The University of Nottingham Ningbo China

SCHOOL OF COMPUTER SCIENCE

A LEVEL 2 MODULE, SPRING SEMESTER, 2018–2019

INTRODUCTION TO IMAGE PROCESSING

Time allowed 90 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 FOUR questions. The total mark is 100.

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

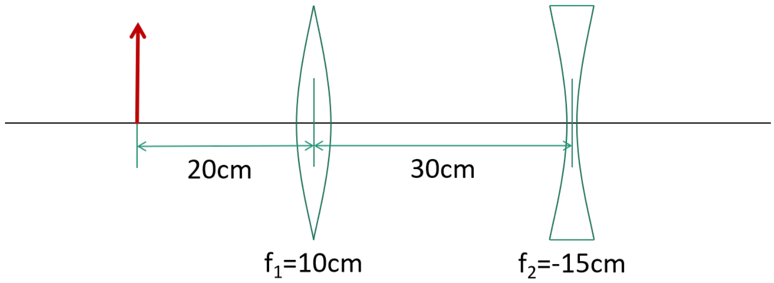
Question 1 (25 marks)

(a) **Aperture**, **optical system** and **screen** are three key components in a simplified imaging device. Explain briefly the functionality of these three components. Find the corresponding components in the human visual system for these three components.

(6 marks)

(b) State the three expansions of digital image processing techniques that mimic and go beyond the human visual system. (3 marks)

(c) Given a convex lens whose focal length is 10 cm, a concave length whose focus length is -15cm, the object is 20 cm in front of the convex lens, and the distance between two lens is 30cm, find where is the image. State whether the image is real or virtual. (6 marks)



(d) This question is about colour models.

(i) RGB and HSV are two common colour models. Explain briefly the meaning of three colour channels in each of these two colour models. If you are going to implement a face detector, which colour model should you use, RGB or HSV? Justify your answer.

(4 marks)

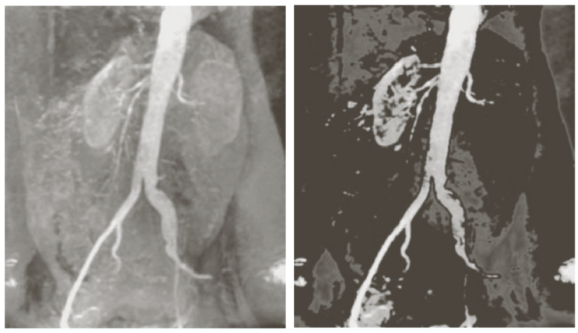
(ii) Use the algorithm stated in APPENDIX I to find HSV values for $RGB = \{150, 100, 50\}$. (Your answer should be rounded to 3 decimal digits.) (6 marks)

Question 2 (25 marks)

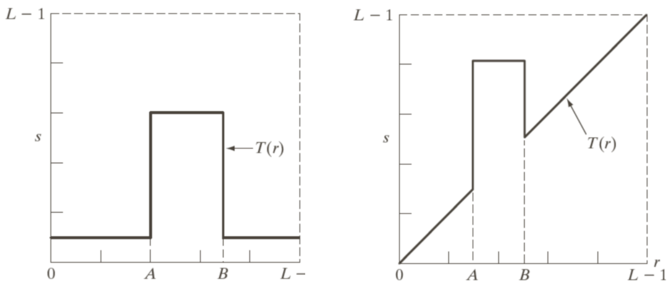
(a) This question is about intensity transform.

(i) Explain what linear intensity transforms are, and how bias and gain affect the appearance of image. (3 marks)

(ii) Gray-level slicing has been applied to image (a) to obtain image (b). Of the functions presenting in (c) or (d), which is most likely to be applied to image (a) in obtaining image (b)? Justify your answer. (3 marks)



(a) (b)



(c) (d)

(iii) Gamma correction has been applied on image (a) to obtain image (b). Which γ, among 0.5, 1 and 2, will be the most possible value to obtain the resulting image (b)? Justify your answer.

(a) (b)

(3 marks)

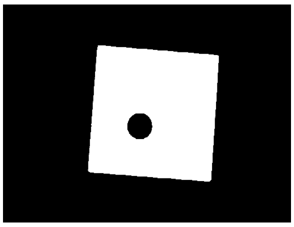
(b) This question is about histogram equalization.
A 3-bit image has a histogram as listed in the following table:

Pixel value	% of pixels	Output value
0	1%	
1	2%	
2	3%	
3	12%	
4	5%	
5	20%	
6	47%	
7	10%	

(i) Histogram equalization is applied to process the image. What will be the corresponding output pixel values? (8 marks)

(ii) Is histogram equalization a suitable processing technique for this image? Explain your answer. (2 marks)

(c) This question is about mathematical morphology.
Mathematical morphology can be used to detect edges. Describe the procedures of detecting the edges in the binary image shown below using morphological operations. (6 marks)



Question 3 (25 marks)

(a) 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	3	4	3	2
3	4	5	21	3
2	3	4	3	2
1	2	3	2	1

(i) 3×3 median filter (2 marks)

(ii) 3×3 mean filter (2 marks)

(iii) Laplacian with the following filtering mask. (2 marks)

1	1	1
1	-8	1
1	1	1

(b) What noise is mainly residing in the image shown below? Which of the methods from part (a) of this question would you use to reduce the noise? Justify your answer. (4 marks)

(c) Sobel filters are normally used in image edge detection.

(i) Which edge, horizontal edge or vertical edge, is the Sobel filter in (a) used to detect? What about the Sobel filter in (b)? (2 marks)

-1	0	1
-2	0	2
-1	0	1

(a)

-1	-2	-1
0	0	0
1	2	1

(b)

8	8	7
7	6	2
5	5	1

(c)

(ii) Compute the gradient magnitude for the center of the image patch shown in (c) using Sobel filters in (a) and (b). (Hint: use correlation when applying the Sobel filters on the image.) (5 marks)

(d) State the four major steps of Canny edge detector and illustrate the functionality of each step. (8 marks)

Question 4 (25 marks)

(a) Otsu's thresholding method involves iterating through all the possible threshold values and calculating a measure of spread for the pixel levels at each side of the threshold, i.e. the pixels that either fall in foreground or background. Assume that a 2-bit image has the histogram shown below. Apply the Otsu's algorithm given in APPENDIX II to find the optimal threshold. You should test threshold $t = 0, 1, 2, 3$ and find the optimal threshold. (Your answer should be rounded to 2 decimal digits.)

Pixel value	Pixel counts
0	10
1	2
2	4
3	9

(9 marks)

(b) 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)

(c) Use Huffman coding to encode the follow message. What is the entropy of this messege? What is the average number of bits per code of the encoded message?
"100000+100000=200000"

Character	Count	Probability	Huffman code
1			
0			
+			
=			
2			

(10 marks)

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}
Δ = V − min{R, G, B}
S = Δ/V
if V==R then
    H = 60 × (G − B)/Δ
else if V==G then
    H = 60 × (B − R)/Δ + 120
else if V==B then
    H = 60 × (R − G)/Δ + 240
end if
```

APPENDIX II

Otsu thresholding aims to minimize:
$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$,
where $q_1(t) = \sum_{i=0}^{t-1} P_i$, $q_2(t) = \sum_{i=t}^{I} P_i$.

Or aim to maximize:
$\sigma_b^2(t) = q_1(t)q_2(t)(\mu_1(t) - \mu_2(t))^2$,
where $\mu_1(t) = \sum_{i=0}^{t-1} iP_i$, $\mu_2(t) = \sum_{i=t}^{I} iP_i$.