CS585 Problem Set 2 (Total points: 40)

Assignment adapted from Margrit Betke and Saraubh Gupta

Instructions

1. Assignment is due at **5 PM on Tuesday Feb 15 2022**.

2. Submission instructions:

   A. A single `.pdf` report that contains your work for Q1, Q2 and Q3. For Q1 and Q2 you can either type out your responses in LaTeX, or any other word processing software. You can also hand write them on a tablet, or scan in hand-written answers. If you hand-write, please make sure they are neat and legible. If you are scanning, make sure that the scans are legible. Lastly, convert your work into a `PDF`.

   For Q3 your response should be electronic (no handwritten responses allowed). You should respond to the questions 3.1, 3.2 and 3.3 individually and include images as necessary. Your response to Q3 in the PDF report should be self-contained. It should include all the output you want us to look at. You will not receive credit for any results you have obtained, but failed to include directly in the PDF report file.

   PDF file should be submitted to Gradescope under `PS2`. Please tag the reponses in your PDF with the Gradescope questions outline as described in Submitting an Assignment.

   B. You also need to submit code for Q3 in the form of a single `.zip` file that includes all your code, all in the same directory. You can submit Python code in `.ipynb` format. Code should also be submitted to Gradescope under `PS2-Code`. *Not submitting your code will lead to a loss of 100% of the points on Q3.*

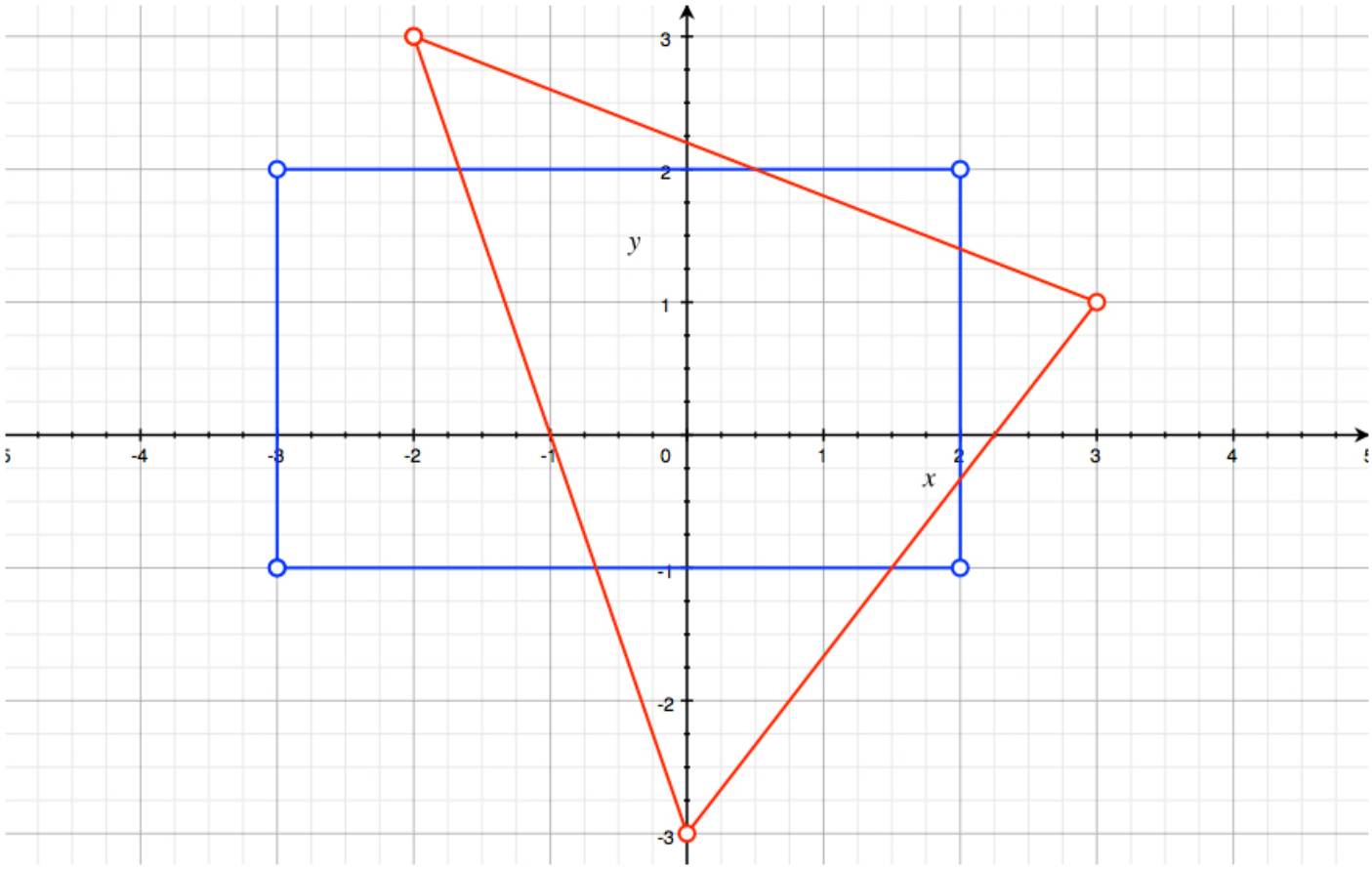
   C. We reserve the right to take off points for not following submission instructions. In particular, please tag the reponses in your PDF with the Gradescope questions outline as described in Submitting an Assignment.

Problems

1. **Hausdorff Distance [10 pts total, 2 parts].**

   There are two shapes in the figure below. The triangle in red has three vertices: A(-2,3), B(3,1), and C(0,-3). The rectangle in blue has four vertices: D(-3,2), E(2,2), F(2,-1), and G(-3, -1).

In [1]:
```
from PIL import Image
from IPython.display import display
display(Image.open('hausdorff.jpg'))
```



1. **Distance between point sets [3 pts]** Consider two point sets S1 and S2, where S1={A, B, C} and S2={D, E, F, G}. Calculate the Hausdorff distance between these two point sets.

2. **Distance between shapes [7 pts]** Now consider all the points forming these two polygons. What's the Hausdorff distance between the triangle and the rectangle?

1.1 Distance Between point sets

In [2]:

```
import numpy as np

A = (-2,3)
B = (3, 1)
C = (0, -3)
D = (-3, 2)
E = (2, 2)
F = (2, -1)
G = (-3, -1)

triangle = [A,B,C]
rectangle = [D,E,F,G]

def distance_euclidean(a,b):
    return np.sqrt((a[0]-b[0])**2 + (a[1] - b[1])**2)

def hausdorff_euclid(set1, set2):
    distance12 = 0
    for i in set1:
        min = float('inf')
        for j in set2:
            current_d = distance_euclidean(j,i)
            if current_d < min:
                min = current_d
        if min > distance12:
            distance12 = min
    distance21 = 0
    for i in set2:
        min = float('inf')
        for j in set1:
            current_d = distance_euclidean(j,i)
            if current_d < min:
```

```
                min = current_d
        if min > distance21:
            distance21 = min

    return max(distance12,distance21)

print('Distance Hausdorff(S1, S2):', hausdorff_euclid(triangle, rectangle))
```

```
Distance Hausdorff(S1, S2): 3.605551275463989
```

This is the distance from G to C: $\sqrt{3^2+2^2} = \sqrt{13}$

1.2 Distance between polygons:

Hausdorff(triangle, rectangle)

max {min H(A, rectangle), min H(B, rectangle), min H(C, rectangle)} = min H(C, rectangle) = MAX1 = 2

max {min H(D, triangle), min H(E, triangle), min H(F, triangle), min H(G, triangle)} = min H(G, triangle) = MAX2 = $\frac{7}{\sqrt{10}}$

Distance Hausdorff = max(MAX1, MAX2) = $\frac{7}{\sqrt{10}}$

Note: I applied the formular for a point to a line from this website: https://tinyurl.com/2pv454yr

Distance to a line and between 2 lines

Let's look at couple examples in 2D space. To calculate the distance between **a point and a straight line** we could go step by step (calculate the segment perpendicular to the line from the line to the point and the compute its length) or we could simply use this 'handy-dandy' equation: $d = |Ax_1 + By_1 + C| / \sqrt{(A^2 + B^2)}$ where the line is given by $Ax+By+C = 0$ and the point is defined by (x_1, y_1).

The only problem here is that a straight line is generally given as $y = mx + b$ so we would need to convert this equation to the previously show form: $y = mx + b \rightarrow mx - y + b = 0$ so we can see that $A = m$, $B = -1$ and $C = b$. This leaves the previous equation with the following values: $d = |mx_1 - y_1 + b| / \sqrt{(m^2 + 1)}$.

1. **Segmentation [10 pts].** The following tables include all the local maxima and local minima of the grayscale histogram of an image.

Table 1: Local Maxima

Gray Values	52	54	103	231
# of Pixels	1000	1170	1750	1300

Table 2: Local Minima

Gray Values	0	53	75	157	255
# of Pixels	500	590	240	190	310

Calculate the highest peakiness and the corresponding threshold using Mode Method.

$p(52, 54, 53) = \frac{[min(H(g_0), H(g_1))]}{H(g_k)} = \frac{1000}{590} = 1.7$

$p(54, 103, 75) = \frac{min(1170, 1750)}{240} = 4.875$

$p(103, 231, 157) = \frac{min(1750,1300)}{190} = 6.842$

Highest peakiness is 6.842 and threshhold is 190

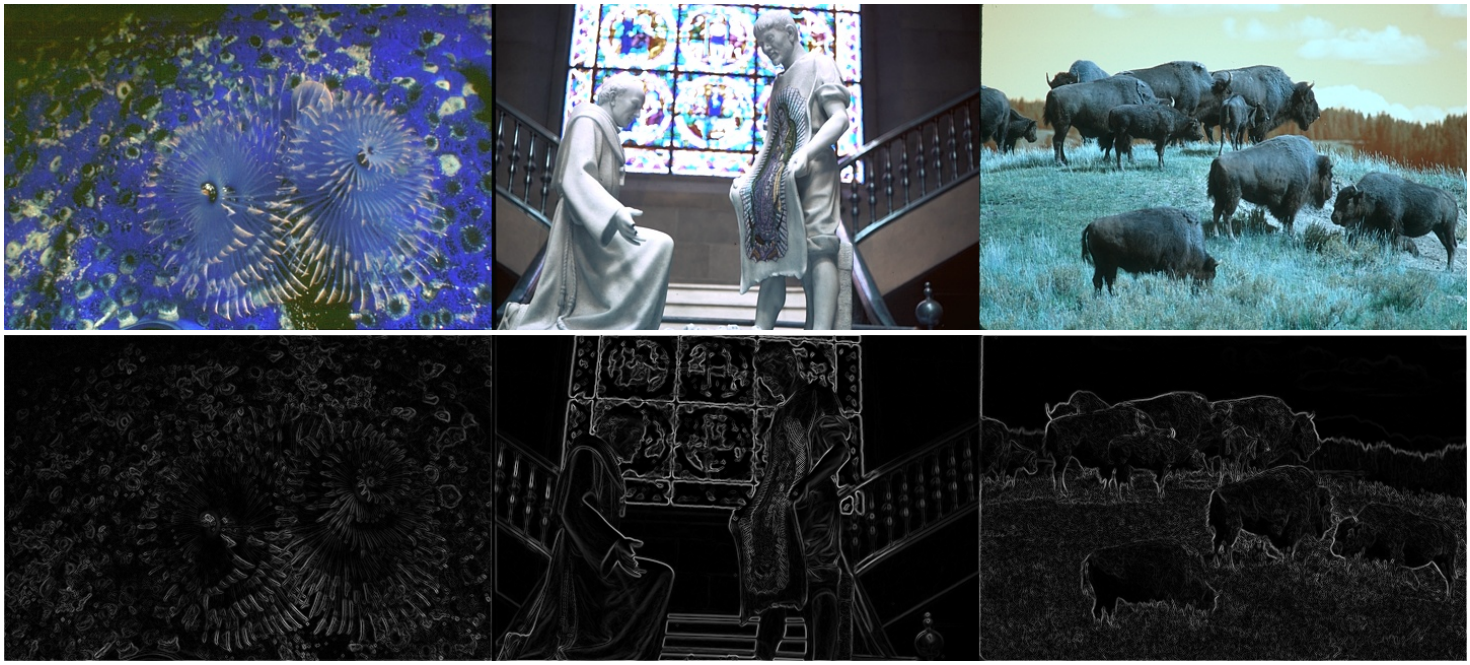
1. **Contour Detection [20 pts]**. In this problem we will build a basic contour detector.

   We have implemented a contour detector that uses the magnitude of the local image gradient as the boundary score as seen below:

In [62]:

```
from PIL import Image
import numpy as np
import cv2, os, glob
from scipy.io import loadmat
from scipy import signal
import evaluate_boundaries


N_THRESHOLDS = 99

def detect_edges(imlist, fn):
    images, edges = [], []
    for imname in imlist:
        I = cv2.imread(os.path.join('data', str(imname)+'.jpg'))
        images.append(I)
        I = cv2.cvtColor(I, cv2.COLOR_BGR2GRAY)
        I = I.astype(np.float32)/255.
        mag = fn(I)
        edges.append(mag)
    return images, edges

def evaluate(imlist, all_predictions):
    count_r_overall = np.zeros((N_THRESHOLDS,))
    sum_r_overall = np.zeros((N_THRESHOLDS,))
    count_p_overall = np.zeros((N_THRESHOLDS,))
    sum_p_overall = np.zeros((N_THRESHOLDS,))
    for imname, predictions in zip(imlist, all_predictions):
        gt = loadmat(os.path.join('data', str(imname)+'.mat'))['groundTruth']
        num_gts = gt.shape[1]
        gt = [gt[0,i]['Boundaries'][0,0] for i in range(num_gts)]
        count_r, sum_r, count_p, sum_p, used_thresholds = \
                  evaluate_boundaries.evaluate_boundaries_fast(predictions, gt,
                                                               thresholds=N_THRESHOLDS,
                                                               apply_thinning=True)
        count_r_overall += count_r
        sum_r_overall += sum_r
        count_p_overall += count_p
        sum_p_overall += sum_p

        rec_overall, prec_overall, f1_overall = evaluate_boundaries.compute_rec_prec_f1(
        count_r_overall, sum_r_overall, count_p_overall, sum_p_overall)

    return max(f1_overall)

def compute_edges_dxdy(I):
    """Returns the norm of dx and dy as the edge response function."""

    dx = signal.convolve2d(I, np.array([[-1, 0, 1]]), mode='same')
    dy = signal.convolve2d(I, np.array([[-1, 0, 1]]).T, mode='same')
    mag = np.sqrt(dx**2 + dy**2)
    mag = normalize(mag)
    return mag

def normalize(mag):
    mag = mag / 1.5
    mag = mag * 255.
    mag = np.clip(mag, 0, 255)
    mag = mag.astype(np.uint8)
    return mag


imlist = [12084, 24077, 38092]
fn = compute_edges_dxdy
images, edges = detect_edges(imlist, fn)
display(Image.fromarray(np.hstack(images)))
display(Image.fromarray(np.hstack(edges)))
```

```
f1 = evaluate(imlist, edges)
print('Overall F1 score:', f1)
```



```
Overall F1 score: 0.4163603293750655
```

1. **[5 pts] Warm-up.** As you visualize the produced edges, you will notice artifacts at image boundaries. Modify how the convolution is being done to minimize these artifacts.

In [63]:

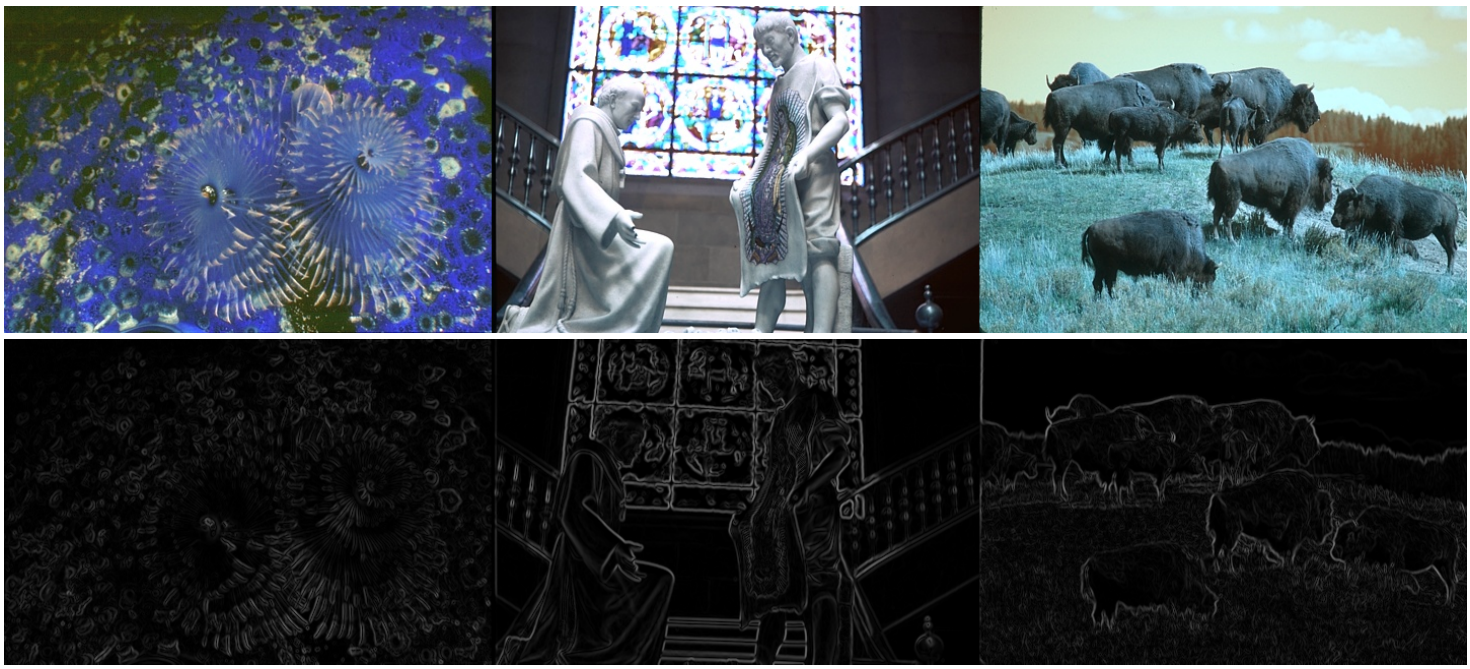
```
def compute_edges_dxdy_warmup(I):
    """Hint: Look at arguments for scipy.signal.convolve2d"""
    # ADD CODE HERE
    dx = signal.convolve2d(I, np.array([[-1, 0, 1]]), mode='same', boundary='symm')
    dy = signal.convolve2d(I, np.array([[-1, 0, 1]]).T, mode='same', boundary='symm')
    mag = np.sqrt(dx**2 + dy**2)
    mag = normalize(mag)
    return mag


imlist = [12084, 24077, 38092]
fn = compute_edges_dxdy_warmup
images, edges = detect_edges(imlist, fn)
display(Image.fromarray(np.hstack(images)))
display(Image.fromarray(np.hstack(edges)))
f1 = evaluate(imlist, edges)
print('Overall F1 score:', f1)
```

```
Overall F1 score: 0.4175307435125027
```

1. **[5 pts] Smoothing.** Next, notice that we are using [−1, 0, 1] filters for computing the gradients, and they are susceptible to noise. Use derivative of Gaussian filters to obtain more robust estimates of the gradient. Experiment with different sigma for this Gaussian filtering and pick the one that works the best.

In [64]:

```
def compute_edges_dxdy_smoothing(I):
    """ Copy over your response from part 3.1 and alter it
    to include this answer. See cv2.GaussianBlur"""
    # ADD CODE HERE
    I = cv2.GaussianBlur(I, (3,3),0.55,0.55, cv2.BORDER_DEFAULT)
    dx = signal.convolve2d(I, np.array([[-1, 0, 1]]), mode='same', boundary='symm')
    dy = signal.convolve2d(I, np.array([[-1, 0, 1]]).T, mode='same', boundary='symm')
    mag = np.sqrt(dx**2 + dy**2)
    mag = normalize(mag)

    return mag


imlist = [12084, 24077, 38092]
fn = compute_edges_dxdy_smoothing
images, edges = detect_edges(imlist, fn)
display(Image.fromarray(np.hstack(images)))
display(Image.fromarray(np.hstack(edges)))
f1 = evaluate(imlist, edges)
print('Overall F1 score:', f1)
```



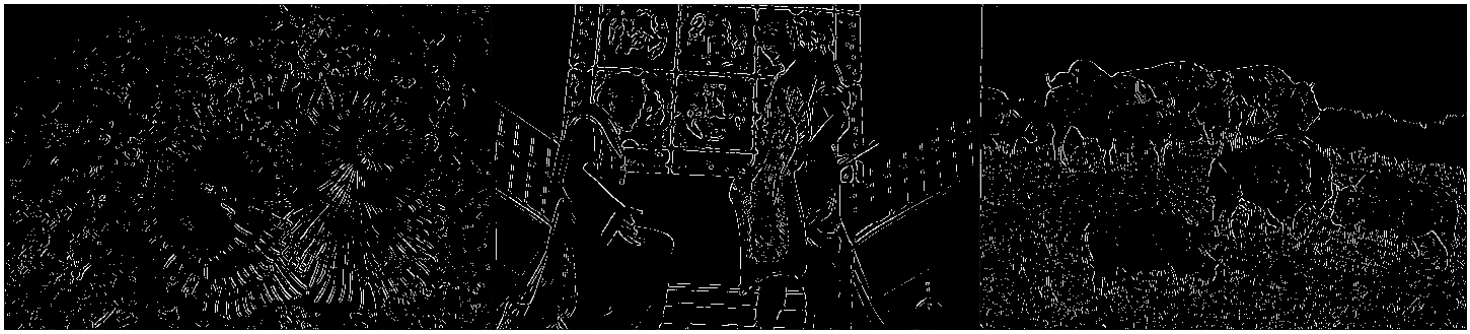
```
Overall F1 score: 0.42027528550437243
```

1. **[10 pts] Non-maximum Suppression.** The current code does not produce thin edges. Implement non-maximum suppression, where we look at the gradient magnitude at the two neighbours in the direction perpendicular to the edge. We suppress the output at the current pixel if the output at the current pixel is not more than at the neighbors. You will have to compute the orientation of the contour (using the X and Y gradients), and then lookup values at the neighbouring pixels.

In [143…

```
def compute_edges_dxdy_nonmax(I):
```

```
    """ Copy over your response from part 3.2 and alter it
    to include this response"""
    # ADD CODE  HERE
    I = cv2.GaussianBlur(I, (3,3),0.55,0.55, cv2.BORDER_DEFAULT)
    dx = signal.convolve2d(I, np.array([[-1, 0, 1]]), mode='same', boundary='symm')
    dy = signal.convolve2d(I, np.array([[-1, 0, 1]]).T, mode='same', boundary='symm')
    mag = np.sqrt(dx**2 + dy**2)
    mag = normalize(mag)


    threshold = 10
    row,column = mag.shape
    theta = np.arctan2(dx,dy)
    angle = theta * 180/np.pi
    angle[angle < 0] += 180
    #newMag = np.ones((row,column), dtype=np.int32)
    newMag = mag.copy()
    for i in range(1, row-1):
        for j in range(1, column-1):
            neighbor1 = 255
            neighbor2 = 255
            #angle 0 degree
            if (0 <= angle[i,j] < 22.5) or (157.5 <= angle[i,j] <= 180):
                neighbor1 = mag[i+1, j].copy()
                neighbor2 = mag[i-1, j].copy()

            #angle 45 degree
            elif (22.5 <= angle[i,j] < 67.5):
                neighbor1 = mag[i-1, j-1].copy()
                neighbor2 = mag[i+1, j+1].copy()

            #angle 90 degree
            elif (67.5 <= angle[i,j] < 112.5):
                neighbor1 = mag[i, j+1].copy()
                neighbor2 = mag[i, j-1].copy()

            #angle 135 degree
            elif (112.5 <= angle[i,j] < 157.5):
                neighbor1 = mag[i-1, j+1].copy()
                neighbor2 = mag[i+1, j-1].copy()

            if (mag[i,j] > neighbor1+threshold) and (mag[i,j] > neighbor2+threshold):
                newMag[i,j] = 255
            else:
                newMag[i,j] = 0

    return newMag


imlist = [12084, 24077, 38092]
fn = compute_edges_dxdy_nonmax
images, edges = detect_edges(imlist, fn)
display(Image.fromarray(np.hstack(images)))
display(Image.fromarray(np.hstack(edges)))
f1 = evaluate(imlist, edges)
print('Overall F1 score:', f1)
```



```
Overall F1 score: 0.5793920868757526
```

In [ ]: