RHODES UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

EXAMINATION: NOVEMBER 2020

COMPUTER SCIENCE HONOURS
PAPER 5 – IMAGE PROCESSING

Internal Examiner: Mr. J Connan
Ms. L Poole

MARKS: 120
DURATION: 3 hours

External Examiners: Prof. I Sanders

GENERAL INSTRUCTIONS TO CANDIDATES

1. This paper consists of 8 questions and 6 pages. ***Please ensure that you have a complete paper.***
2. State any assumptions and show all workings.
3. Diagrams are encouraged and should be labelled.
4. Provide answers that are concise, legible and clearly numbered.
5. Use the mark allocation as a guide to the depth of your answer.
6. The Concise Oxford English Dictionary may be used during this examination.
7. You may use a calculator (though it should not be needed).

My castle is under siege. The raiding party is at the gate. You have come to steal my marks and all I have left for protection are these 8 questions. Luckily, you can each carry a maximum of 120 away with you. Prepare for a fight to the bitter end ...

FOR GLORY!!!!!

PLEASE DO NOT TURN OVER THIS PAGE UNTIL TOLD TO DO SO.

Section A Theory [70 Marks]

Question 1 **(6 + 4 + 2 = 12 marks)**

A digital image is a representation of a physical phenomenon. It is normally stored in a specific file format. The Netpbm image formats were widely used during this course.

a. Provide a brief description of the structure of these files and how the image data is stored in them.

b. With the aid of a diagram, briefly describe RGB and HSV.

c. Sometimes it is desirable to remove colour information from images. Provide two reasons why this might be desirable.

Question 2 **(3+3+3+3 =12 marks)**

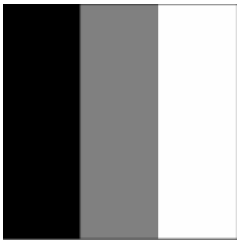


Figure 1

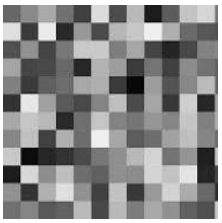


Figure 2

Refer to Figure 1 and Figure 2. Assume that the images have the same dimensions and the maximum pixel value is 255:

a. Draw and label the histogram for Figure 1.

b. Draw and label the histogram for Figure 2.

Assume that the filter *h* is applied to the image in Figure 1. Pad the image with zeros where necessary and assume that it is a 6x6 pixel image.

$$h=\begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

c. Write down the pixel values for Figure 1 after the filter *h* has been applied to it.

d. Assume the same 6x6 pixel image, as originally depicted in Figure 1, is scaled to twice its size using the Linear Interpolation method. Make a sketch of the resultant image (this is not an art class, so it must be legible but does not have to be a work of art).

Question 3 **(6 + 12 = 18 marks)**

a. Provide a brief overview of the Lempel-Ziv-Welch (LZW) encoding algorithm.

b. Use the Lempel-Ziv-Welch algorithm to compress the string banana_bandana. Show all your working.

Question 4 **(12+6=18 marks)**

a. Use the following data to create a Huffman tree and to determine an appropriate code for each symbol.

Symbol	a_1	a_2	a_3	a_4	a_5	a_6
Probability	0.1	0.4	0.06	0.1	0.04	0.3
Code						

b. Use your codes from *part a* to illustrate how an instantaneous block code works.

Question 5 **(10 marks)**

Microbiologists use Petri dishes to culture cells such as bacteria and mosses. A growth medium is placed in the dish and cells from the desired specimen are placed in the growth medium. The cells are then allowed time to grow and develop. Different dishes may contain different elements, such as antibiotics, or be placed in different environments, such as extreme heat or cold.

As the cells develop they form what are known as colonies. By examining these colonies and looking at for example the number of colonies or the size of colonies, microbiologists can make conclusions about the influences of the environment on the specimens.

You have been asked to develop a system to assist the microbiologists. Your system needs to be able to provide user feedback only on the number of colonies and the colony sizes.

How would you go about implementing such a system? Provide an overview of the entire system, from data acquisition to user feedback. Also highlight the strengths and weaknesses of your proposed solution as well as possible extensions.

8 colonies

Section B Practical [50 Marks]

Question 6 (6 marks)

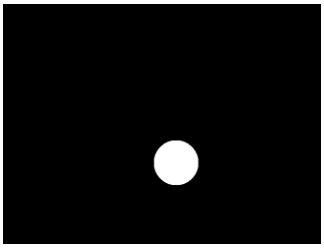
The following code was written by a week 1 OpenCV student. The student presented the program to his friends for feedback. The code is fully functional and returns a valid image, however, writing code in this manner does not follow best coding practice. Furthermore, the student's friends complained that it was difficult to view the image. Assuming the resulting image is incorrect, outline how this program should be refactored and give advice to the student on how to debug their result.

```
1. import cv2 as cv # OpenCV

2. image = cv.imread("Potato.png")

3. image = cv.cvtColor(image,cv.COLOR_BGR2GRAY)
4. image = cv.resize(image,(300,300),0,0,cv.INTER_LINEAR)

5. r, image = cv.threshold(image,125,255,cv.THRESH_BINARY)

6. cv.imshow("A Image",image)
7. cv.waitKey(1)
```

Question 7 (2+4+6=12 marks)

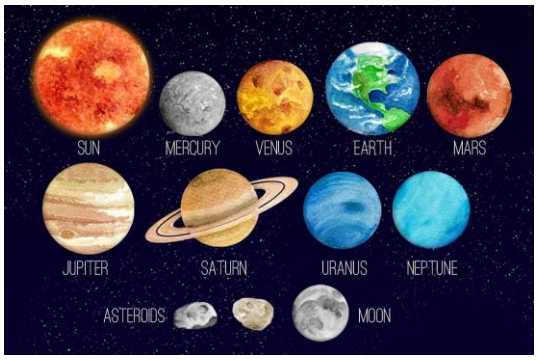
a. Write a program **`badSleight.py`** that reads in **`coins.png`** as a greyscale image. The desired greyscale image as shown.

b. In the same program, create a circle with a radius of **`45`** at coordinates `[348, 317]` on a blank image as shown.



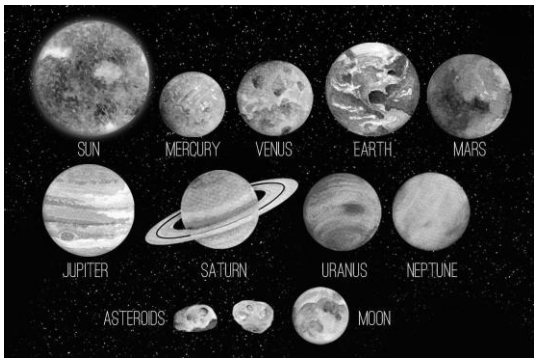
c. Replace the coin with the average pixel value in the rest of the image as shown.

Question 8 **(3+3+3+5+6+6+6=32 marks)**



`manyPlanets.png`

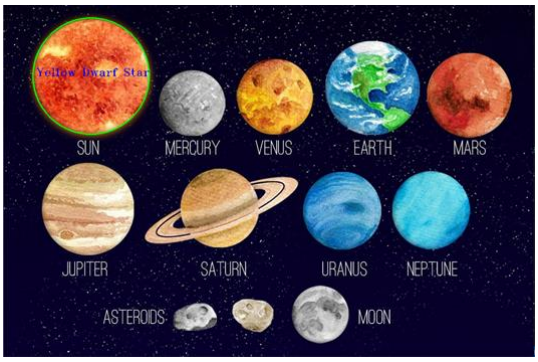
a. Write a program **`planets.py`** that reads in **`manyPlanets.png`**, unchanged with the alpha channel. Then convert the image to greyscale. The desired greyscale image is shown below:



b. Apply a bilateral filter to the grayscale image using a 9x9 kernel size.

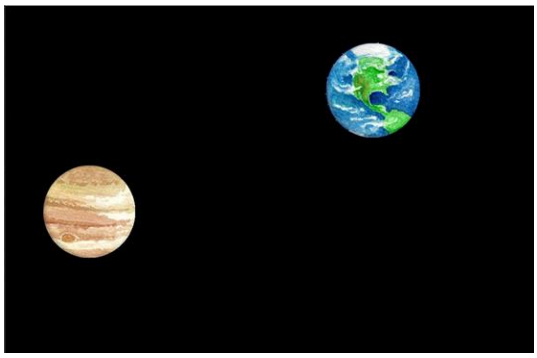
c. Apply appropriate thresholding to the filtered image.

d. The Sun is known as a Yellow Dwarf Star. Detect and circle the Sun, and display the circled Sun on the colour image. Add text to the Sun, labelling it 'Yellow Dwarf Star'. Example output is shown below:

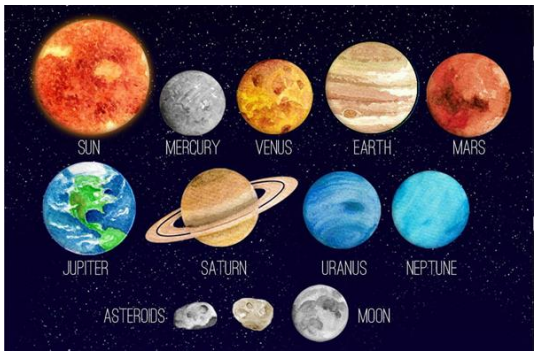


e. Use either **`findContours()`** or **`HoughCircles()`** to detect and count all the planets, including the Sun and the Moon (but not the asteroids). Print out the value of count.

f. Create a mask of Earth and Jupiter only. Hence display Earth and Jupiter in colour on a new blank image of the same resolution as **`manyPlanets.png`**:



g. NASA has hired you to trick their scientists. Use the work you have done in the previous question to swop Earth and Jupiter:



And so peace once again descended on the land.

END OF EXAMINATION