RHODES UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

EXAMINATION: JUNE 2017

COMPUTER SCIENCE HONOURS
PAPER 1 – IMAGE PROCESSING

Internal Examiner: Mr. J Connan

MARKS: 120
DURATION: 2 hours

External Examiners: Prof. M Kuttel

GENERAL INSTRUCTIONS TO CANDIDATES

1. This paper consists of 10 questions and 6 pages. ***Please ensure that you have a complete paper.***
2. Answer all questions in the answer book provided.
3. State any assumptions and show all workings.
4. Diagrams are encouraged and should be labelled.
5. Provide answers that are concise, legible and clearly numbered.
6. Use the mark allocation as a guide to the depth of your answer.
7. The Concise Oxford English Dictionary may be used during this examination.
8. 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 10 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.

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.

Two commonly used colour spaces/models are RGB and HSV.

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)**

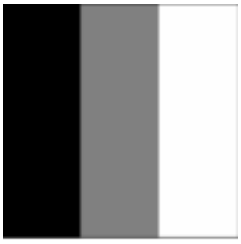


Figure 1

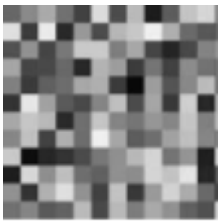


Figure 2

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 $h=\begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$ is applied to the image in Figure 1. Pad the image with zeros where necessary and assume that it is a 6x6 pixel image.

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 **(8+10=18 marks)**

a. With the aid of a diagram, explain histogram equalization.

b. Apply histogram equalization to this $\begin{vmatrix} 75 & 125 & 155 & 125 & 75 \\ 90 & 140 & 155 & 140 & 90 \\ 90 & 140 & 155 & 140 & 90 \\ 75 & 125 & 155 & 125 & 75 \end{vmatrix}$ image, given $h(v) = round\left(\frac{cdf(v) - cdf_{min}}{(MxN) - cdf_{min}} x(L-1)\right)$.

Question 4 **(12+6=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 5 **(8 marks)**

Explain how image compression differs from compressing other data.

Question 6 **(10 marks)**

In this course you had a close look at two object tracking methods. Describe each and highlight the main strengths and weaknesses of each method.

Question 7 **(5 marks)**

When the images in below are overlapped a secret message is revealed. Briefly explain how these images are created and why overlapping them reveals the hidden message.

Question 8 **(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 is 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

Question 9 **(5 +3 + 3 + 2 + 5 = 16 marks)**

```
1. import cv2 as cv # OpenCV

2. stars = cv.imread("Stars.png",0)

3. ellipse = cv.getStructuringElement(cv.MORPH_ELLIPSE,(9,9))

4. image_source = stars

5. img_result_1 = cv.morphologyEx(image_source, cv.MORPH_ERODE, ellipse, 1)
6. img_result_2 = cv.morphologyEx(image_source, cv.MORPH_DILATE, ellipse, 1)

7. image_to_show = img_result_1

8. cv.imshow("Result",image_to_show)
9. cv.waitKey(0)
```

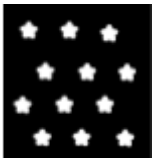
Briefly look at the above code and answer the following questions:

a. On line 5, explain what the variable "ellipse" contains and draw a small diagram showing how opencv stores it.

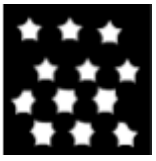
Figure 3

The image of "Stars.png" seen on line 3 is depicted in Figure 3.

b. By changing the source image and order of lines 9 and 10, create this output image (b) and describe what the resulting operation is called.

b. 

c. By changing the source image and order of lines 9 and 10, create this output image (c) and describe what the resulting operation is called.

c. 

d. Give a useful "real world" application for the operators used in part b and c.

```
img_result_3 = cv.morphologyEx(image_source, cv.MORPH_GRADIENT, ellipse,1
```

e. The image in Figure 4 was created with the code above. This is called a Gradient morphology which outlines the edges inside a binary image with a given mask. However it can also be achieved by using a sequence of Erode, Dilate, and other bit-wise operations. With the help of psuedo- or actual code, explain how the Gradient morphology could be achieved.

Figure 4

Question 10 **(8 + 3 = 11 marks)**

1. The following code was written by a week 1 OpenCV student. The code is fully functional and returns a valid image, however writing code in this manner is risky. 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("Stars.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("Our Image",image)
7. cv.waitKey(0)
```

2. The following code produces a blank image as a result. State where this error occurs.

```
1. import cv2 as cv # OpenCV

2. image = cv.imread("Stars.png",0)

3. r, image = cv.threshold(image,125,255,cv.THRESH_BINARY)
4. _,contours,_ = cv.findContours(image,cv.RETR_EXTERNAL,
   cv.CHAIN_APPROX_SIMPLE)
5. print len(contours)

6. cv.imshow("Our Image",image)
7. cv.waitKey(0)
```

And so peace once again descended on the land.

END OF EXAMINATION