UNIVERSITY OF COLOMBO, SRI LANKA

UNIVERSITY OF COLOMBO SCHOOL OF COMPUTING

DEGREE OF BACHELOR OF INFORMATION TECHNOLOGY (EXTERNAL)
Academic Year 2009/2010 – 3rd Year Examination – Semester 5

IT5503- Computer Graphics & Image Processing

Structured Question Paper
26th March, 2010
TWO HOURS

To be completed by the candidate

BIT Examination Index No: .....

Important Instructions:

- The duration of the paper is **2 (Two) hours**.
- The medium of instruction and questions is English.
- This paper has **4 questions** and **12 pages**.
- **Answer all 4 questions: Each question carries 25 marks.**
- **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. [X]) 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) Give 3x3 filters for the following image processing operations.

(08 marks)

ANSWER IN THIS BOX

(i) Neighbourhood averaging	**1/9 1/9 1/9** **1/9 1/9 1/9** **1/9 1/9 1/9**
(ii) Horizontal line detection	**-1 -1 -1** **2 2 2** **-1 -1 -1**
(iii) Horizontal edge detection	**-1 -2 -1** **0 0 0** **1 2 1**
(iv) Laplacian edge detection	**0 -1 0** **-1 4 -1** **0 -1 0**

(b) Define ‘edge’ in a digital image.

(04 marks)

ANSWER IN THIS BOX

In a digital image, ‘edge’ is defined as a position with intensity variation.

(c) Give a 3x3 filter which can be used for edge detection together with the filter given in 1 (a) (iii).

(03 marks)

ANSWER IN THIS BOX

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

(d) Give an algorithm to detect edges in an image using filters 1 (a) (iii) and 1 (c).

(10 marks)

ANSWER IN THIS BOX

1. **Apply convolution of the two filters to the whole image.**
2. **Repeat.**

Let Gx(x,y) and Gy(x,y) be the values of the convolution of the two filters at pixel (x,y)

Calculate overall gradient G(x,y) = | Gx(x,y)| + | Gy(x,y)|

If G(x,y) > T then (x,y) is an edge pixel,

where T is a user defined Threshold.

3. **Until all the pixels in the image are processed.**

2) (a) "The intensity histogram of a digital image gives some useful clues about the shapes of the objects in the image" Do you agree with this statement? Justify your answer.

(03 marks)

ANSWER IN THIS BOX

No.

Intensity histogram shows the distribution of intensity values in the image. It does not indicate the shapes of the objects in the image.

(b) What is the purpose of 'Histogram Equalization' operation?

(03 marks)

ANSWER IN THIS BOX

The purpose of 'Histogram Equalization' is to enhance an image if it has a small intensity range with a low contrast. In order to enhance the image using 'Histogram Equalization', the intensity values are transformed to obtain more equitable sharing of the intensity range.

(c) Describe the 'Histogram Equalization' operation with appropriate mathematical details.

(05 marks)

ANSWER IN THIS BOX

Let $P(r_i)$ = Probability of having grey-level i in the image
= n_i/n , where

n_i = number of pixels with grey-level i, and
n = number of pixels in the image.

Consider the transformation

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

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

Then the grey-level k is transformed to grey-level

round (S_k * L),

where L is the highest grey-level value in the image.

(d) Explain briefly the following two noise removal techniques.

(i) Neighbourhood averaging

(ii) Median filtering

(06 marks)

ANSWER IN THIS BOX

(i)

Neighbourhood averaging

A pixel value is replaced by the average of grey-levels in its defined neighbourhood including itself.

$$G(x,y) = 1/n \sum_{(r,s)\in S} f(r,s)$$

where S is the neighbourhood and n is the number of pixels in S

(ii)

Median Filtering

A pixel value is replaced by the median value in its defined neighbourhood.

(e) Calculate the new pixel values of the shaded pixel of the following image when the above two techniques are applied separately using a 3x3 neighbourhood. Give steps of your calculations.

2	4	6	5	4
4	6	5	6	5
7	6	0	4	6
8	7	7	7	7
9	7	8	9	8

(08 marks)

ANSWER IN THIS BOX

(i)

New value = (2+4+6+4+6+5+7+6+0)/9

= round (4.44)

= 4

(ii)

New value = median of (2, 4, 6, 4, 6, 5, 7, 6, 0)

= 5

3) (a) Explain the following terms

(i) Random Scan Devices

(03 marks)

ANSWER IN THIS BOX

Random Scan devices produce the graphics display by drawing lines and curves at the appropriate output positions. There is no scanning of the whole output area as in raster devices.

Eg. Plotters, Vector CRTs (Random Scan CRTs), Plasma Panel displays.

(ii) Raster Scan Devices

(03 marks)

ANSWER IN THIS BOX

Raster devices scan the whole output area in raster fashion (scan the whole output area row by row starting from the top) to produce the output.

Eg. Raster CRT, Laser Printer.

(b) Discuss advantages and disadvantages of both Random scan devices and Raster scan devices.

(06 marks)

ANSWER IN THIS BOX

Raster devices are good to produce high quality graphics with large numbers of colours. Easy to display filled areas.

Random Scan devices have limited number of colours, image size is small and difficult to display filled areas.

(c) What is hidden surface removal?

(03 marks)

ANSWER IN THIS BOX

It is the removal of those parts of a model which cannot be seen in the view being rendered. It is necessary to reduce the rendering time, which would otherwise be taken up with parts of the model which will not be seen because they are obstructed by other parts.

(d) Explain the z-buffer method of hidden surface removal.

(06 marks)

ANSWER IN THIS BOX

Two buffers of identical spatial resolution are used, one for the picture (colour values) and one for the depth (z values). The latter is initialised to its largest value ('infinity'). Each model facet (e.g. triangle) can be rendered independently.
When a facet is rendered, it produces a depth value and a colour value for each pixel. Check the depth value against the value in the z-buffer. If it is nearer than the z-buffer value, then update both the z-buffer value and the colour value in the two buffers, with the values just calculated. Otherwise discard both and move on to the next pixel.

(e) Describe two properties of Bezier curves?

(04 marks)

ANSWER IN THIS BOX

For any 2 points stated below, give 4 marks.

(i) Let P0, P1,….. , Pn be (n+1) control points. Then the Bezier curve is defined as:
$$P(u) = \sum P_k \, {}^nC_k \, u^k \, (1-u)^{n-k}$$
(ii) A Bezier curve passes through the starting and ending control points.
(iii) When the number of control points (n) increases, the degree of the polynomial increases making the use of the Bezier function computationally expensive.
(iv) The accuracy of the curve, too, decreases as the degree of the polynomial increases.
(v) If the number of control points is large, the curve can be approximated by a collection of cubic Bezier curve segments.
(vi) The positional continuity (zero order continuity) can be achieved by selecting
$$P3 = Q0$$
(vii) In order to get a smooth continuation, the tangential continuity (first order continuity) should be satisfied. i.e., The tangents to two curves at the joining point should be aligned. In order to achieve this continuity, the following condition should be satisfied.
$$(P3-P2) = k(Q1-Q0)$$ ***where k is a constant.***

4) (a) Explain briefly the reasons for using Homogeneous coordinates when representing transforms.

(03 marks)

ANSWER IN THIS BOX

It allows us to combine additive operations (translation) with multiplicative ones (scale, rotations) in the same matrix.

(b) What is the homogeneous form of the point (9, 6, 3, 3)?

(02 marks)

ANSWER IN THIS BOX

(3,2,1)

(c) Write down the 4x4 matrix for a general rotation about the y axis.

(03 marks)

ANSWER IN THIS BOX

$$\begin{bmatrix} \cos(\theta) & 0 & \sin(\theta) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(\theta) & 0 & \cos(\theta) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(d) What is the simplified 4x4 matrix for rotating an object around the y axis by 90˚?

(03 marks)

ANSWER IN THIS BOX

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(e) Prove that a uniform scaling ($S_x = S_y$) and a rotation form a commutative pair of operations but that, in general, scaling and rotation are not commutative operations.

(08 marks)

ANSWER IN THIS BOX

Transformation matrix for scaling is $\begin{pmatrix} S_x & 0 & 0 \\ 0 & S_y & 0 \\ 0 & 0 & 1 \end{pmatrix}$, and

that for a rotation (by an angle α) is $\begin{pmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

Scaling followed by a rotation is given by the

matrix: $\begin{pmatrix} S_x\cos\alpha & -S_x\sin\alpha & 0 \\ S_y\sin\alpha & S_y\cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$, and

a rotation followed by a scaling is given by $\begin{pmatrix} S_x\cos\alpha & -S_y\sin\alpha & 0 \\ S_x\sin\alpha & S_y\cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$.

Thus, the scaling and rotation would be commutative only if the scaling operation is uniform, i..e. $S_x = S_y$.

(f) Find the transformation matrix which corresponds to rotating an object through 45 degrees about the origin and then scaling by 2 in X and Y directions.

(06 marks)

ANSWER IN THIS BOX

Substituting in $\begin{pmatrix} S_x\cos\alpha & -S_y\sin\alpha & 0 \\ S_x\sin\alpha & S_y\cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$

$$\begin{pmatrix} 2\cos 45° & -2\sin 45° & 0 \\ 2\sin 45° & 2\cos 45° & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 1.41 & -1.41 & 0 \\ 1.41 & 1.41 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

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