UNIVERSITY OF COLOMBO, SRI LANKA

UNIVERSITY OF COLOMBO SCHOOL OF COMPUTING

DEGREE OF BACHELOR OF INFORMATION TECHNOLOGY (EXTERNAL)
Academic Year 2005/2006 – 3rd Year Examination – Semester 5

IT5502 : Image Processing and Vision

Structured Question Paper

01st April, 2006
THREE HOURS

To be completed by the candidate

BIT Examination Index No: ....

Important Instructions:

- The duration of the paper is **3 (Three) hours**.
- The medium of instruction and questions is English.
- This paper has **4 questions** and **16 pages**.
- **Answer all 4 questions**.
- **Write your answers** in English using the space provided **in this question paper**.
- Do not tear off any part of this answer book.
- Under no circumstances may this book, used or unused, be removed from the Examination Hall by a candidate.
- Note that questions appear on both sides of the paper.
  If a page is not printed, please inform the supervisor immediately.
- **Non-programmable Calculators may be used.**

Questions Answered

Indicate by a cross (×), (e.g. ☒) the numbers of the questions answered.

	Question numbers				
To be completed by the candidate by marking a cross (×).	1	2	3	4	
To be completed by the examiners:					

Index No: ………………...

1) (a) Explain the following terms with respect to digital image capturing.

(04 marks)

ANSWER IN THIS BOX

Sampling

In order to convert an analogue image to a form suitable to be represented in a computer, the analogue image coordinates should be digitized. This coordinate digitization is called image sampling.

Quantization

The amplitude values of an analogue image is continuous and finite. These amplitude values too should be digitized so that they can be represented in the memory of a computer. This amplitude digitization is called Quantization.

Image resolution

Image resolution represents the total number of pixels in an image.

Aliasing

If the image function is under sampled, then image may get corrupted and edges may be displayed in a jagged form. This phenomenon is called aliasing.

(b) "An intensity histogram of an image gives some useful clues about the shape of the objects in the image". Can you agree with this statement? Give your reasons.

(02 Marks)

ANSWER IN THIS BOX

No.

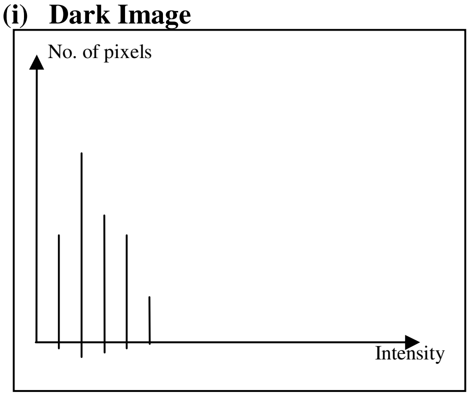
An intensity histogram shows the distribution of intensity values in an image.

It does not give an indication of shapes of objects in the image.

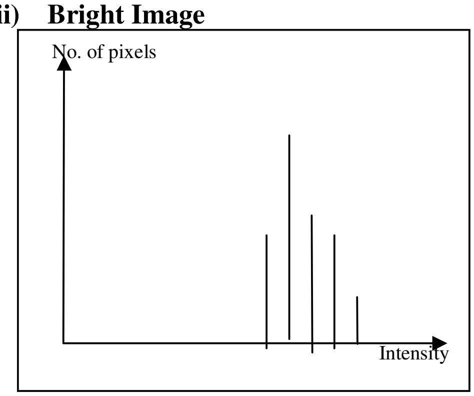
(c) Sketch examples of the intensity histograms of the following images.

(04 marks)

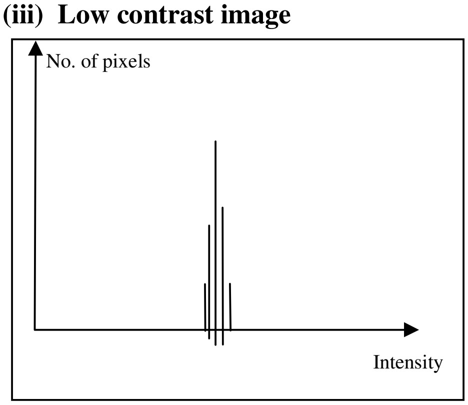
(i) Dark Image



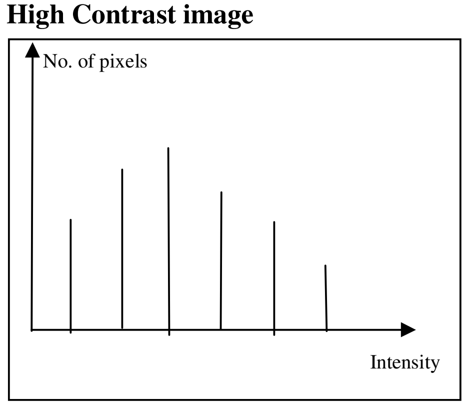
(ii) Bright Image



(iii) Low contrast image



(iv) High Contrast image



(d) An image has L grey levels (0,.., L-1) and k is a grey level in the image. r_k is defined as k/(L-1). In a histogram modification based image processing technique r_k is transformed into another level s_k using the formula

$$s_k=T(r_k)$$

Indicate the two conditions which the transformation T should satisfy.

(04 marks)

ANSWER IN THIS BOX

(i) $T(r_k)$ is single-valued and monotonically increasing in the interval $0 \le r_k \le 1$

(ii) $0 \le T(r_k) \le 1$ for $0 \le r_k \le 1$

(e) Explain the grey level transformation used in Histogram Equalization and indicate how the new grey levels can be calculated.

(05 marks)

Answer IN THIS BOX

In the histogram equalization technique, the grey level transformation $T(r_k)$ is defined as

$$T(r_k) = \sum_{i=0}^{k} P(r_i) \quad \text{= Cumulative probability up to k}$$

$$= \sum_{i=0}^{k} \frac{n_i}{n} = s_k$$

where n_i is the number of pixels in the image having grey level i and n is the total number of pixels in the image. $P(r_i)$ is the probability that the grey level i occurs in the image.

The grey level value k in the image is transformed to a new value round(s_k*L) in the histogram equalized image.

Continued…

(f) In some applications, it is useful to model the intensity histogram of an input image as a Gaussian probability density function of the form

$$P(r) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(r-m)^2}{2\sigma^2}\right)$$

where m and σ are respectively the mean and standard deviation of the Gaussian probability density function. The approach is to let m and σ be measures of average grey level and standard deviation of grey levels (contrast) of a given image. Considering the continuous Gaussian function, obtain the transformation function you would use for Histogram Equalization.

. **(06 marks)**

ANSWER IN THIS BOX

If the probability density function is a continuous Gaussian function, the transfer function under histogram equalization can be given as

$$T(r_k) = \int_0^k P(r)\,.dr$$

$$= \int_0^k \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(r-m)^2}{2\sigma^2}\right) dr$$

Continued…

2) (a) The discrete convolution of f(x,y) and h(x,y) of size MxN is denoted by f(x,y)*h(x,y). Give the equation for f(x,y)*h(x,y).

(02 marks)

ANSWER IN THIS BOX

$$f(x,y)*h(x,y) = \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)h(x-m, y-n)$$

(b) Give the equation for the discrete Fourier transform F(u,v) of an image with image function f(x,y) of size MxN.

(02 marks)

ANSWER IN THIS BOX

$$F(u,v) = \frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y) \exp\left(-j2\pi\left(\frac{ux}{M} + \frac{vy}{N}\right)\right)$$

Where $j=\sqrt{-1}$

(c) Give the equation for the discrete Inverse Fourier transform f(x,y) of F(u,v) of size MxN.

(02 marks)

ANSWER IN THIS BOX

$$f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{M-1} F(u,v) \exp(j2\pi(ux/M + vy/N))$$

Where $j=\sqrt{-1}$

(d) Give the transfer function for the Ideal Lowpass Filter H(u,v) of a Fourier function F(u,v) with cutoff frequency D_0. Explain all the symbols in your answer.

(04 marks)

ANSWER IN THIS BOX

$$H(u,v) = \begin{cases} 1 & if\ .D(u,v) \geq D_0 \\ 0 & if\ .D(u,v) < D_0 \end{cases}$$

where D(u,v) is the distance from origin to the point (u,v) of the frequency spectrum.

(e) Give the transfer function of a Butterwoth lowpass filter H(u,v). Explain all the symbols in your equation.

(04 marks)

ANSWER IN THIS BOX

$$H(u,v) = \frac{1}{1 + (D(u,v)/D_0)^{2n}}$$

where n is the order if the transformation.

(f) Explain giving details how the transfer function given in (e) can be used for smoothing an image.

(04 marks)

ANSWER IN THIS BOX

1. **Fourier Transform the image f(x,y) to obtain F(u,v).**
2. **Convolute F(u,v) and H(u,v)**

   to give G(u,v) = H(u,v)* F(u,v).

3. **Inverse Fourier transform G(u,v).**

(g) Give 3x3 filters suitable for the following image processing operations

(03 marks)

ANSWER IN THIS BOX

(i) Image smoothing by mean filtering

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

(ii) Detecting vertical edges

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

(iii) Detecting horizontal lines

-1	-1	-1
2	2	2
-1	-1	-1

(h) Convolute the filter given in g (i) with the following image segment and obtain the resultant values for the shaded area of the image. Indicate any assumption you would make.

10	10	200	10	20
10	10	20	20	20
10	20	20	10	20
10	20	200	10	20
10	20	20	10	20

(04 marks)

ANSWER IN THIS BOX

34	36	38
36	17	38
36	37	37

3) (a) An image has L grey-levels (0,.. ,L-1) and n pixels. Also note the following notations

n_k = the number of pixels having grey-level k (k=0,…L-1) .
r_k = k/(L-1).
$l(r_k)$ denotes the number of bits used to represent each value of r_k.

Give the equations for (i) the probability that r_k occurs in the image.
(ii) the average number of bits required to represent each pixel.

(02 marks)

ANSWER IN THIS BOX

(i) $P(r_k) = {}^{n_k}/_{n}$

(ii) $L_{avg} = \sum_{k-0}^{L-1} l(r_k)P(r_k)$

(b) An 8-level (0,..,7) image with size 64x64 has the following grey level distribution.

Grey-level	No. of pixels	Code 1	Code 2
0	790	000	11
1	1023	001	01
2	850	010	10
3	656	011	001
4	329	100	0001
5	245	101	00001
6	122	110	000001
7	81	111	000001

Code 2 is used in place of code1 to represent the respective grey levels. Fill the table given in the answer box and obtain the following.

(i) The compression ratio
(ii) The exact level of redundancy

(10 marks)

ANSWER IN THIS BOX

r_k	$P(r_k)$	Code 1 $l_1(r_k)$	Code 2 $l_2(r_k)$
0	0.19	3	2
1/7	0.25	3	2
2/7	0.21	3	2
3/7	0.16	3	3
4/7	0.08	3	4
57	0.06	3	5
6/7	0.03	3	6
1	0.02	3	6

L_{avg} using code 1 $= \sum_{k-0}^{L-1} l_1(r_k)P(r_k)$ **= 3**

L_{avg} using code 2 $= \sum_{k-0}^{L-1} l_2(r_k)P(r_k)$

= 2(0.19)+2(0.25)+2(0.21)+3(0.16)+4(0.08)+5(0.06)+6(0.03) +6(0.02)

=2.7

Compression ratio = 3/2.7 = 1.11

Exact level of redundancy $= 1 - \frac{1}{1.11}$ **= 0.099**

Continued…

(c) Outline the difference between lossy and lossless compression.

(05 marks)

ANSWER IN THIS BOX

(d) Consider the following image.

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

Indicating all the steps you use to derive, compress the above 8x8 image using

(i) Huffman code.
(ii) Run-length code.

(08 marks)

ANSWER IN THIS BOX

Continued…

Index No: ………………...

4) (a) “Although Vision seems like such an effortless and immediate faculty for humans and other animals, it has proven exceedingly difficult to automate.” Give two reasons to justify the above statement.

(04 marks)

ANSWER IN THIS BOX

Any of the following two:

(i) **The human vision system sees a scene as a three dimensional image while the computer sees it as a two dimensional image (2d Projection) Because of this reason many of details in the image will be lost.**

(ii) **The human vision system uses knowledge on scene/objects to make visual interpretations. Computers find it difficult to give general purpose interpretations on a visual scene.**

(iii) **Occlusions make it difficult to make interpretations.**

(b) A real time automated system needs to be designed and implemented to identify motor vehicles by recognizing the registration number displayed in the number plate. The registration number consists of 6 digits each of which is selected from [0, 1, 2, 3, 4, 5, 6, 7, 8, 9], separated by a hyphen as shown in the following figure.

The image of a number plate is captured through a digital still camera. Each digit of the registration number is then recognized from left to right using a trained Artificial Neural Network (ANN) and the recognized ordered collection of digits.

(i) Explain how image processing techniques can be used to segment each of the six digits.

(04 marks)

ANSWER IN THIS BOX

(i) Noise removal

(ii) Possible alignment

(iii) Binarization

(iv) Horizontal projection to segment the line containing six digits with hyphen

(v) Vertical segmentation to segment each digit

(ii) How would you prepare the images of each digit as the input to the ANN?

(04 marks)

ANSWER IN THIS BOX

Since the segmented image of digits contains rectangular frames of different dimensions, normalization of each image needs to be done to a predefined size (e.g. 8x10).

The normalized image needs to be converted to a column vector (row wise or column wise).

(iii) Explain the process of the preparation of training data.

(04 marks)

ANSWER IN THIS BOX

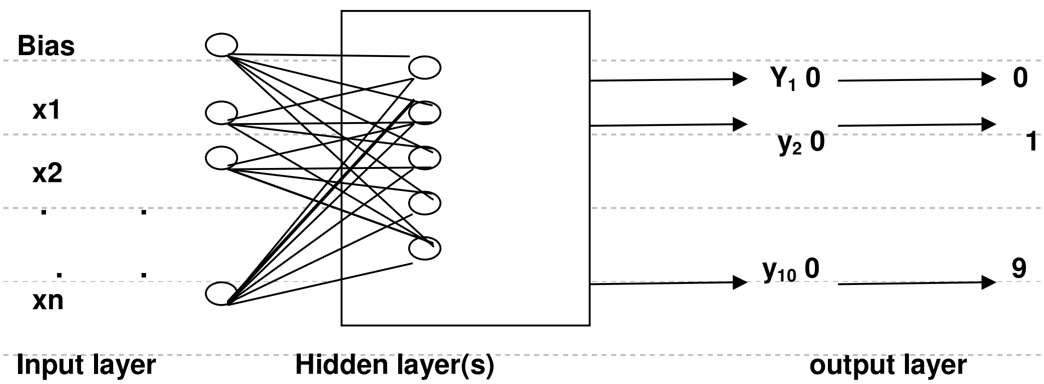
Training data should be represented as a fair sample of an actual data population.

A substantial amount of images from each digit (e,g. 100 0s , 100 1s etc) should be selected.

(iv)) Sketch the structure of the ANN you would use for this process and label the main components.

(05 marks)

ANSWER IN THIS BOX



(v) How do you evaluate the performance of the ANN? Justify your answer.

(04 marks)

ANSWER IN THIS BOX

- **A model 'Test Set' similar to 'Training Set' is selected for testing.**
- **Trained N/W is tested for the expected output classes using 'Test Set'**
- **Test data is then taken from real world angles and the N/W is tested for the expected output classes.**

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