images[2][i] , cv.COLOR_GRAY2BGR))

    ax[i][0].set_title(titles[0][i])
    ax[i][1].set_title(titles[1][i])
    ax[i][2].set_title(titles[2][i])

print('Threshold value for hexnut image:',ret1)
print('Threshold value for square image:',ret2)
print('Threshold value for conveyor image:',ret3)
```

```
Threshold value for hexnut image: 20.0
Threshold value for square image: 20.0
Threshold value for conveyor image: 20.0
```

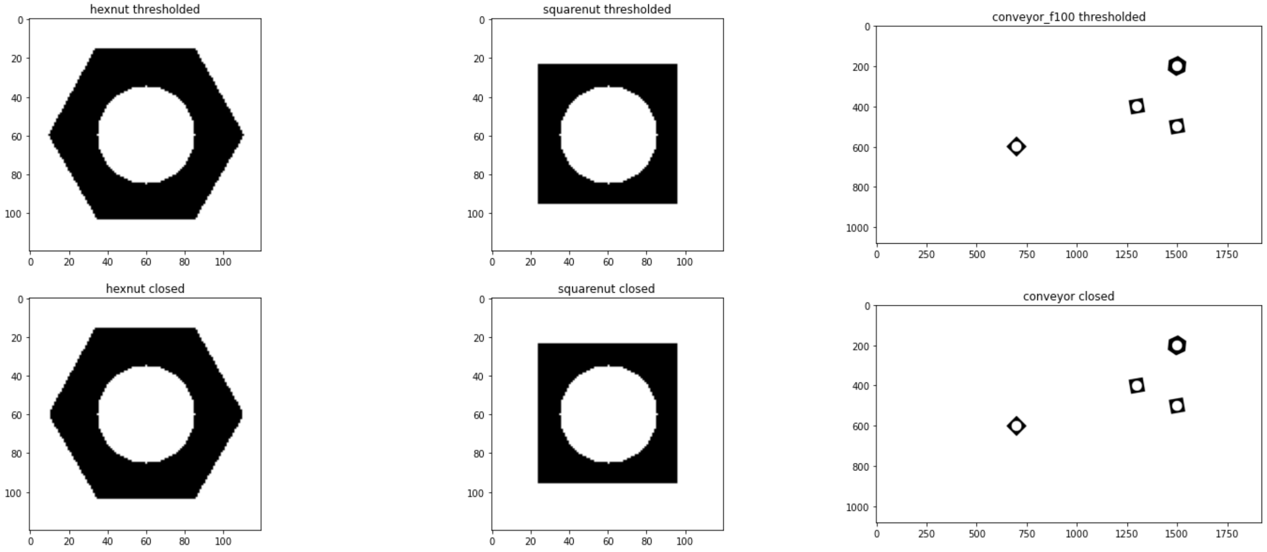


1. Carry out morphological closing to remove small holes inside the foreground. Use a 3×3 kernel. See https://docs.opencv.org/master/d9/d61/tutorial_py_morphological_ops.html for a guide.

In [ ]:

```
kernel = np.ones((3,3),np.uint8)

hexnut_closed = cv.morphologyEx(th1, cv.MORPH_CLOSE, kernel)
squarenut_closed = cv.morphologyEx(th2, cv.MORPH_CLOSE, kernel)
conveyor_closed = cv.morphologyEx(th3, cv.MORPH_CLOSE, kernel)

fig, ax = plt. subplots(2,3, figsize = (25,10))

ax[0][0].imshow(cv.cvtColor(images[0][1] , cv.COLOR_GRAY2BGR))
ax[0][1].imshow(cv.cvtColor(images[1][1] , cv.COLOR_GRAY2BGR))
ax[0][2].imshow(cv.cvtColor(images[2][1] , cv.COLOR_GRAY2BGR))
```

```
ax[0][0].set_title(titles[0][i])
ax[0][1].set_title(titles[1][i])
ax[0][2].set_title(titles[2][i])

ax[1][0].imshow(cv.cvtColor(hexnut_closed , cv.COLOR_GRAY2BGR))
ax[1][1].imshow(cv.cvtColor(squarenut_closed , cv.COLOR_GRAY2BGR))
ax[1][2].imshow(cv.cvtColor(conveyor_closed , cv.COLOR_GRAY2BGR))

ax[1][0].set_title('hexnut closed')
ax[1][1].set_title('squarenut closed')
ax[1][2].set_title('conveyor closed')

plt.show()
```



1. Connected components analysis: apply the `connectedComponentsWithStats` function (see https://docs.opencv.org/4.5.5/d3/dc0/group__imgproc__shape.html#ga107a78bf7cd25dec05fb4dfc and display the outputs as colormapped images. Answer the following questions

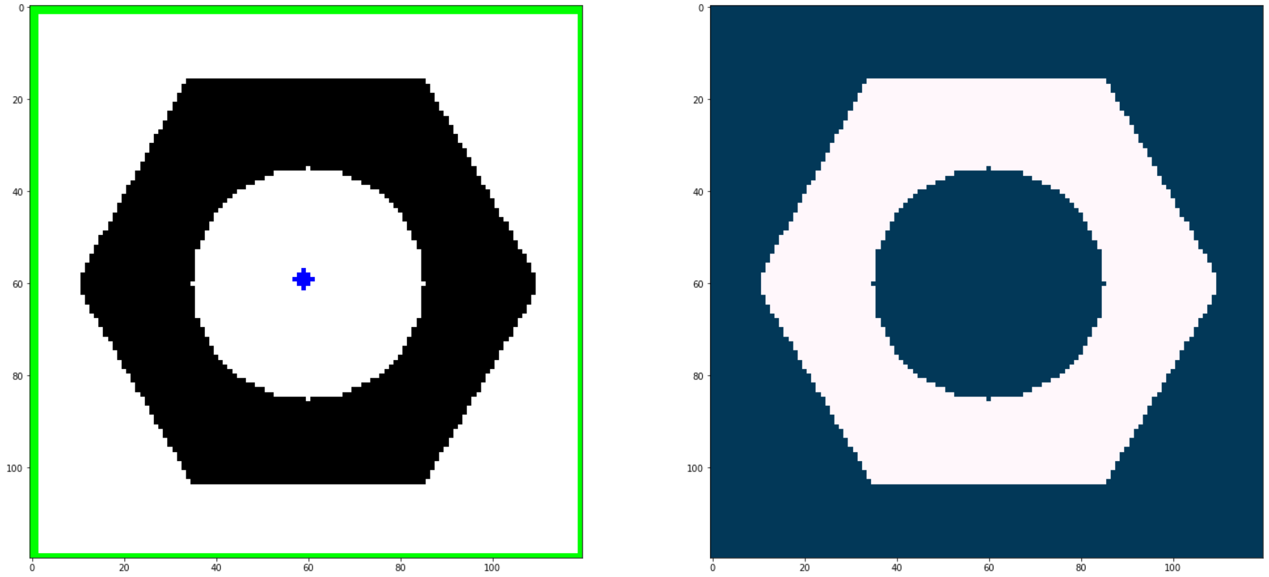
- How many connected components are detected in each image?
- What are the statistics? Interpret these statistics.
- What are the centroids?

For the hexnut template, you should get the object area in pixel as approximately `4728`.

In [ ]:

```
images_for_componentAnalysis = [hexnut_closed, squarenut_closed, conveyor_closed]
titles = ["Hexnut Template", "Squarenut Template", "Conveyor_f100"]

for j in range(len(images_for_componentAnalysis)):
    # You need to choose 4 or 8 for connectivity type
    connectivity = 4
    # Perform the operation
    invert = cv.bitwise_not(images_for_componentAnalysis[j])
    output = cv.connectedComponentsWithStats(invert , connectivity, cv.CV_32S)
    # Get the results
    # The first cell is the number of labels
    num_labels = output[0]
    # The second cell is the label matrix
    labels = output[1]
    # The third cell is the stat matrix
    stats = output[2]
    # The fourth cell is the centroid matrix
    centroids = output[3]

    fig, ax = plt. subplots(num_labels,2,figsize = (25,25))
    print(titles[j])
    print("Number of connected components-", num_labels)

    for i in range(0, num_labels):
        x = stats[i, cv.CC_STAT_LEFT]
        y = stats[i, cv.CC_STAT_TOP]
        w = stats[i, cv.CC_STAT_WIDTH]
        h = stats[i, cv.CC_STAT_HEIGHT]
        area = stats[i, cv.CC_STAT_AREA]
        (cX, cY) = centroids[i]

        if(i == 0):
            print("Background", ':', 'Area:', area,'|', 'centroid:', (cX, cY))
        else:
            print("Component ",i, ':', 'Area:', area,'|', 'centroid:', (cX, cY))

        output = images_for_componentAnalysis[j].copy()
        output = cv.cvtColor(output , cv.COLOR_GRAY2BGR)
        cv.rectangle(output, (x, y), (x + w, y + h), (0, 255, 0), 2)
        cv.circle(output, (int(cX), int(cY)), 2, (0, 0, 255), -1)

        componentMask = (labels == i).astype("uint8") * 255


        # show our output image and connected component mask
        ax[i][0].imshow(output)
        ax[i][1].imshow(componentMask, cmap = 'PuBu')
```

```
Hexnut Template
Number of connected components- 2
Background : Area: 9678 | centroid: (59.337259764414135, 59.635358545153956)
Component  1 : Area: 4722 | centroid: (59.83354510800508, 59.22257518000847)
Squarenut Template
Number of connected components- 2
Background : Area: 11177 | centroid: (59.58772479198354, 59.58772479198354)
Component  1 : Area: 3223 | centroid: (59.19578032888613, 59.19578032888613)
Conveyor_f100
Number of connected components- 5
Background : Area: 2059670 | centroid: (957.3660615535498, 540.4427194647686)
Component  1 : Area: 4628 | centroid: (1499.2411408815904, 199.28435609334485)
Component  2 : Area: 3083 | centroid: (1299.1819656179046, 399.18196561790467)
Component  3 : Area: 3083 | centroid: (1499.1819656179046, 499.18196561790467)
Component  4 : Area: 3136 | centroid: (700.0, 600.0)
```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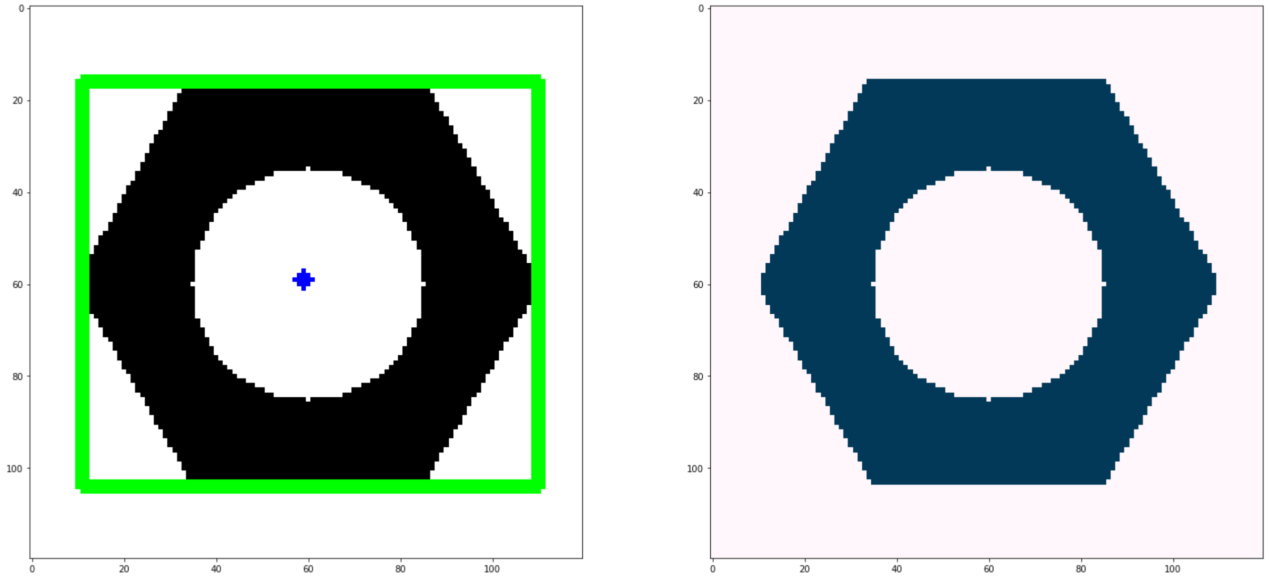
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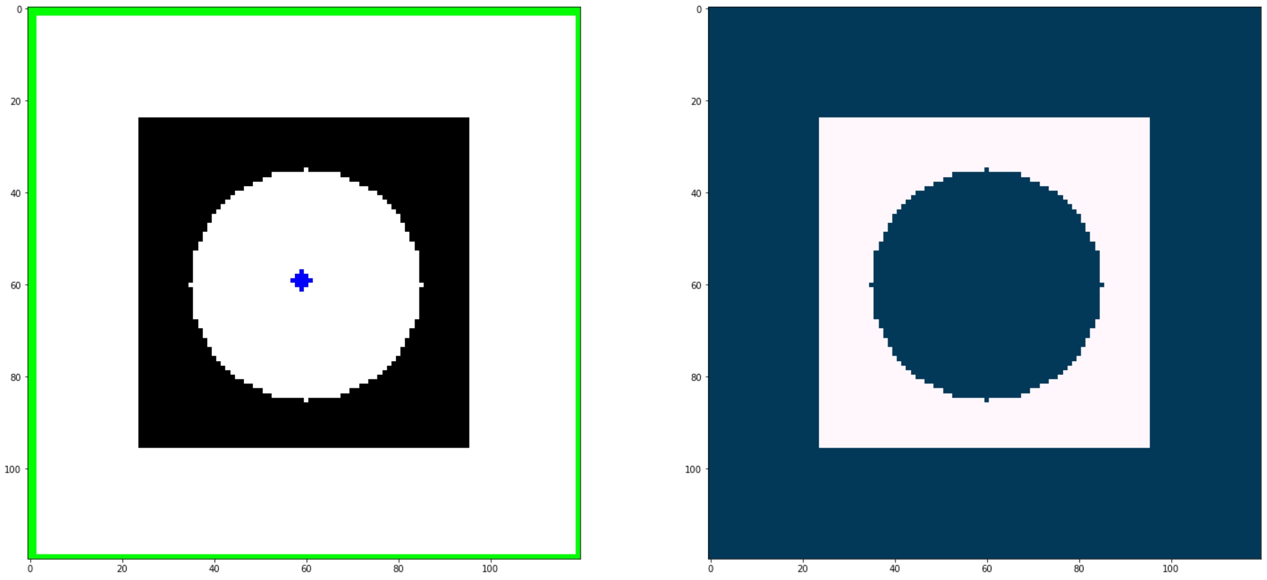
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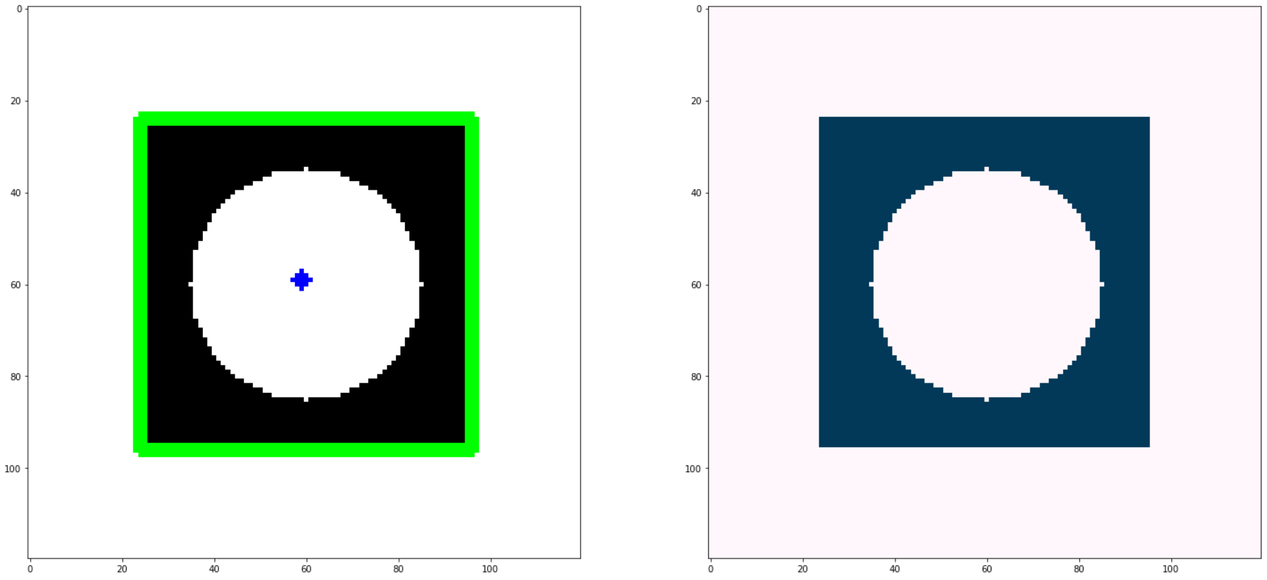
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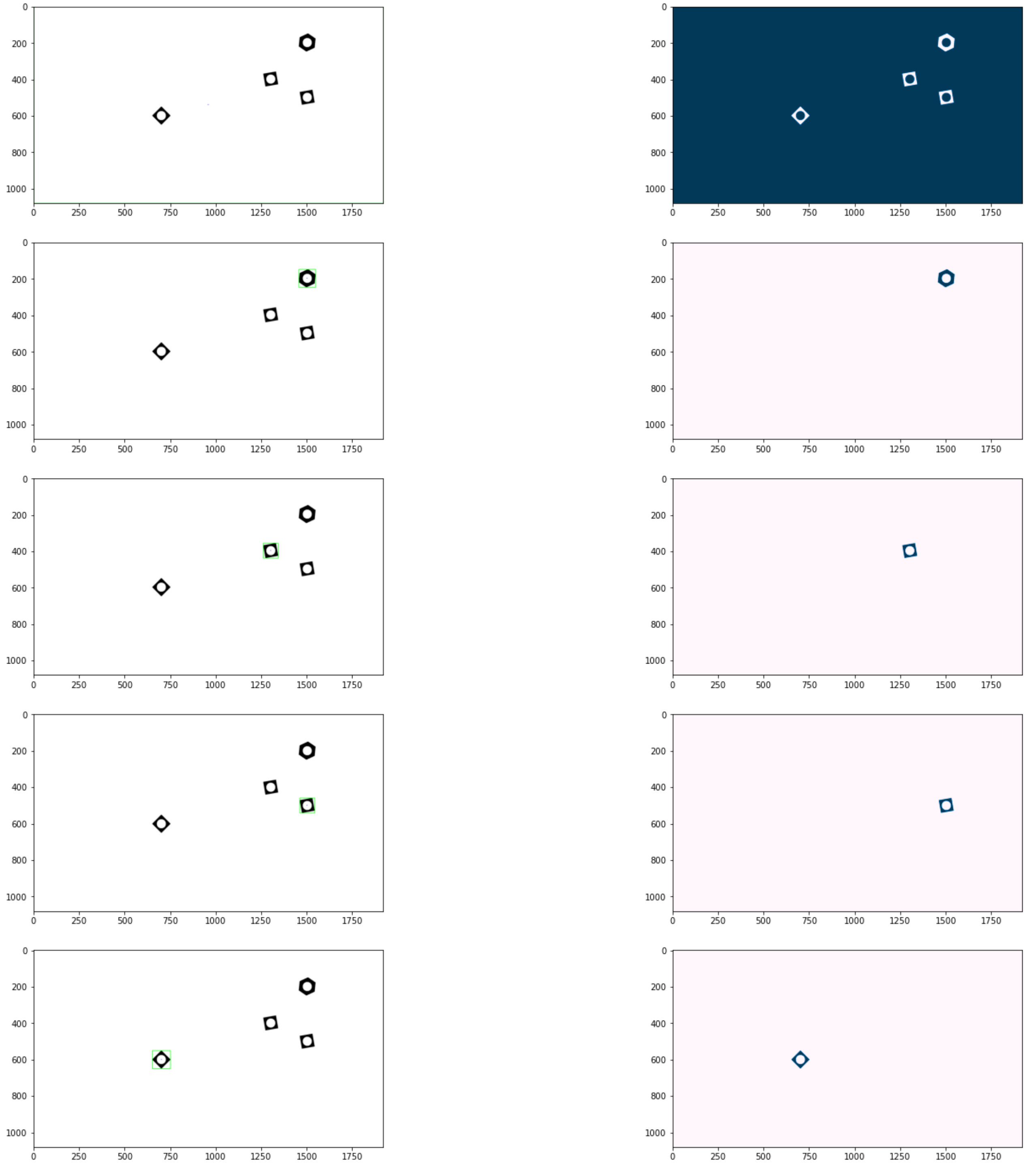


1. Contour analysis: Use `findContours` function to retrieve the *extreme outer* contours. (see https://docs.opencv.org/4.5.2/d4/d73/tutorial_py_contours_begin.html for help and https://docs.opencv.org/4.5.2/d3/dc0/group__imgproc__shape.html#gadf1ad6a0b82947fa1fe3c3d4 for information.

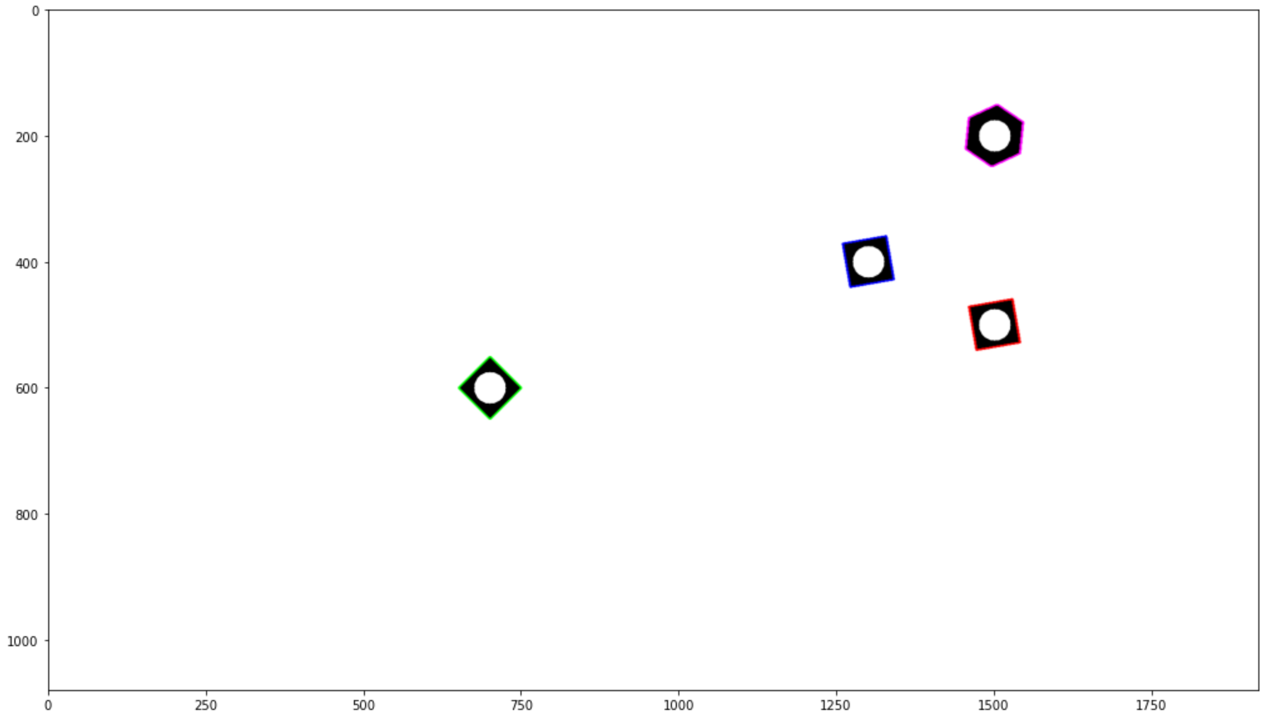
Display these contours. You should see something like the following:

extreme_outer_contours

In [ ]:

```
invert = cv.bitwise_not(conveyor_closed)
```

```
contours, hierarchy = cv.findContours(invert , mode=cv.RETR_EXTERNAL, method=cv.CHAIN_A
image_copy = conveyor_closed.copy()
colors = ((0,255,0), (255,0,0), (0,0,255), (255,0,255))

image_copy = cv.cvtColor(image_copy , cv.COLOR_GRAY2BGR)
for i in range(len(contours)):
    cv.drawContours(image=image_copy, contours=contours[i], contourIdx=-1, color=colors

fig,ax = plt.subplots(figsize = (25,10))
ax.imshow(image_copy)
plt.show()
```



Detecting Objects on a Synthetic Conveyor

In this section, we will use the synthetic `conveyor.mp4` sequence to count the two types of nuts.

1. Open the sequence and play it using the code below.

In [ ]:

```
cv.namedWindow('Conveyor', cv.WINDOW_NORMAL)
cap = cv.VideoCapture('conveyor.mp4')
f = 0
frame = []
while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        print("Can't receive frame (stream end?). Exiting.")
        break

    f += 1
    text = 'Frame:' + str(f)
    cv.putText(frame,text , (100, 100), cv.FONT_HERSHEY_COMPLEX, 1, (0,250,0), 1, cv.LI
    cv.imshow('Conveyor', frame)

    if cv.waitKey(1) == ord('q'):
        break

cap.release()
cv.destroyAllWindows()
```

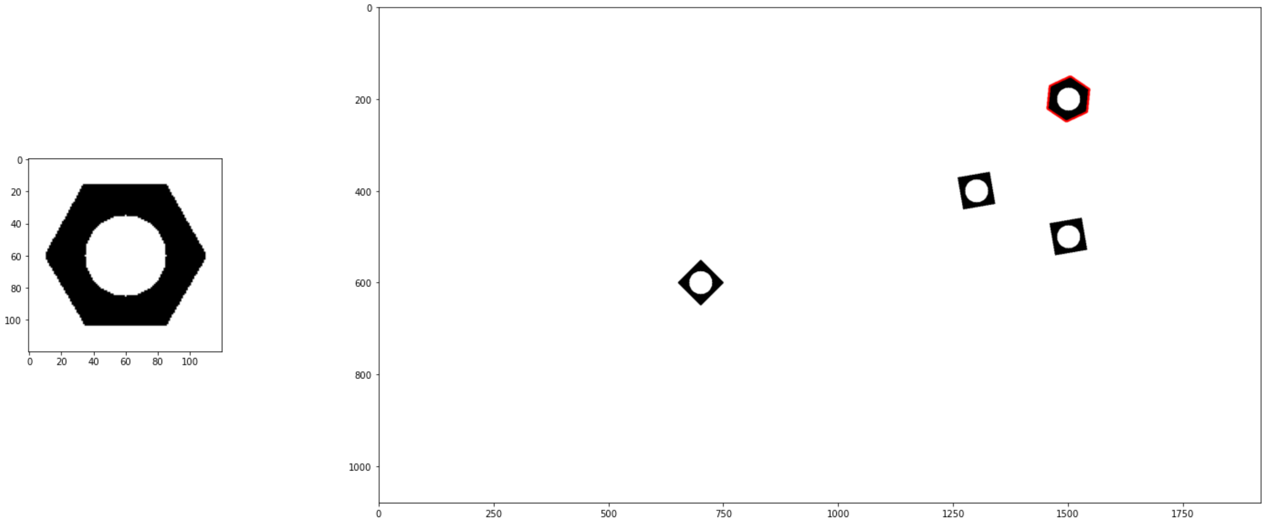
```
Can't receive frame (stream end?). Exiting.
```

1. Count the number of matching hexagonal nuts in `conveyor_f100.png` . You can use `matchCountours` function as shown in https://docs.opencv.org/4.5.2/d5/d45/tutorial_py_contours_more_functions.html to match contours in each frame with that in th template.

In [ ]:

```
invert_2 = cv.bitwise_not(hexnut_closed)
contours_hex, hierarchy_hex = cv.findContours(invert_2 , mode=cv.RETR_EXTERNAL, method=

frame_1 = conveyor_closed
image_to_be_matched = contours_hex[0]

matches = 0
matched_contours = []

for i in contours:
    ret = cv.matchShapes(i, image_to_be_matched ,1,0.0)
    if (ret < 0.0001):
        matches += 1
        matched_contours.append(i)

print("Number of matches:", matches)

image_copy = conveyor_closed.copy()
image_copy = cv.cvtColor(image_copy , cv.COLOR_GRAY2BGR)
for i in range(len(matched_contours)):
    cv.drawContours(image=image_copy, contours=matched_contours[i], contourIdx=-1, colo

fig,ax = plt.subplots(1,2, figsize = (25,10), gridspec_kw={'width_ratios': [1, 5]})
ax[0].imshow(cv.cvtColor(hexnut_closed , cv.COLOR_GRAY2BGR))
ax[1].imshow(image_copy)
plt.show()
```

```
Number of matches: 1
```



1. Count the number of objects that were conveyed along the conveyor belt: Display the count in the current frame and total count upto the current frame in the output video. Please compress your video (using Handbreak or otherwise) before uploading. It would be good to experiment first with the two adjacent frames `conveyor_f100.png` and `conveyor_f101.png` . In order to disregard partially appearing nuts, consider comparing the contour area in addition to using the `matchCountours` function.

In [ ]:

```
cap = cv.VideoCapture('conveyor.mp4')

f = 0
frame = []
tot_matches = 0
frame_array = []
initalizer = 0
initial_cord = []

while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        print("Can't receive frame (stream end?). Exiting.")
        break

    #matching hexnuts in the frame
    frame_gray = cv.cvtColor(frame , cv.COLOR_RGB2GRAY)
    ret_frame,th_frame = cv.threshold(frame_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU

    kernel = np.ones((3,3),np.uint8)
    frame_closed = cv.morphologyEx(th_frame, cv.MORPH_CLOSE, kernel)

    invert = cv.bitwise_not(frame_closed)

    #connected component analysis
    connectivity = 4
    output = cv.connectedComponentsWithStats(invert , connectivity, cv.CV_32S)
    num_labels = output[0]
    labels = output[1]
    stats = output[2]
    centroids = output[3]
    matches = 0
    matched_contours = []

    for i in range(1, num_labels):
        x = stats[i, cv.CC_STAT_LEFT]
        y = stats[i, cv.CC_STAT_TOP]
        w = stats[i, cv.CC_STAT_WIDTH]
        h = stats[i, cv.CC_STAT_HEIGHT]
        area = stats[i, cv.CC_STAT_AREA]
        (cX, cY) = centroids[i]


        componentMask = (labels == i).astype("uint8") * 255
        contours_mask, hierarchy_mask = cv.findContours(componentMask , mode=cv.RETR_EX


        image_to_be_matched = contours_hex[0]
        for i in contours_mask:
            ret = cv.matchShapes(i, image_to_be_matched ,1,0.0)
            if (ret < 0.001 and area > 4600):
                matches += 1

                matched_contours.append(i)

                if(initalizer == 0):
                    initial_cord.append([cX,cY])
                    initalizer += 1


                if (cX < initial_cord[0][0]+5 and cX >= initial_cord[0][0]-5):

                    tot_matches += 1

    image_copy = frame_closed.copy()
    image_copy = cv.cvtColor(image_copy , cv.COLOR_GRAY2BGR)
    for i in range(len(matched_contours)):
        cv.drawContours(frame, contours=matched_contours[i], contourIdx=-1, color= (255


    f += 1
    text = 'Frame:' + str(f)
    cv.putText(frame,text , (100, 50), cv.FONT_HERSHEY_COMPLEX, 1, (0,0,255), 1, cv.LIN
    cv.putText(frame, "Matches in current frame:"+ str(matches) , (100, 100), cv.FONT_H
    cv.putText(frame, "Total matches:"+ str(tot_matches) , (100, 150), cv.FONT_HERSHEY_
    frame_array.append(frame)


cap.release()


shape = (1080, 1920, 3)

# Your code here


out = cv.VideoWriter('./conveyor_result_190443T.mp4',cv.VideoWriter_fourcc(*'h264'), 30

for i in range(len(frame_array)):
    cv.imshow('Frame', frame_array[i])
    if cv.waitKey(1) == ord('q'):
        break
    out.write(frame_array[i])

out.release()
cv.destroyAllWindows()
```

```
Can't receive frame (stream end?). Exiting.
```

In [ ]:

```
hexnut_template = cv.imread('hexnut_template.png', cv.IMREAD_COLOR)

conveyor_f100 =  cv.imread('conveyor_f100.png', cv.IMREAD_COLOR)
conveyor_f101 =  cv.imread('conveyor_f101.png', cv.IMREAD_COLOR)

hexnut_gray = cv.cvtColor(hexnut_template, cv.COLOR_RGB2GRAY)
conveyor100_gray = cv.cvtColor(conveyor_f100, cv.COLOR_RGB2GRAY)
conveyor101_gray = cv.cvtColor(conveyor_f101, cv.COLOR_RGB2GRAY)
```

```
ret1,th1 = cv.threshold(hexnut_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
ret2,th2 = cv.threshold(conveyor100_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)
ret3,th3 = cv.threshold(conveyor101_gray ,0,255,cv.THRESH_BINARY+cv.THRESH_OTSU)

hexnut_closed = cv.morphologyEx(th1, cv.MORPH_CLOSE, kernel)
conveyor100_closed = cv.morphologyEx(th2, cv.MORPH_CLOSE, kernel)
conveyor101_closed = cv.morphologyEx(th3, cv.MORPH_CLOSE, kernel)

connectivity = 4
# Perform the operation
invert = cv.bitwise_not(conveyor101_closed)
output = cv.connectedComponentsWithStats(invert , connectivity, cv.CV_32S)
# Get the results
# The first cell is the number of labels
num_labels = output[0]
# The second cell is the label matrix
labels = output[1]
# The third cell is the stat matrix
stats = output[2]
# The fourth cell is the centroid matrix
centroids = output[3]

for i in range(num_labels):
    x = stats[i, cv.CC_STAT_LEFT]
    y = stats[i, cv.CC_STAT_TOP]
    w = stats[i, cv.CC_STAT_WIDTH]
    h = stats[i, cv.CC_STAT_HEIGHT]
    area = stats[i, cv.CC_STAT_AREA]
    (cX, cY) = centroids[i]
    print("area:", area, " ", "(cx,cy) = ", (cX, cY))
```

```
area: 2059670   (cx,cy) =  (957.4336937470566, 540.4427194647686)
area: 4628   (cx,cy) =  (1489.2411408815904, 199.28435609334485)
area: 3083   (cx,cy) =  (1289.1819656179046, 399.18196561790467)
area: 3083   (cx,cy) =  (1489.1819656179046, 499.18196561790467)
area: 3136   (cx,cy) =  (690.0, 600.0)
```

In [ ]: