Assignment A05: Object Counting on a Convey Belt

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1 Introduction

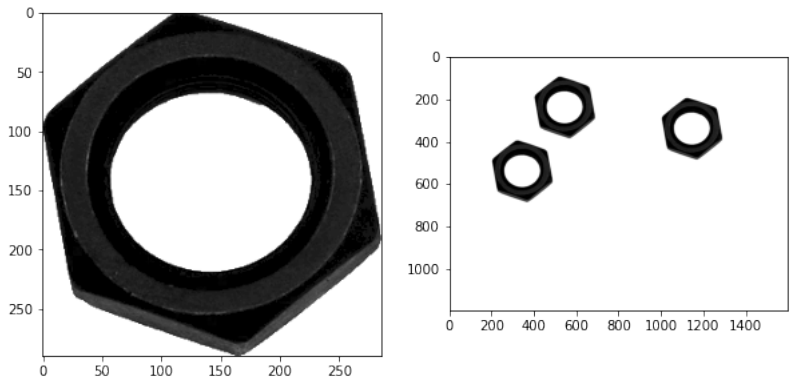
In this assignment, we will be counting and tracking the hexagonal nuts on a moving convey belt.

1.1 Import required libraries

[1]:
```
import cv2 as cv
import numpy as np
import matplotlib.pyplot as plt
# magic commands
%config IPCompleter.greedy=True
%config Completer.use_jedi = False
%matplotlib inline
```

1.2 Load and visualize the template image and the convey belt snapshot at a given time

[2]:
```
template_im = cv.imread(r'template.png', cv.IMREAD_GRAYSCALE)
belt_im =  cv.imread(r'belt.png', cv.IMREAD_GRAYSCALE)

fig, ax = plt.subplots(1,2,figsize=(10,10))
ax[0].imshow(template_im, cmap='gray')
ax[1].imshow(belt_im, cmap='gray')
plt.show()
```



2 Part - I

2.1 Otsu's thresholding

Otsu's method avoids having to choose a value and determines an optimal global threshold value from the image histogram automatically. It is returned as the first output.

[3]:
```
th_t, img_t = cv.threshold(template_im,0,255,cv.THRESH_BINARY_INV+cv.THRESH_OTSU)
th_b, img_b = cv.threshold(belt_im,0,255,cv.THRESH_BINARY_INV+cv.THRESH_OTSU)
```

2.2 Morphological closing

Carrying out morphological closing to remove small holes inside the foreground. Use a 3×3 kernel. Morphological closing is just dilation followed by erosion.

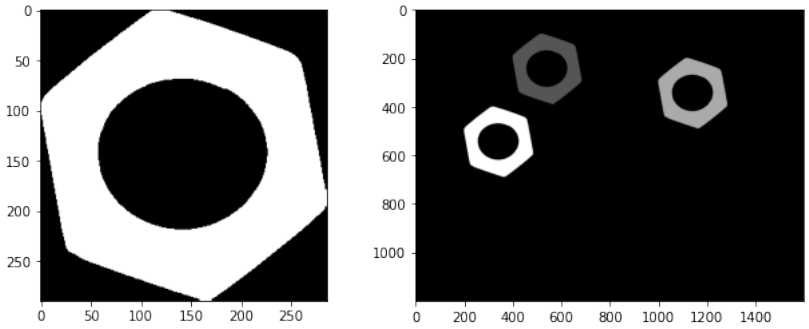
1. **Dilation**: a pixel element is '1' if atleast one pixel under the kernel is '1'. So it increases the white region
2. **Erosion**: a pixel element is '1' if all the pixel under the kernel is '1'. So it decreases the white region

[4]:
```
# 3x3 matrix with all ones, with uint8 dtype
kernel = cv.getStructuringElement(cv.MORPH_RECT, (3,3))
closing_t = cv.morphologyEx(img_t, cv.MORPH_CLOSE, kernel) # Dilation followed by Erosion
closing_b = cv.morphologyEx(img_b, cv.MORPH_CLOSE, kernel) # Dilation followed by Erosion
```

2.3 Connected component analysis

Apply the `cv.connectedComponentsWithStats` function

[5]:
```
retval_t, labels_t, stats_t, centroids_t = cv.connectedComponentsWithStats(closing_t)
retval_b, labels_b, stats_b, centroids_b = cv.connectedComponentsWithStats(closing_b)

def cca_stats(img_name, retval, labels, stats, centroids):
    print(img_name.center(50,"="))
    print("Number of labels: ", retval)
    plt.imshow(labels.astype('uint8'), cmap ='gray'); plt.show()
    print("Stats: \n", stats,'\n') # stats[label,cv.CC_STAT_quantity])
    print("Centroids: \n", centroids,'\n')

cca_stats("Template Image", retval_t, labels_t, stats_t, centroids_t)
cca_stats("Belt Image", retval_b, labels_b, stats_b, centroids_b)
```



(a) Template Image (b) Belt Image

```
==================Template Image==================
Number of labels:  2

Stats:
 [[    0     0   286   290 42290]
 [    0     0   286   290 40650]]

Centroids:
 [[142.18770395 145.19172381]
 [142.82489545 143.780369  ]]

====================Belt Image====================
Number of labels:  4

Stats:
 [[      0       0    1600    1200 1798161]
 [    400     100     286     290   40613]
 [   1000     200     286     290   40613]
 [    200     400     286     290   40613]]

Centroids:
 [[ 807.85728475  614.56805258]
 [ 542.82567158  243.78479797]
```

```
[1142.82567158  343.78479797]
[ 342.82567158  543.78479797]]
```

1. How many connected components are detected in each image?
   Template Image = 2 (*including background*)
   Belt Image = 4 (*including background*)

2. What are the statistics? Interpret these statistics.
   Statistics are properties related to each connected component. Statistics object is a 2D array where each column represent a different quantity related to a given connected component as described below.

   - **Column 1:** *cv.CC_STAT_LEFT*: the leftmost (x) coordinate which is the inclusive start of the bounding box in the horizontal direction.
   - **Column 2:** *cv.CC_STAT_TOP*: the topmost (y) coordinate which is the inclusive start of the bounding box in the vertical direction.
   - **Column 3:** *cv.CC_STAT_WIDTH*: the horizontal size of the bounding box.
   - **Column 4:** *cv.CC_STAT_HEIGHT*: the vertical size of the bounding box.
   - **Column 5:** *cv.CC_STAT_AREA*: the total area (in pixels) of the connected component.

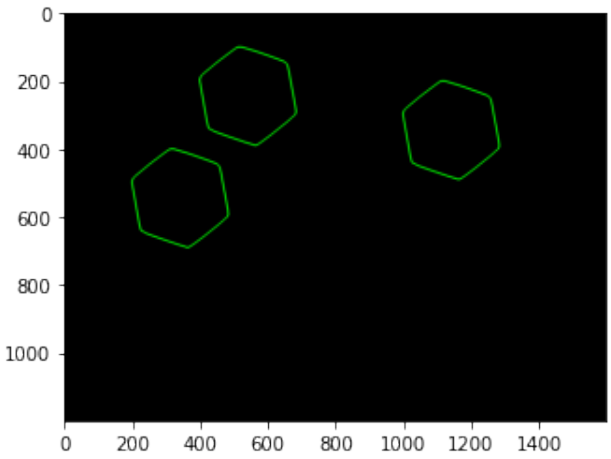
3. What are the centroids?
   Each row of the 2D `Cenroids` obejct represents the (x,y) coordinates of centroid of the corresponding connected component.

2.4 Contour analysis

Use `cv.findContours` function to retrieve the *extreme outer* contours.

The functions output contours is a Python list of all the contours in the image. Each individual contour is a Numpy array of (x,y) coordinates of boundary points of the object. Display these countours.

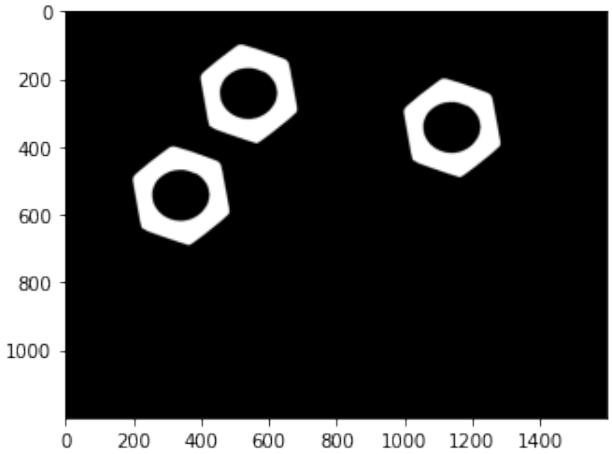
[6]:
```
# cv.RETR_EXTERNAL retrieve only the extreme outer contours
contours_t,_ = cv.findContours(closing_t, cv.RETR_EXTERNAL, cv.CHAIN_APPROX_SIMPLE)
contours_b,_ = cv.findContours(closing_b, cv.RETR_EXTERNAL, cv.CHAIN_APPROX_SIMPLE)

# Visualizing contours (-1 argument to plot all the contours)
im_contours_belt = np.zeros((belt_im.shape[0],belt_im.shape[1],3), np.uint8)
conts = cv.drawContours(im_contours_belt, contours_b, -1, (0,255,0), 3).astype('uint8')
plt.imshow(conts), plt.show()
```



2.5 Count the number of matching hexagonal nuts in `belt.png`.

`cv.matchShapes` function enables us to compare two shapes, or two contours and returns a metric showing the similarity. The lower the result, the better match it is. `retval=cv.matchShapes(contour1, contour2, method, parameter)`

[7]:
```
label = 1 # remember that the label of the background is 0
belt = ((labels_b >= label)*255).astype('uint8')
plt.imshow(belt, cmap ='gray'),plt.show()
belt_cont,_ = cv.findContours(belt, cv.RETR_EXTERNAL, cv.CHAIN_APPROX_SIMPLE)
for j,c in enumerate(belt_cont):
        print("Contour ", j +1,"-->", cv.matchShapes(contours_t[0], c, cv.
 ↪CONTOURS_MATCH_I1, 0.0))
```




```
Contour  1 --> 0.00010071698397173812
Contour  2 --> 0.00010071698397950968
Contour  3 --> 0.00010071698397506879
```

3 Part - II

3.1 Frame tracking through image moments.

Use the `cv.contourArea()` to calculate the the area of the `contours_b[1]`

[8]:
```
ca = cv.contourArea(contours_b[1])
print(ca)
```

```
60059.5
```

Use the `cv.moments` to extract the x and y coordinates of the centroid of `contours_b[1]`.

[9]:
```
M = cv.moments(contours_b[1])
print("Area = ", M['m00'])

cx, cy = int(M['m10']/M['m00']), int(M['m01']/M['m00'])
print("Centroid = ({}, {})".format(cx,cy))
```

```
Area =  60059.5
Centroid = (1142, 343)
```

Make a variable called `count` to represent the number of contours and set it to the value 1. Make an np array [cx, cy, ca, count] and name this as `object_prev_frame`.

[10]:
```
count = 1
object_prev_frame = np.array([cx, cy, ca, count])
```

Similarly, you can create the `object_curr_frame`(to describe the current values) and define the threshold `delta_x` to check whether the corresponding element of both the `object_curr_frame` and `object_prev_frame` are less than the `delta_x`. You can set `delta_x` as 15 or so. (Here the `delta_x` can be thought of as the movement of the cx from frame to frame)

[11]:
```
delta_x = 15
```

4 Part - III

4.1 1. Implement the function `get_indexed_image`, which takes an image as the input, performs thresholding, closing, and connected component analysis and return retval, labels, stats, centroids. (Grading)

[12]:
```
def get_indexed_image(im):
    """ Thresholding, closing, and connected component analysis lumped
    """

    _, img = cv.threshold(im,0,255,cv.THRESH_BINARY_INV+cv.THRESH_OTSU)
    kernel = cv.getStructuringElement(cv.MORPH_RECT, (3,3))
    closing = cv.morphologyEx(img, cv.MORPH_CLOSE, kernel) # Dilation followed by Erosion
    retval, labels, stats, centroids = cv.connectedComponentsWithStats(closing)

    return retval, labels, stats, centroids
```

4.2 2. Implement the function `is_new`, which checks the dissimilarity between 2 vectors. (Grading)

[13]:
```
def is_new(a, b, delta, i):
    """ Vector Dissimilarity with an Array of Vectors
    Checks if vector b is similar to a one or more vectors in a outside the tolerances␣
↪specified in delta.
    vector i specifies which elements in b to compare with those in a.
    """

    absolute_different = np.abs(a - b) # getting the absolute differences
    states = [] # arry to store result of each column
    for element in i:
        # compare each value in ith column with the specified delta
        absolute_different[:,element] = (absolute_different[:,element] > delta[element])
        # check whether the condition is true for all the values in that column
        states.append(absolute_different[:,element].all())

    'Check whether the absolute different between all the elements of ith column of each␣
↪array is greater than the ith delta value (See thee example in the next cell)'
    # summarize the results of each column to get the final result.
    state = np.array(states).all()

    return state
```

[14]:
```
# check is_new  expected answer False
a = np.array([[1.36100e+03, 5.53000e+02, 5.99245e+04, 2.00000e+00],
              [7.61000e+02, 4.53000e+02, 5.99385e+04, 1.00000e+00],
              [1.55200e+03, 2.43000e+02, 6.00585e+04, 3.00000e+00]])

b = np.array( [7.51000e+02, 4.53000e+02, 5.99385e+04, 3.00000e+00])
delta = np.array([delta_x])
i = np.array([0])

assert is_new(a, b, delta, i) == False, " Check the function "
```

4.3 3. If the array a is in the shape of (number of nuts , len(object_prev_frame)) (i.e. array a is made by stacking all the object_prev_frame for each frame. If b is in the form of [cx, cy, ca, count], write the function prev_index to find the index of a particular nut in the previous frame. (Grading)

[15]:
```
def prev_index(a, b, delta, i):
    """ Returns Previous Index
    Returns the index of the apppearance of the object in the previous frame.
    (See thee example in the next cell)
    """
    index = -1
    absolute_different = np.absolute(a - b)
    matching_rows = []
    for element in i:
        absolute_different[:,element] = (absolute_different[:,element] <= delta[element])
        # find the row where the above condition is true.
        matching_row = np.where(absolute_different[:,element])[0]
        matching_rows.append(matching_row)

    # get the best match out of all the matches
    values, counts = np.unique(matching_rows, return_counts=True)
    best_match = values[np.argmax(counts)]

    matching_nut = a[best_match]
    index = matching_nut[-1] # since count keeps the index of a nut.

    return index
```

[16]:
```
# check prev_index  expected answer 1
a = np.array([[1.36100e+03, 5.53000e+02, 5.99245e+04, 2.00000e+00],
              [7.61000e+02, 4.53000e+02, 5.99385e+04, 1.00000e+00],
              [1.55200e+03, 2.43000e+02, 6.00585e+04, 3.00000e+00]])

b = np.array( [7.51000e+02, 4.53000e+02, 5.99385e+04, 3.00000e+00])
delta = np.array([delta_x])
i = np.array([0])

assert prev_index(a,b,delta,i) == 1, " Check the function "
```

4.4 Access video frames

You can use following code snippet load and access each frame of a video

[17]:
```
color_frames = [] # list to store RGB frames

cap = cv.VideoCapture('conveyor_with_rotation.mp4') # give the correct path here
while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        print("Can't receive frame (stream end?). Exiting ...")
        break
    color_frames.append(frame)
    cv.imshow("Frame", frame)
    if cv.waitKey(1) == ord('q'):
        break

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

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

5 Implement a code to detect hexagonal nuts in a moving convey belt. (Grading)

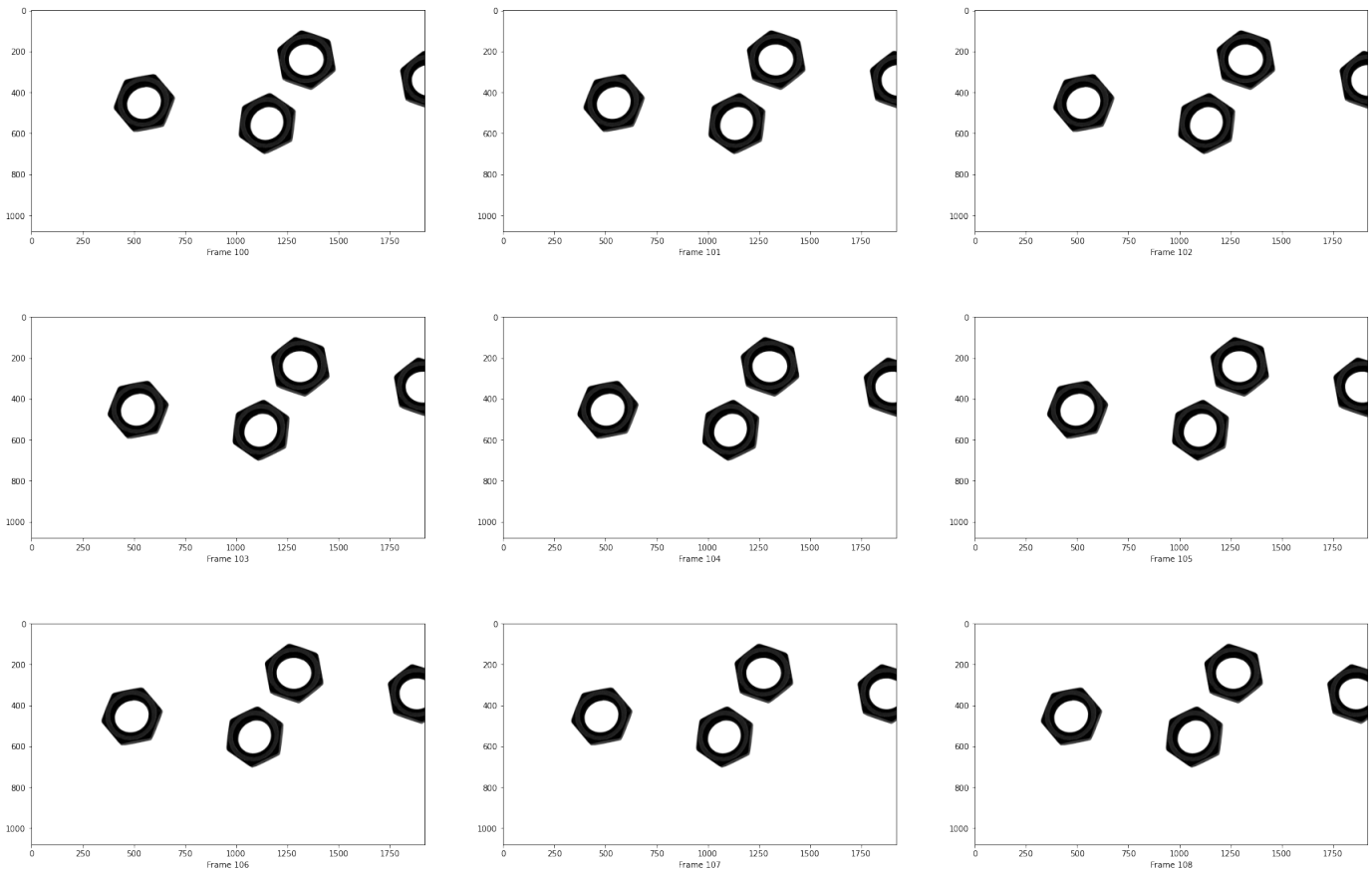
1. Use the above code snippet to access each frame and remember to convert the frame into grey scale. Name the variable as `grey`
2. Call `get_indexed_image` and extract `retval, labels, stats, centroids`.
3. Find contours of all nuts present in a given frame of the belt.
4. Initiate a 3-D array with zeros to draw contours. Call this `im_contours_belt`
5. Draw each contour. Use `cv.drawContours`. See this

5.1 Accessing each frame and convert them into gray scale

[18]:
```
gray_frames = []  # list to store Gray Scale frames
cap = cv.VideoCapture('conveyor_with_rotation.mp4') # give the correct path here
print("Video capturing is in progress...")
while cap.isOpened():
    ret, frame = cap.read()
    if not ret:
        print("Can't receive frame (stream end?). Exiting ...")
        break
    frame = cv.cvtColor(frame, cv.COLOR_BGR2GRAY) # convert to grayscale
    gray_frames.append(frame) # store the grayscale frame images

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

cap.release()
cv.destroyAllWindows()
print("Video capturing completed.")
```

```
Video capturing is in progress...
Can't receive frame (stream end?). Exiting ...
Video capturing completed.
```

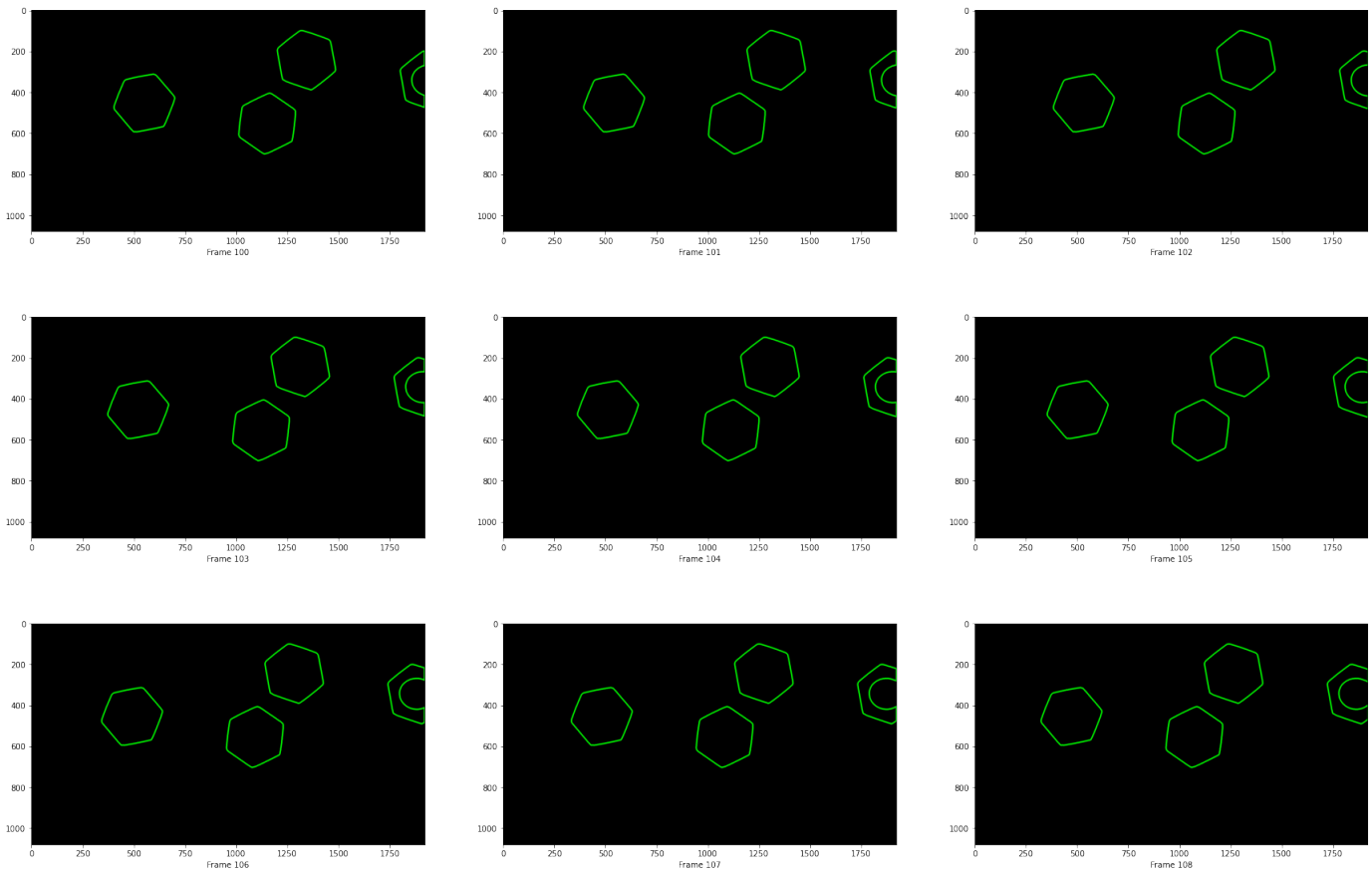
[19]:
```
# visualizing some of the captured frames
plt.figure(figsize=(30,20))
for i in range(9):
    plt.subplot(3,3,i+1)
    plt.imshow(gray_frames[100 +i], cmap ='gray')
    plt.xlabel("Frame " + str(100 +i))
plt.show()
```



5.2 Finding contours of all connected components in a given frame

[20]:
```
# Find contours of all nuts present in a given frame of the belt
contour_plots = []
contours_list = []
for gray in gray_frames:
    # finding contours
    _, labels, _, _ = get_indexed_image(gray) # Conn: Comp: Analysis
    belt = ((labels >= 1)*255).astype('uint8')
    contours,_  = cv.findContours(belt, cv.RETR_EXTERNAL, cv.CHAIN_APPROX_SIMPLE)
    contours_list.append(contours)
    # plotting contours
    im_contours_belt = np.zeros((belt.shape[0],belt.shape[1],3), np.uint8)
    cont_plot = cv.drawContours(im_contours_belt, contours, -1, (0,255,0), 5).
↪astype('uint8')
    contour_plots.append(cont_plot)
```

[21]:
```
# visualizing some of the contour plots on frames
plt.figure(figsize=(30,20))
for i in range(9):
    plt.subplot(3,3,i+1)
    plt.imshow(contour_plots[100 +i])
    plt.xlabel("Frame " + str(100 +i))
plt.show()
```



6 Object detection and tracking

For each contour of the belt frame,

1. Use `is_new` and `prev_index` functions to track each frame and get the indices of each nut.
2. Write a code to detect and track hexagonal nuts in each frame.

Hint: *If you are thresholding on areas (template and contour) you can use 500 as the threshold. You can set the matching threshold to be 0.5 and experiment.*

6.1 Extracting details about each contour in each frame

[22]:
```
# frame tracking through image moments
# extracting details about each contour in each frame
video = []
print("Details extraction is in progress...")
for gray in gray_frames:
    # finding contours
    _, labels, _, _ = get_indexed_image(gray)
    belt = ((labels >= 1)*255).astype('uint8')
    contours,_  = cv.findContours(belt, cv.RETR_EXTERNAL, cv.CHAIN_APPROX_SIMPLE)

    count = 0 # number of nuts in a given frame
    frame = []

    for contour in contours:
        metric = cv.matchShapes(contours_t[0], contour, cv.CONTOURS_MATCH_I1, 0.0)
        # Set the matching threshold to be 0.5
        if metric <= 0.5: # if only a complete hexagonal nut
            count +=1
            M  = cv.moments(contour)
            ca = M['m00']
            cx, cy = int(M['m10']/M['m00']), int(M['m01']/M['m00'])
            frame.append(np.array([cx, cy, ca, count]))

    video.append(frame)
print("Details extraction completed.")
```

```
Details extraction is in progress...
Details extraction completed.
```

6.2 Nut counter Implementation

[23]:
```
# Nut counter Implementation
# last element keeps the number of nuts in a given frame.
# Therefore, initial number of nuts is as follows.
total_nuts = int(video[0][-1][-1])
print("Number of nuts in the zeroth frame: ",total_nuts)

delta_x = np.array([15])
i = np.array([0])

prev_frame = video[0] # Reference frame to compare with the upcoming frame

for frame_num in range(1, len(video)):
    current_frame = video[frame_num] # frame to be compared

    for nut in current_frame:
        # Checking the current nut with previous frame
        # if it is a new nut count it.
        if is_new(prev_frame, nut, delta_x, i):
            total_nuts +=1

    prev_frame = current_frame

print("Total number of nuts found: ",total_nuts)
```

```
Number of nuts in the zeroth frame:  1
Total number of nuts found:  5
```

6.3 Tracking nuts: An extension of the previous nut counting algorithm

[24]:
```
# trackig nuts: An extension of the previous counting nuts algorithm
print("Detection and indexing is in progress...")
total_nuts = int(video[0][-1][-1]) #initial number of nuts in frame 0
delta_x = np.array([15])
i = np.array([0])
prev_frame = video[0] # Reference frame to compare with the upcoming frame

for frame_num in range(1, len(video)):
    current_frame = video[frame_num] # frame to be compared

    for nut in current_frame:
        # Checking the current nut with previous frame
        # if it is a new nut count it and assign a new index
        if is_new(prev_frame, nut, delta_x, i):
            total_nuts +=1
            nut[-1] = total_nuts # assignment of a new index

        else:
            # to be tracked the nut must not be a new nut
            nut_index = prev_index(prev_frame, nut, delta_x, i)
            nut[-1] = nut_index # assign the same index it had previously, for old nuts

    prev_frame = current_frame
print("Detection and indexing completed.")
```

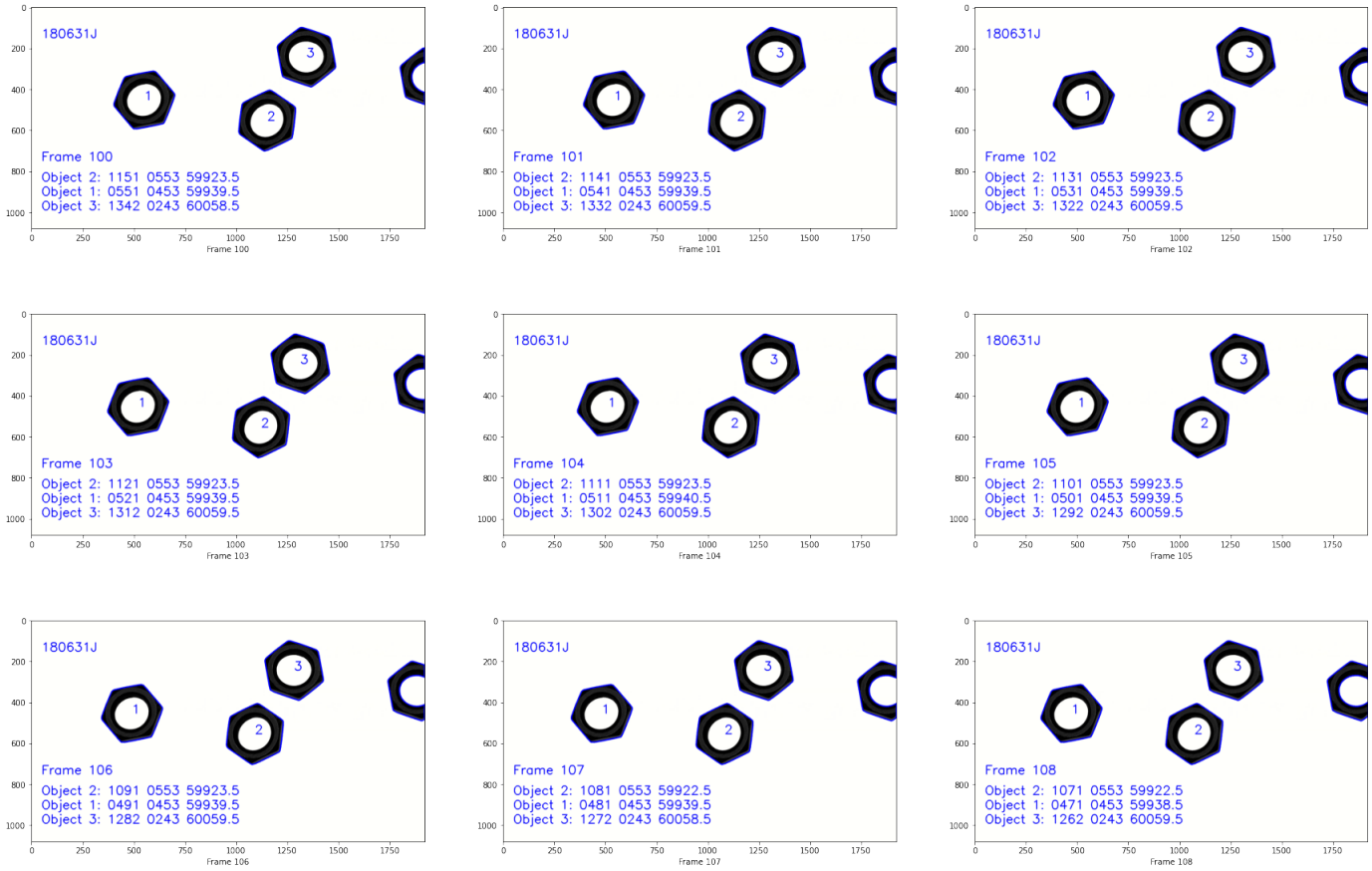
```
Detection and indexing is in progress...
Detection and indexing completed.
```

6.4 Frame annotation with the extracted details

[25]:
```
# frame annotation with the extracted details

annotated_frames =[]
frame_num = 0
print("Frame annotation is in progress...")
for frame, color_frame, contours in zip(video, color_frames, contours_list):

    # Annotation was done on the frames of the original video
    img = color_frame
    y = 0 # to change the vertical position of 'object details' of a frame

    for nut in frame:
        # Annotate the nut index
        img = cv.putText(img, str(int(nut[-1])),\
                (int(nut[0]),int(nut[1])),cv.FONT_HERSHEY_SIMPLEX, 2, (255,0,0), 4)
        # Annotate the nut(object) details
        img = cv.putText(img, "Object {}: {:04} {:04} {:05}".format(int(nut[-1]),␣
 ↪int(nut[0]), int(nut[1]), nut[2]),\
                         (50,850 + 70*y), cv.FONT_HERSHEY_SIMPLEX, 2, (255,0,0), 4)

        y +=1 # change vertical position for next object details annotation.

    # Annotation of the frame number and draw the extracted contours
    img = cv.putText(img, "Frame "+str(frame_num) , (50,750) , cv.FONT_HERSHEY_SIMPLEX, 2,␣
 ↪(255,0,0), 3)
    img = cv.drawContours(img, contours, -1, (255,0,0), 5).astype('uint8')

    # Index number 180631J
    img = cv.putText(img, "180631J" , (50,150) , cv.FONT_HERSHEY_SIMPLEX, 2, (255,0,0), 3)
    annotated_frames.append(img)
    frame_num +=1
print("Frame annotation completed.")
```

```
Frame annotation is in progress...
Frame annotation completed.
```

[26]:
```
# visulaizing some annotated frames
plt.figure(figsize=(30,20))
for i in range(9):
    plt.subplot(3,3,i+1)
    plt.imshow(annotated_frames[100 +i][:,:,::-1])
    plt.xlabel("Frame " + str(100 +i))
plt.show()
```



6.5 Save the frames as a video

[27]:
```
# Defining necessary parameters for video write

output = '180631j_en2550_a05.mp4' # Name of the output video file.
fourcc = cv.VideoWriter_fourcc(*'MP4V') # 4-character code of codec used to compress the␣
 ↪frames
duration = 9 # duration of the source video
fps = int(len(annotated_frames)/duration) # Framerate of the created video stream
height, width,_ = annotated_frames[0].shape
frame_size = (width, height)
isColor = True # to write color images to the video
print('Frame Size(WxH) :', frame_size ,'\nFrames Per Second :', fps)

# Creating the Video Writer object
out = cv.VideoWriter(output, fourcc, fps, frame_size, isColor)
print("Video writer in progress...")
for frame in annotated_frames:
    out.write(frame)

# Release everything if job is finished
out.release()
print("Video writing completed.")
```

```
Frame Size(WxH) : (1920, 1080)
Frames Per Second : 31
Video writer in progress...
Video writing completed.
```

– Executable code can be found on GitHub –