General Sir John Kotelawala Defence Univesity, SRI LANKA
Faculty of Engineering
Department of Electrical and Electronic Engineering
B.Sc. Engineering
Semester 5 Final Examination

ET3112—IMAGE PROCESSING AND MACHINE VISION

Time Allowed: 2 hours July 2020

ADDITIONAL MATERIAL

None.

INSTRUCTIONS TO CANDIDATES

- This paper contains 4 questions on 7 pages.
- Answer **all** the questions.
- This examination accounts for 70% of the module assessment.
- This is a closed-book examination.
- The symbols used in this paper have their usual meanings.
- Clearly state any assumptions that you may make.
- Neat and orderly presentation is important.

Q1. (a) State two example each of [4]

i. Intensity transformations, and

ii. Spatial filtering.

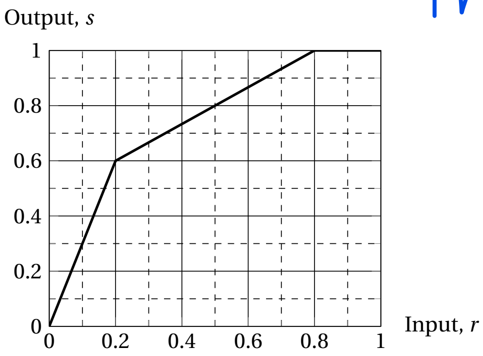
convolution, histogramming

(b) Figure Q1(b) shows an intensity transfer function and an input image. Note that, in the transfer function, $s, r \in [0,1]$, and the image $f(i,j) \in [0,255]$.

i. Apply this transfer function to the input image and show the resulting values in the grid shown. [6]

ii. What is the typical way of programmatically applying such a transformation using an image processing library? [2]

indexing intensity with LUT



i. Transfer function

220	220	220
100	100	100
10	100	100
10	10	10

ii. Input image $f(i,j)$

211	211	211
185.3	'	''
30.6	'	'
31.1	30.6	30.6

iii. Grid for output

Figure Q1(b): Intensity transfer function, input image, and grid for output.

(c) Consider the gamma correction designated by

$$g = f^{\gamma}$$

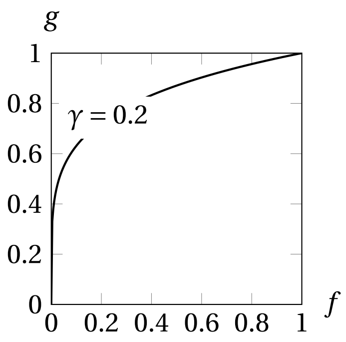
where f is the input image, and g is the output image. $g, f \in [0,1]$ and $\gamma = 0.2$. Figure Q1(c) shows this transfer function, an input image, and a grid for showing the output.

i. What is the effect of this transformation? [2]

ii. Show the gamma-corrected output in the gird shown. [4]

0.2

y = d



i. Transfer function

220	220	220
100	100	100
10	100	100
10	10	10

ii. Input image $f(i,j)$

247		
212		
134		

iii. Grid for output

Figure Q1(c): Grama correction function, input image, and grid for output.

(d) Figure Q1(d) shows an image and a grid.

i. Sketch the histogram of this image. [3]

ii. Carry out histogram equalization and show the resulting image in the grid. [4]

1	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1
0	0	0	0	0	1	2	2
0	0	0	0	1	3	3	1
0	1	1	3	5	5	4	2
1	2	2	3	5	5	6	4
2	2	2	2	5	5	6	5
2	2	2	3	5	5	6	5
6	6	6	7	7	7	7	7

4	2	2	2	2			
4							
							5
			5			7	6
5	5	5	5			7	6
2	2	2	2	2	2	2	2

Figure Q1(d): Image for histogram operations and grid for showing the results

Q2. (a) Show 3 × 3 filtering kernels for following operations: [**6**]

i. Average filtering.

ii. Smoothed vertical edge detection.

iii. Sharpening.

(b) Figure Q2(b)shows a part of un-normalized 3 × 3 Gaussian kernel with $\sigma = 1$

0.6065		

Figure Q2(b): A part of un-normalized 3 × 3 Gaussian kernel.

i. Fill the other entries in the kernel. [**3**]

ii. Compute the normalized kernel. [**2**]

iii. What happens if σ is chosen to be 3? [**2**]

to large σ, close

(c) Figure Q2(c) shows an image, a filtering kernel, and a grid for displaying the output. Carry out the filtering operation on the image using this kernel. Show the output in the given grid. [**6**]

10	50	50	40	20
20	50	50	40	30
40	170	200	100	60
30	40	50	30	20

i. Image

0.1	0.1	0.1
0.1	0.2	0.1
0.1	0.1	0.1

ii. Kernel

iii. Grid for output

Figure Q2(c): Image, kernel, and output grid for **Q2**c.

(d) A conveyor, sketched in Figure Q2(d), carries two types of objects, circular and rectangular. Design a method using filtering to detect and count these two types of objects. [**6**]

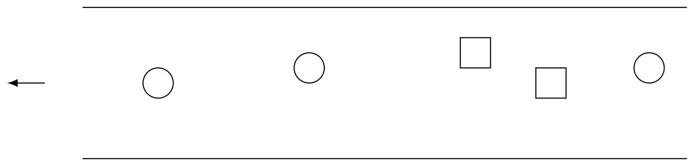


Figure Q2(d): A sketch of a conveyor.

Q3. (a) List four applications of image segmentation. [**4**]

(b) It is possible to find the threshold value automatically when segmenting an image with a bi-modal histogram. Figure Q3(b)i. shows an image to be segmented using thresholding. Figure Q3(b)ii. shows its histogram.

i. Select a suitable threshold by observation. Sate the threshold value and justify. [**2**]

ii. Segment the image using this threshold. [**3**]

iii. From the result, identify a problem of thresholding. [**3**]

(c) Segment the image in Figure Q3(c) using region growing. Use the shade pixel at (7, 10) with value 15 as the seed and a threshold of 2.1. [**6**]

(d) Figure Q3(d) shows a 3×4 image.

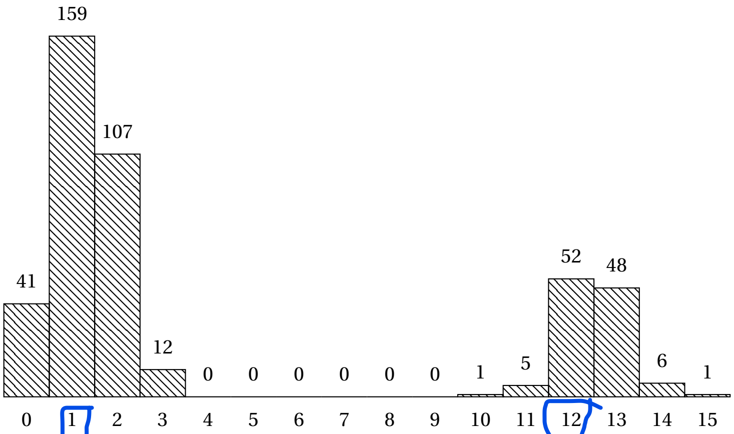
i. Carry out one iteration of k-means clustering in the intensity space. Use Manhattan distance and $K = 2$. Select (0, 3) and (2, 0) as initial cluster centers. [**3**]

ii. Carry out one iteration of k-means clustering in the intensity space and spatial space. Scale the spatial coordinated by 100. Use the parameters mentioned in **Q3**(d)i. [**4**]

Show the results in the grids in Figure Q3(d).

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	1	1	2	2	1	2	1	1	1	1	2	2	2	3	2	1	1	1	1	1	0	2	1	1
1	2	2	0	1	1	1	2	1	2	2	3	1	1	2	1	1	1	2	0	1	1	1	1	1
2	1	0	0	2	1	1	2	2	1	2	1	1	11	2	2	2	1	0	2	2	0	2	1	1
3	1	3	1	2	1	1	1	1	2	12	14	13	12	12	12	12	1	3	2	0	2	1	1	1
4	2	1	2	0	2	2	1	2	12	12	14	13	12	12	13	13	13	1	1	2	1	2	1	1
5	0	1	1	1	2	1	0	12	13	11	13	14	12	12	13	13	12	12	1	2	1	2	2	2
6	0	2	1	1	2	1	0	13	12	12	13	13	12	12	12	13	12	13	1	1	1	2	3	1
7	1	1	1	2	1	1	0	12	13	13	15	13	12	12	12	13	12	12	2	1	2	1	2	1
8	2	1	1	2	2	1	13	12	13	12	13	13	12	13	12	13	14	10	12	2	3	0	2	1
9	2	1	1	1	1	1	1	13	13	12	13	13	13	12	12	12	12	13	1	1	1	0	2	1
10	1	2	1	1	2	1	1	12	14	11	12	12	14	13	13	12	13	12	2	2	0	3	2	3
11	2	1	0	1	0	2	1	12	13	12	13	12	11	12	13	13	13	12	0	0	2	1	2	2
12	0	1	2	1	1	1	1	0	13	12	13	12	13	13	13	13	11	2	1	0	0	2	2	2
13	2	1	2	0	1	2	1	0	0	12	12	13	13	12	12	13	2	1	1	1	2	1	0	0
14	2	2	1	0	2	11	13	1	1	1	2	1	13	1	2	2	1	2	3	3	2	1	2	0
15	0	2	1	1	11	12	12	1	2	1	1	2	2	2	1	1	1	1	1	2	2	1	0	2
16	0	1	2	2	1	1	3	1	2	1	1	2	1	1	3	3	2	2	1	2	1	1	1	2
17	1	1	1	1	2	1	1	1	2	0	2	1	2	0	0	1	1	3	1	0	2	1	0	0

i. Image for showing the thresholding result.



ii. Histogram.

Figure Q3(b): Image and histogram for **Q3**b.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	1	1	2	2	1	2	1	1	1	1	2	2	2	3	2	1	1	1	1	1	0	2	1	1
1	2	2	0	1	1	1	2	1	2	2	3	1	1	2	1	1	1	2	0	1	1	1	1	1
2	1	0	0	2	1	1	2	2	1	2	1	1	11	2	2	2	1	0	2	2	0	2	1	1
3	1	3	1	2	1	1	1	1	2	12	14	13	12	12	12	12	1	3	2	0	2	1	1	1
4	2	1	2	0	2	2	1	2	12	12	14	13	12	12	13	13	13	1	1	2	1	2	1	1
5	0	1	1	1	2	1	0	12	13	11	13	14	12	12	13	13	12	12	1	2	1	2	2	2
6	0	2	1	1	2	1	0	13	12	12	13	13	12	12	12	13	12	13	1	1	1	2	3	1
7	1	1	1	2	1	1	0	12	13	13	15	13	12	12	12	13	12	12	2	1	2	1	2	1
8	2	1	1	2	2	1	13	12	13	12	13	13	12	13	12	13	14	10	12	2	3	0	2	1
9	2	1	1	1	1	1	1	13	13	12	13	13	13	12	12	12	12	13	1	1	1	0	2	1
10	1	2	1	1	2	1	1	12	14	11	12	12	14	13	13	12	13	12	2	2	0	3	2	3
11	2	1	0	1	0	2	1	12	13	12	13	12	11	12	13	13	13	12	0	0	2	1	2	2
12	0	1	2	1	1	1	1	0	13	12	13	12	13	13	13	13	11	2	1	0	0	2	2	2
13	2	1	2	0	1	2	1	0	0	12	12	13	13	12	12	13	2	1	1	1	2	1	0	0
14	2	2	1	0	2	11	13	1	1	1	2	1	13	1	2	2	1	2	3	3	2	1	2	0
15	0	2	1	1	11	12	12	1	2	1	1	2	2	2	1	1	1	1	1	2	2	1	0	2
16	0	1	2	2	1	1	3	1	2	1	1	2	1	1	3	3	2	2	1	2	1	1	1	2
17	1	1	1	1	2	1	1	1	2	0	2	1	2	0	0	1	1	3	1	0	2	1	0	0

Figure Q3(c): Image for showing the region growing result of **Q3**c.

	0	1	2	3
0	~~120~~	~~200~~	~~240~~	50
1	~~50~~	~~60~~	~~100~~	~~120~~
2	10	~~40~~	~~20~~	~~30~~

i. *k*-means

	0	1	2	3
0	120	200	240	50
1	50	60	100	120
2	10	40	20	30

ii. *k*-means with spatial

Figure Q3(d): Image and the grids for segmentation **Q3**d.

Q4. (a) Sate four vision tasks for which machine learning or deep learning is extensively used. [4]

(b) Corner detection is a first step in many conventional computer vision algorithms. It computes a cornerness measure. Figure Q4(b) shows a portion of values of the cornerness measure of an image.

0.0198	0.0198	0.0170	0.0119	0.0057
0.0220	0.0225	0.0201	0.0152	0.0092
0.0201	0.0213	0.0196	0.0156	0.0103
0.0149	0.0168	0.0163	0.0134	0.0092
0.0082	0.0108	0.0112	0.0095	0.0065

Figure Q4(b): Cornerness values of a image.

i. State an expression for the cornerness measure used in the Harris corner detector. [2]

ii. Identify the location of the corner. [2]

iii. State how to identify a corner in a scale covariant manner. [1]

(c) Consider a dataset of three classes of images, say, dogs, cats, and bunnies. An image is represented by a 4-dimensional vector. A liner classifier (after the learning process) is represented by

$$\mathrm{W} = \begin{bmatrix} -0.4 & 0.5 & -0.3 & ,0.6 \\ 0.4 & 0.5 & -0.2 & -0.6 \\ 0.5 & -0.3 & 0.8 & -0.6 \end{bmatrix}, \text{ and}$$

$$\boldsymbol{b} = \begin{bmatrix} 0.2 & 5.2 & 3.2 \end{bmatrix}^{\mathrm{T}}.$$

The first row of W and $\boldsymbol{b}$ is the one-vs-all classifier for dogs, the second for cats, and the third for bunnies.

i. State the steps for representing an image with a such 4-dimensional feature vector. [3]

ii. Determine the class of a image with a feature vector $\boldsymbol{x} = \begin{bmatrix} 0.3 & -1.5 & 1.6 & 8.1 \end{bmatrix}^{\mathrm{T}}$. [3]

(d) Consider a neural network implementation for character recognition. There are 52 characters, from a to z, lower-case and upper-case. Assume that each character is 32×32 in grayscale. The network flattens the input first. There is a dense layer of 128 nodes, and a dense softmax output layer.

i. How many nodes must be there in the softmax layer? 52 [2]

ii. Sketch the network. [2]

iii. Compute the number of learnable parameters in this network. [3]

iv. If the network is altered to have, first, a convolutional layer of 3×3 convolutions with 64 filters, followed by a max-pooling layer of 2×2 pooling window, and then the aforementioned dense network, compute the number of learnable parameters. [3]

1024 128 52