2110431 Introduction to Digital Imaging

2147329 Digital Image Processing and Vision Systems

Homework #3

Deadline: November 21, 2023 @23:59

Submissions: (1) PDF version of this file ONLY problem 1 and 3 will be graded.

Submissions: (1) PDF version of this file

(2) .ipynb file; template in this link

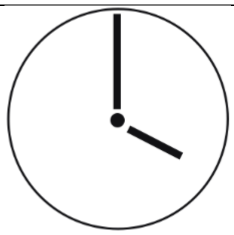
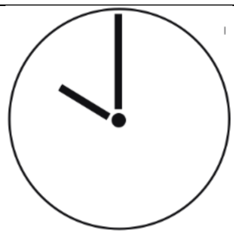
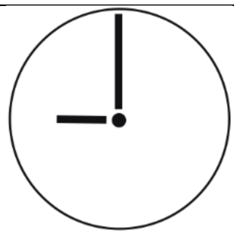
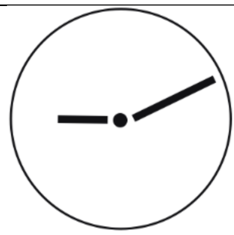
All images are in the hw3 folder.

IMPORTANT! (1) Before submitting the python file, please make sure it can be successfully compiled and correctly in its format name

(2) The scores will be 0 for all students whose source codes are very similar to each other.

1. (10 points) Reading a (very) simple clock

Use image processing to read a simple clock provided below and write a program using python library to provide output in the format displayed "HH:MM", such as "04:00" for the most left clock, "10:00" for the second clock, and so on. (HH in the range [01,12], MM in [00,59])

			
04:00	10:00	09:00	09:10

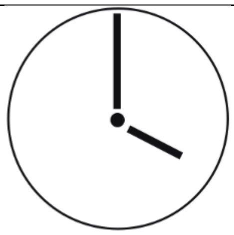
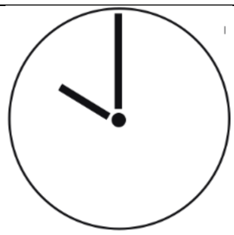
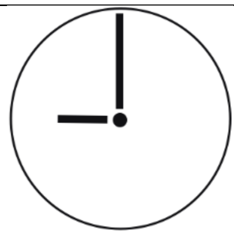
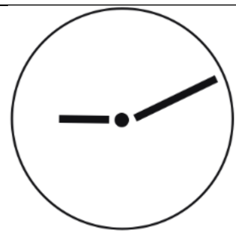
Note: your algorithm does not have to be 100% accurate; you should explain your results.

1.1) Describe steps of your algorithm

Steps	Description and purposes
1	Convert RGB image to gray for computer to easy understand
2	Make circle mask. - Black circle with r=140 to remove outer circle of clock - White circle with r=15 to remove black circle at center
3	Threshold the image to make binary image
4	Dilate the black area to make clock hand thinner

5	Apply the created mask
6	Apply canny to detect edge
7	Using Hough Line Transform to detect clock hand
8	If the clock hand is thick, we need to combine the two line that detected
9	Getting x2, y2 that return from Hough Line Transform and calculate the angle
10	Convert angle to time
11	Show the result

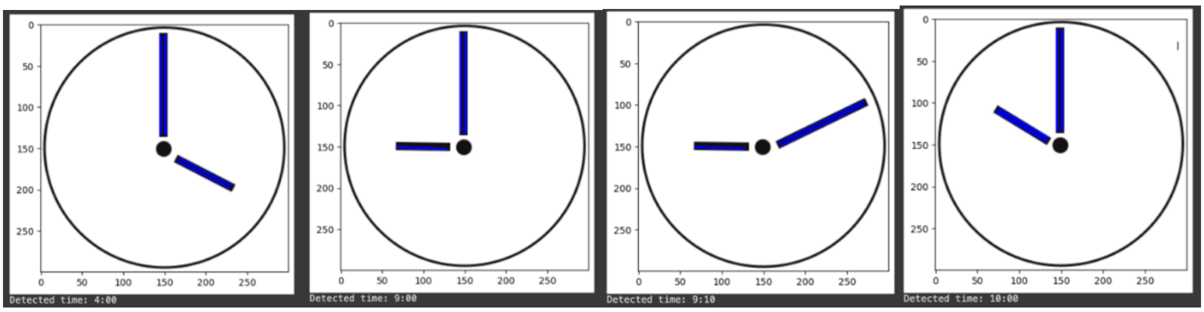
1.2) Write down the results from your program:

			
04:00	10:00	09:00	09:10

1.3) Analyze the results.

Hint: in terms of how accurate is your technique, any further improvement can be done?

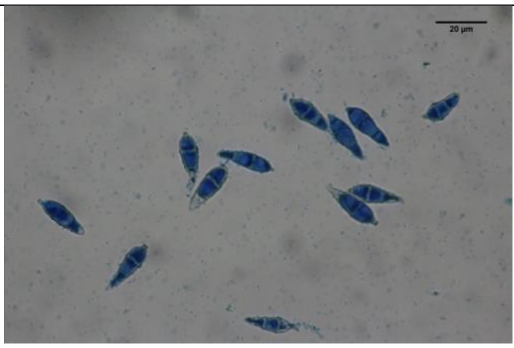
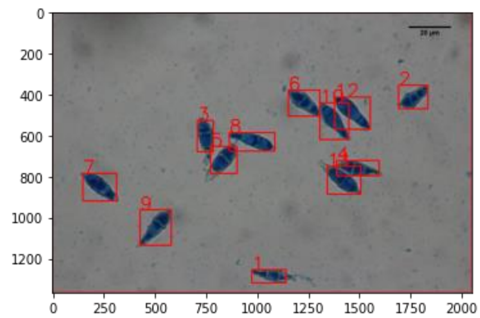
My result is 100% accurate.



```python
import cv2
import numpy as np
import matplotlib.pyplot as plt
import math



def detect_hands_and_calculate_time(image_path):
    # Load the image
    img = cv2.imread(image_path)

    # Convert to gray
    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

    # Make circle mask
    m,n,_ = img.shape
    m,n = m//2,n//2
    mask1,mask2 = np.ones_like(gray),np.ones_like(gray)
    cv2.circle(mask1,(m,n),140,0,-1)
    cv2.circle(mask1,(m,n),15,1,-1)

    # Threshold
    _,gray = cv2.threshold(gray,128,1,cv2.THRESH_BINARY)

    # Dilate the white area to make clock hand thinner
    kernel = np.ones((5, 5), np.uint8)
    gray = cv2.dilate(gray, kernel, iterations=1)

    # Apply mask
    gray = cv2.bitwise_or(mask1,gray)

    # Apply Canny to detect the edge
    edges = cv2.Canny(gray, 0, 1, apertureSize=3)

    # Hough Line Transform
    lines = cv2.HoughLinesP(edges, 1, np.pi/180, threshold=40, minLineLength=30, maxLineGap=5)

    # Assuming the longest line is the minute hand and second longest is the hour hand
    if lines is not None:
        lines = sorted(lines, key=lambda x: np.linalg.norm(x[0][:2] - x[0][2:4]), reverse=True)
        minute_hand = lines[0][0]

        if len(lines) > 3:
          hour_hand = np.array([(lines[2][0][0] + lines[3][0][0])/2, (lines[2][0][1] + lines[3][0][1])/2, (lines[2][0][2] +
lines[3][0][2])/2, (lines[2][0][3] + lines[3][0][3])/2])
        elif len(lines) > 2:
          hour_hand = lines[len(lines) - 1][0]
        else:
          hour_hand = None

        # Calculate angles and time
        center = (img.shape[0] // 2, img.shape[1] // 2)
        minute_angle = calculate_angle(minute_hand, center)
        hour_angle = calculate_angle(hour_hand, center) if hour_hand is not None else None

        minute = math.floor(minute_angle / 360 * 60) % 60
        hour = math.ceil(hour_angle / 360 * 12) if hour_angle is not None else None

        for line in lines:
            for x1,y1,x2,y2 in line:
                cv2.line(img, (x1, y1), (x2, y2), (0, 0, 255), 2)

        plt.imshow(img)
        plt.show()
        return hour, minute
    else:

        plt.imshow(img)
        plt.show()
        return None, None

def calculate_angle(line, center):
    x1, y1, x2, y2 = line
    x = x2 - 150
    y = y2 - 152
    angle = math.atan( abs(x) / abs(y) )
    angle = np.degrees(angle)

    if x < 0 and y >= 0:
      angle = 180 + angle
    elif x < 0 and y < 0:
      angle = 360 - angle
    elif x >= 0 and y >= 0:
      angle = 180 - angle

    return angle

hour, minute = detect_hands_and_calculate_time('clock0900.png')
if hour is not None and minute is not None:
    print(f"Detected time: {hour}:{minute:02d}")
else:
    print("Could not detect clock hands")
```

2. (Optional – for practice) Pyricularia Oryzae, rice blast fungus can cause rice blast disease. To identify the possibility of the occurrence of rice blast disease, the density of the spores of Pyricularia Oryzae can be calculated. Plant pathologist knows that you studied image processing, so they have asked you to help them automatically count the number of spores using image processing. They have provided two image samples below for you to develop an algorithm to count them. You should provide your results in terms of `num_count` and `resulted_image` (labeled count) (you can use cv2.rectangle(…) and cv2.putText(…) functions) as the example shown below

Note: your algorithm does not have to be 100% accurate; you should explain your results.

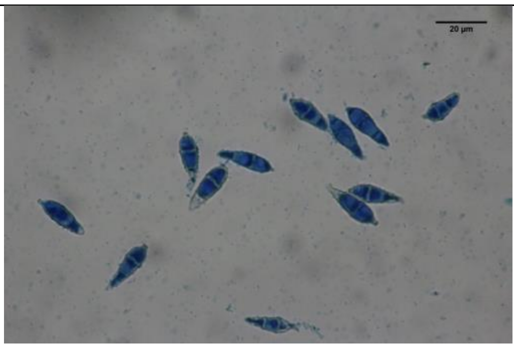
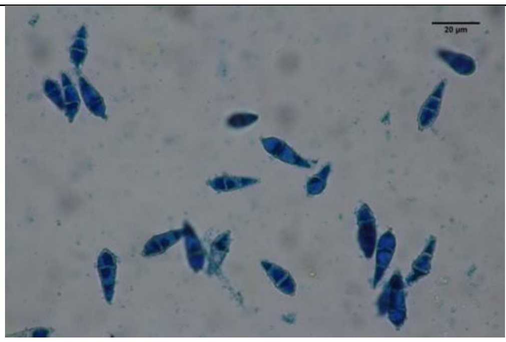
Original image	**Your results / number of counted spores**
 pyri02.png	**EXAMPLE**  **num_count = 12**

2.1) Describe steps of your algorithm

Steps	**Description and purposes**
1	
2	
3	

2.2) Results

Original image	**Your results / number of counted spores**

 pyri02.png	
 pyri02.png	

2.3) Analyze the results.

Hint: in terms of how accurate is your technique, any further improvement can be done?

3. (10 points) Separate and segment the oil in the beaker by distinguishing between solid (darker) and liquid oil. The container has a width and height, as shown in Figure 3.1. The equation for volume is $\pi r^2 h$, where r represents the radius and h is the height of the beaker, respectively.

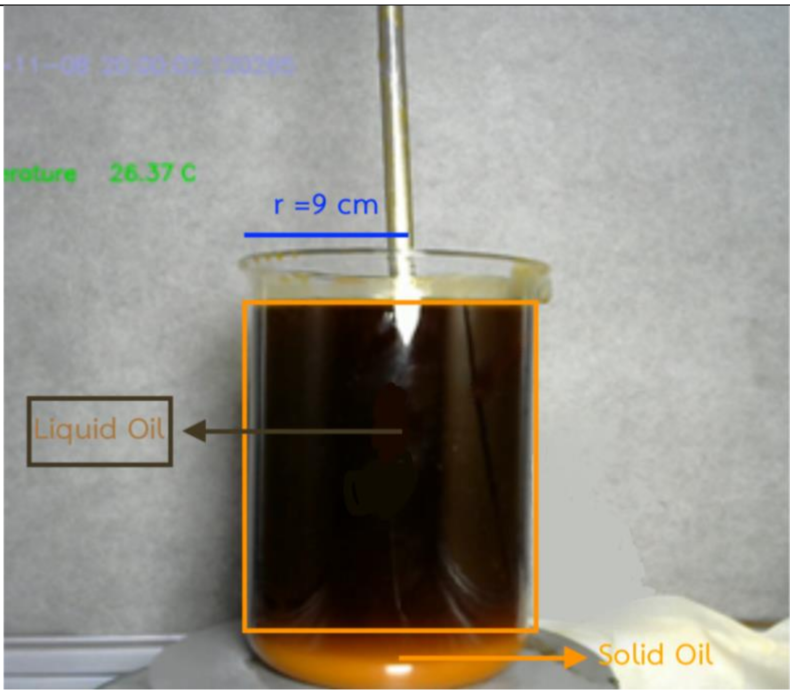
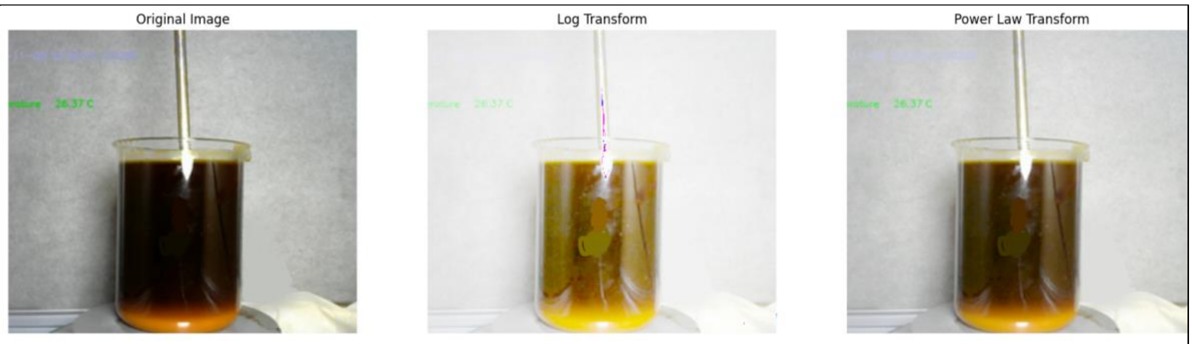


Fig 3.1 Crude oil (Oil.png)

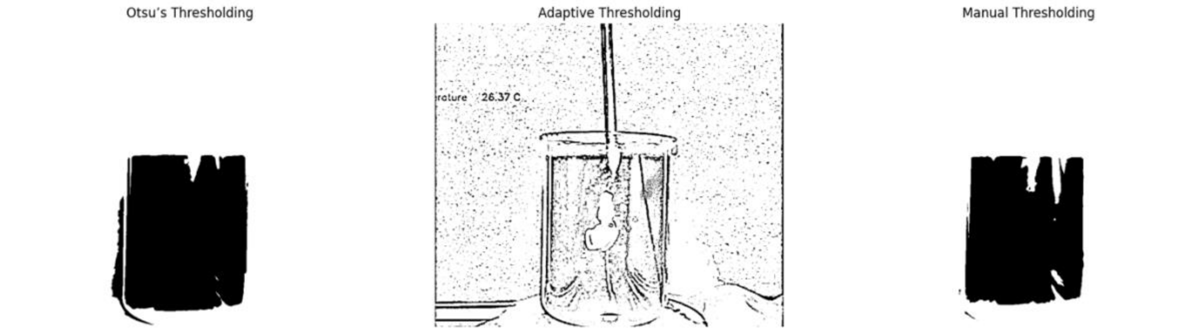
3.1 Find the volume of the oil in the liquid state.

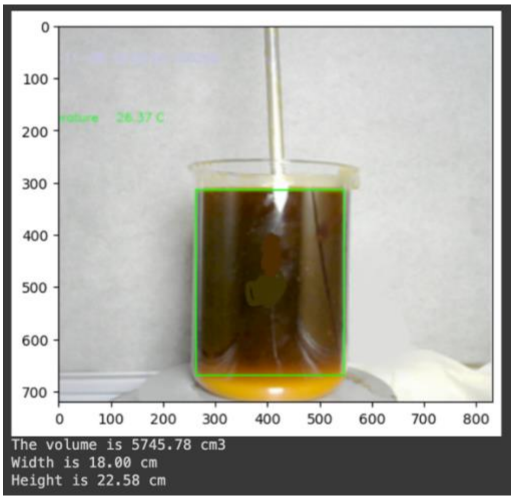
Please use image enhancement, such as, Log transform, Power Law before apply segmentation. Then, you can use Otsu's, Adaptive Thresholding, Region Growing, and Manual Threshold to find the volume. Put your image results in the blank areas below.

Optional Enhancement image



Enhanced image





Segmented regions of the liquid oil and show width and height of the segmented image

Explain your steps and techniques used briefly:

1. Use Power Law transform to make image brighter and easy to thresholding.
2. Use manual threshold to threshold the image.
3. Use find contour and get the second largest contour.
4. Use bounding rectangle to bound the largest contour.
5. Get x, y, w, h of bounded rectangle and calculate the volume.

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

# Load the image
image = cv2.imread('Oil.png', cv2.IMREAD_COLOR)
image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

# Apply log transform for image enhancement
img_log = (np.log(image + 1)/(np.log(1 + np.max(image)))) * 255
img_log = np.array(img_log, dtype=np.uint8)

# Apply gamma correction for power law transform
gamma = 0.5
img_gamma = np.array(255*(image / 255) ** gamma, dtype='uint8')

# Display the images
fig, ax = plt.subplots(1, 3, figsize=(20, 10))
ax[0].imshow(image)
ax[0].set_title('Original Image')
ax[0].axis('off')
ax[1].imshow(img_log)
ax[1].set_title('Log Transform')
ax[1].axis('off')
ax[2].imshow(img_gamma)
ax[2].set_title('Power Law Transform')
ax[2].axis('off')
```

```python
from skimage.filters import threshold_otsu
from skimage import measure
import cv2
import numpy as np
import matplotlib.pyplot as plt

# Using power-law image and convert to grayscale
gray_power_law = cv2.cvtColor(img_gamma, cv2.COLOR_RGB2GRAY)

# Apply Otsu's thresholding
thresh_val_otsu = threshold_otsu(gray_power_law)
otsu_mask = gray_power_law > thresh_val_otsu

# Apply Adaptive Thresholding
adaptive_thresh = cv2.adaptiveThreshold(gray_power_law, 255, cv2.ADAPTIVE_THRESH_GAUSSIAN_C, cv2.THRESH_BINARY, 11, 2)

# Manual Thresholding - we select a threshold value that might be suitable
manual_thresh_value = 100
_, manual_mask = cv2.threshold(gray_power_law, manual_thresh_value, 255, cv2.THRESH_BINARY)

# Display the segmentation results
fig, ax = plt.subplots(1, 3, figsize=(20, 10))
ax[0].imshow(otsu_mask, cmap='gray')
ax[0].set_title('Otsu’s Thresholding')
ax[0].axis('off')
ax[1].imshow(adaptive_thresh, cmap='gray')
ax[1].set_title('Adaptive Thresholding')
ax[1].axis('off')
ax[2].imshow(manual_mask, cmap='gray')
ax[2].set_title('Manual Thresholding')
ax[2].axis('off')
```

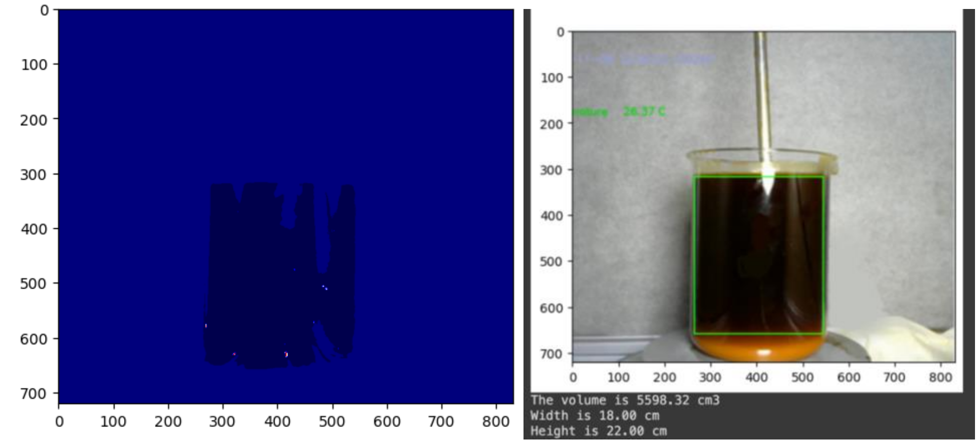
```python
def segment_dark_area(image_binary, image_rgb):
  # Find the contours of the dark area.
  contours, _ = cv2.findContours(image_binary, cv2.RETR_LIST, cv2.CHAIN_APPROX_SIMPLE)

  areaArray = []

  #   print(contours)
  for i, c in enumerate(contours):
    area = cv2.contourArea(c)
    areaArray.append(area)

  sorteddata = sorted(zip(areaArray, contours), key=lambda x:x[0], reverse=True)

  # Find the largest contour.
  largest_contour = sorteddata[1][1]

  # Draw a rectangle around the largest contour.
  x, y, w, h = cv2.boundingRect(largest_contour)
  cv2.rectangle(image_rgb, (x, y), (x + w, y + h), (0, 255, 0), 2)

  # Calculate the height of the rectangle.
  height = h
  width = w

  return image_rgb, height, width
```

```python
def volumeCal(height_pixel,width_pixel):
    cm_per_pix = 18 / width_pixel
    width_cm = 18
    height_cm = cm_per_pix * height_pixel
    volumn = np.pi * (width_cm/2)**2 * height_cm
    return volumn, width_cm, height_cm
```

```python
img_con = np.copy(img_gamma)
im, height_pixel, width_pixel = segment_dark_area(manual_mask,img_con)
plt.imshow(im)
plt.show()

print(f"The volumn is {volumeCal(height_pixel,width_pixel)[0]:.2f} cm3")
print(f"Width is {volumeCal(height_pixel,width_pixel)[1]:.2f} cm")
print(f"Height is {volumeCal(height_pixel,width_pixel)[2]:.2f} cm")
```

3.2 Segment the liquid oil again using Connected-component-with-stats method and compare the segmented result and calculated volume with 3.1.

Hint: Don't forget to use image Enhancement and connectivity either 4 or 8



Segmented region of the liquid oil using Connected Component with stats method.

Explain your steps and techniques used briefly:

1. Convert the image to gray.
2. Thresholding the image.
3. Find the connected components with stats.
4. Sort the stats to find the second largest component.
5. Get w, y, w, h of the second largest component.
6. Calculate the volume.

```python
img_concom_rgb = cv2.imread('Oil.png', cv2.IMREAD_COLOR)
img_concom = cv2.cvtColor(img_concom_rgb, cv2.COLOR_BGR2GRAY)
ret,thresh1 = cv2.threshold(img_concom,28,255,cv2.THRESH_BINARY)

# Connectivity type
connectivity = 4

# Get Connected Components With Stats
output = cv2.connectedComponentsWithStats(thresh1, connectivity, cv2.CV_32S)

# The the labels matrix
labels = output[1]

# The the stat matrix
stats = output[2]

# Sort the component to get second largest component
sortedstat = sorted(stats, key=lambda x: x[4], reverse=True)

# Get w, y, w, h of the second largest component
x,y,w,h,_ = sortedstat[1]

# Draw the rectangle
cv2.rectangle(img_concom_rgb, (x, y), (x + w, y + h), (0, 255, 0), 2)

# Show lables image
plt.imshow(labels, cmap="seismic")
plt.show()

# Show result image
plt.imshow(cv2.cvtColor(img_concom_rgb, cv2.COLOR_BGR2RGB))
plt.show()

print(f"The volume is {volumeCal(h,w)[0]:.2f} cm3")
print(f"Width is {volumeCal(h,w)[1]:.2f} cm")
print(f"Height is {volumeCal(h,w)[2]:.2f} cm")
```

From 3.1: The calculated height is 22.58 cm., and the volume is 5745.78 cm^3.

From 3.2: The calculated height is 22.00 cm., and the volume is 5598.32 cm^3.

So, the different between calculated height is less than 1 cm. I think these 2 results are very similar.

Note: You will get full score if the calculated volume for both 3.1 and 3.2 are within 10% error from our reference volume.