The University of Nottingham Ningbo China

SCHOOL OF COMPUTER SCIENCE

A LEVEL 2 MODULE, SPRING SEMESTER, 2020–2021

INTRODUCTION TO IMAGE PROCESSING

Time allowed 60 Minutes

Candidates may complete the front covers of their answer books and sign their desk cards but must NOT write anything else until the start of the examination period is announced.

Answer all THREE questions. The total mark is 60.

Only silent, self contained calculators with a Single-Line Display or Dual-Line Display are permitted in this examination.

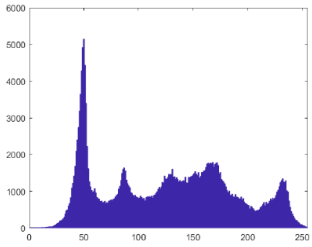
Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

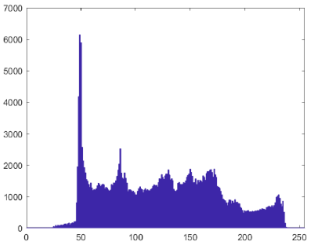
DO NOT turn examination paper over until instructed to do so

Question 1 (20 marks)

(a) Given the two histograms shown below, one from a focused image and another from its de-focused version.



(a) Histogram 1



(b) Histogram 2

(i) Identify which histogram is more likely obtained from the **de-focused** image. Briefly justify your answer. (4 marks)

(ii) Briefly explain how auto-focus works. (2 marks)

(b) The **Bayer pattern** is also known as the **Color Filter Array**, which is often used to form a color image of three channels despite the fact that only one CCD is used for each pixel. Draw a **Bayer pattern** of 6×6 pixels. Briefly explain how a color image of three channels is formed by using the Bayer pattern. (4 marks)

(c) Use the algorithm stated in APPENDIX I to find HSV values for $RGB = \{200, 100, 100\}$. (Keep 3 decimal digits.) (4 marks)

(d) Contrast stretching converts a source image in which intensities range from s_{min} to s_{max} to one in which they range from t_{min} to t_{max} using a linear transformation.

(i) Write down the transformation function from source image $f(x, y)$ to target image $g(x, y)$ for contrast stretching. (2 marks)

(ii) Given an image with the following histogram in the range of $[0, 7]$, show the resulting histogram (similarly as the table below) after contrast stretching to make full use of the dynamic range of $[0, 7]$. (4 marks)

Intensity value	0	1	2	3	4	5	6	7
Pixel count	0	0	40	20	30	10	0	0

Question 2 (20 marks)

(a) Briefly explain the causes of salt & pepper noise in the context of image formation. Which filter is most effective to filter out salt & pepper noise? (3 marks)

(b) The pixel values of a small 5×5 image patch are shown below. Compute the output of the **center** pixel for the following spatial filtering operations (approximate your answer to the nearest integer).

1	2	3	2	1
2	2	3	4	2
3	4	**5**	3	3
2	3	3	13	2
1	2	3	2	1

(a) Image patch

-1	-1	-1
-1	9	-1
-1	-1	-1

(b) Laplacian enhancement filter

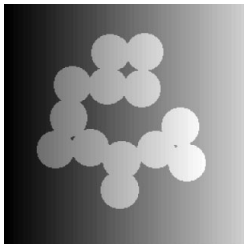
(i) 3×3 median filter (2 marks)

(ii) The Laplacian enhancement filter shown in (b). (2 marks)

(c) Briefly state the functionalities of the two Gaussian functions used in the Bilateral filter, and the differences between the bilateral filter and the Gaussian filter in terms of the kernel function. (4 marks)

(d) What are the three assumptions that must hold for Ostu's algorithm to properly threshold an input image? (3 marks)

(e) Describe an algorithm to calculate the number of coins in the image below. At each step, you should state precisely the method used and the resulting output. (6 marks)



Question 3 (20 marks)

(a) Briefly explain Rosin's unimodal method for unimodal thresholding. Give one type of image where unimodal thresholding could be applied. (4 marks)

(b) State the two necessary image conditions for histogram equalization to properly improve the image contrast. If histogram equalization is applied on each of the following images, state whether it could properly improve the contrast. (4 marks)

(a) Image 1

(b) Image 2

(c) List the three types of redundancy that can be exploited for image compression. For each type of redundancy, give an example compression technique. (6 marks)

(d) Use Huffman coding to encode the following message:
200+300+200+300=1000
What is the entropy of this messege? What is the average number of bits per code of the encoded message? (6 marks)

Character	Probability	Huffman code
2		
0		
+		
3		
=		
1		

APPENDIX I

Algorithm 1 Convert from RGB colour space to HSV colour space.

Input: R,G,B

Output: H,S,V

Normalize R,G,B to [0,1].
$V = \max\{R, G, B\}$
$\Delta = V - \min\{R, G, B\}$
$S = \Delta / V$
if V==R **then**
    $H = 60 \times (G - B)/\Delta$
else if V==G **then**
    $H = 60 \times (B - R)/\Delta + 120$
else if V==B **then**
    $H = 60 \times (R - G)/\Delta + 240$
end if