UNIVERSITY OF COLOMBO, SRI LANKA

UNIVERSITY OF COLOMBO SCHOOL OF COMPUTING

DEGREE OF BACHELOR OF INFORMATION TECHNOLOGY (EXTERNAL)
Academic Year 2008/2009 – 3rd Year Examination – Semester 5

IT5503: Computer Graphics & Image Processing

Structured Question Paper
15th May, 2009
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 **16 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. ☒) 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:					

1) (a) Explain the two terms "Raster scan displays" and "Random scan displays" highlighting their advantages and disadvantages**.**

(06 marks)

ANSWER IN THIS BOX

Raster scan displays	Random scan displays
• **In these devices, an electric beam is swept across the screen, one row at a time from top to bottom.** • **Picture definition is stored in an area called a frame buffer.** • **These intensity values are retrieved row by row moving from top to bottom to produce the input/output as pixels.** • They c**an display quality graphics with large number of colours and filled areas.** • **However they Produce jagged lines.**	• **In these devices, the electron beam is directed only to the parts of the screen where a picture is to be drawn.** • **Pictures are drawn one line at a time without scanning the whole input/output area.** • **They are designed for line drawing applications and cannot display realistic shaded scenes.** • **They have a higher resolution than raster systems and Produce smooth line drawings.**

(b) Why are 3D points in computer graphics represented using a 4-vector coordinate system, known as **homogeneous coordinates?**

(03 marks)

ANSWER IN THIS BOX

To represent a point (x,y,z) in homogeneous coordinates, we add a 1 in the fourth column: (x,y,z) -> (x,y,z,1)
To map an arbitrary point (x,y,z,w) in homogenous coordinates back to a 3D point, we divide the first three terms by the fourth (w) term. Thus: (x,y,z,w) -> (x/w, y/w, z/w)
We can represent transformations such as rotation, scaling, and translation using homogeneous coordinates by using a 4x4 matrix. Note that if we were to simply restrict ourselves to a 3x3 matrix, we could not perform translations.In that case, we would have to explicitly add. But using a full 4x4 matrix, not only can we represent a translation using a 4x4 matrix, but we can derive all sorts of interesting properties, including easily translating back from screen coordinates to world coordinates.

(c) What is the general matrix for rotating an object around the y axis by an angle θ?

(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) Using the answer given in (c), write down the 4x4 matrix for rotating an object by 90 degrees around the y axis.

(03 marks)

ANSWER IN THIS BOX

$\theta = 90$, so $\cos(\theta) = 0$ and $\sin(\theta) = 1$. Thus, the matrix is

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

(e) Prove that, in general, a scaling followed by a rotation are not commutative operations. Identify the criteria for a scaling and a rotation to be a commutative pair of operations.

(10 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

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

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

Rotation and scaling gives $\begin{pmatrix} S_x \cos\alpha & -S_y \sin\alpha & 0 \\ S_x \sin\alpha & S_y \cos\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix}$

Thus, in general, a scaling followed by a rotation are not commutative operations. The scaling and rotation would be commutative only if the scaling operation is uniform, i..e. $S_x = S_y$.

2) (a) Compare the Digital Differential Analyzer (DDA) and Bresenham line drawing algorithms. What are the advantages of the Bresenham algorithm?

(04 marks)

ANSWER IN THIS BOX

DDA uses float numbers and uses operators such as division and multiplication in its calculation. Bresenhams algorithm uses integers and only uses addition and subtraction. Due to the use of only addition subtraction and bit shifting, Bresenham's algorithm is faster than DDA in producing the line.

(b) Consider the line which starts at location (5, 14) and ends at position (21, 2).

(i)How many pixels will there be in this line?

(02 marks)

ANSWER IN THIS BOX

16

(ii)Which is the primary direction?

(02 marks)

ANSWER IN THIS BOX

x

(iii)With the DDA algorithm, what will be the amount (amt in notes) added to the secondary component each time through the loop?

(02 marks)

ANSWER IN THIS BOX

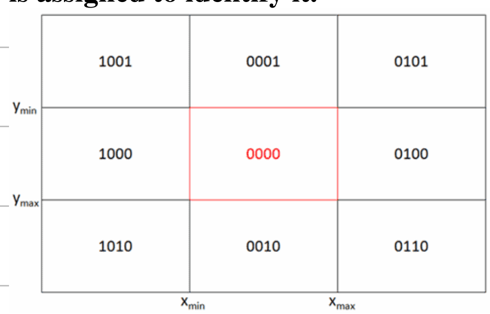
-3/4

(c) When using the Cohen-Sutherland line clipping algorithm, how do we check the outcodes to see if a line can be trivially accepted or rejected?

(06 marks)

ANSWER IN THIS BOX

Divide the complete 2D space into 9 areas where the window to be clipped against is in the middle and the other 8 are around it. To each of the nine regions, a 4-bit code is assigned to identify it.



For every endpoint of a line, we assign a region code to it depending on its position (x,y) (as convention we declare the leftmost bit as bit 3 and the rightmost bit 0) :

Bit 3 is 1 <=> Point lies **left** from the window : $x < x_{min}$

Bit 2 is 1 <=> Point lies **right** from the window : $x > x_{max}$

Bit 1 is 1 <=> Point lies **below** from the window : $y > y_{max}$

Bit 0 is 1 <=> Point lies **above** from the window : $y < y_{min}$

This idea allows us to handle two special cases easily. Therefore we have a line from point p1 to point p2:

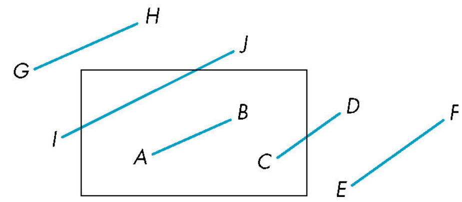
Case 1:
The line can be *trivially rejected* - that means it lies *completely* outside the window: code(p1) && code(p2) != 0.

Case 2:
The line can be trivially accepted - that means it lies *completely* inside the window: code(p1) || code(p2) == 0.

In all other cases, if the line cannot be trivially rejected or accepted, it has to be intersected. Therefore the intersection with the four window edges is calculated step by step, the line endpoints are updated with these new ones and the trivial cases are tested again after each intersection. The intersection itself is quite easy because the four window edges are the two horizontal lines y_{max} and y_{min} and the two vertical ones x_{max} and x_{min}. Can therefor calculate the intersection point with some thought and linear interpolation

(d) Which of the following five line segments can be trivially rejected on the first pass of Cohen-Sutherland line clipping? Explain your answer.

(03marks)



ANSWER IN THIS BOX

EF
Since both end points of the line segment EF belong to the same region.

Thus, they have similar outcodes.

(e) Briefly explain how each of the following is computed:
(i) Flat shading;
(ii) Gouraud shading;
(iii) Phong shading

(06marks)

ANSWER IN THIS BOX

(i)
Each triangle is given a fixed colour. This method is Fast

(ii) **Each vertex is given a colour (by averaging adjacent normals to get a surface direction; then applying lighting model). Bi-linear interpolation is used across the triangle. Gives illusion of curved surfaces, hiding the edges.**

(iii)

Similar to Gouraud but bi-linear interpolate normals. Apply lighting at every pixel. Highlights possible.

3) (a) Fill in the blanks in the following paragraph with suitable words:

(05 marks)

An analogue image has ____***continuous***________________ spatial coordinates x and y . Since light is a form of energy, the __________***amplitude***____________________ of the image at (x,y) must be _____***continuous***___________, non-zero and ____***finite***____________________. That is $0< f(x,y)<\infty$. To be suitable for computer processing, an image function f(x,y) must be digitized both __***spatially***________________and in ____***amplitude***_________________. Digitization of the _____***spatial***___________________ coordinates (x,y) is called _________***image sampling***__________________, and ________***amplitude***______________ digitization is called_____***grey-level quantization***_______________.

(b) Histogram Equalization is a widely used Image Enhancement technique. Give the grey-level transformation formula given in this technique explaining every symbol in your formula.

(04 marks)

ANSWER IN THIS BOX

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

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

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

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.

(c) Calculate the value of the shaded pixel of the following image segment when the following smoothing techniques are applied with 3x3 neighbourhood. Give the steps of your calculation.

(i) Neighbourhood averaging
(ii) Median filtering

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

(06 marks)

(i) Neighbourhood Averaging	***Average of 3x3 neighbouhood*** ***= (3+5+7+2+3+6+2+5+6)/9*** ***= 39/9*** ***=4.333*** ***=4 (app.)***
(ii) Median Filtering	***Median value of the 3x3 neighbourhood*** ***2,2,3,3,5,5,6,6,7*** ***= 5***

(d) Median filtering is considered as a better smoothing technique than Neighbourhood averaging. Give reasons for this.

(04 marks)

ANSWER IN THIS BOX

(1) It preserve the sharpness and location of edges.

(2) The blurring effect is low.

(e) Give the formula for the Fourier Transformation of a discrete function f(x,y),where x and y are discrete variables with $0 \leq x \leq M$, $0 \leq y \leq N$

(03 marks)

ANSWER IN THIS BOX

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

Where $j^2 = -1$

(f) If F(u,v) is the Fouier Transform of a digital image f(x,y), give a filter suitable for smoothing the image.

(03 marks)

ANSWER IN THIS BOX

$$H(u,v) = \exp\ (- D^2(u,v)/2\sigma^2)$$

or

$$H(u,v) = 1/\ (1+[D(u,v)/D0]^{2n})$$

where D(u,v) is the distance function.

4 (a) Define an ‘edge pixel’ in a digital image.

(03 marks)

ANSWER IN THIS BOX

Edge pixel means a pixel which shows a discontinuity of grey-level

(b) An image contains a circuit diagram with horizontal and vertical lines. Explain a technique to detect these lines.

(06 marks)

ANSWER IN THIS BOX

(1) Convolute the image with the following two masks

-1	_-1	-1
2	2	2
-1	-1	-1

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

(a) - Horizontal line detector **(b) – vertical line detector**

(2) The high output of (a) gives the horizontal lines and the high values of (b) give the vertical; lines.

(c) Give steps of detection of edges using the Laplacian operator

(05 marks)

ANSWER IN THIS BOX

(1) Convolute the image with digital Laplacian filter

0	*-1*	*0*
-1	*4*	*-1*
0	*-1*	*0*

(2) Identify zero-crossings as edge points.

(d) If n^1 and n^2 denote the number of information carrying units in two data sets which represent the same information, write the formula for *relative data redundancy* R_D of the first data set (the one characterized by n^1).

(03 marks)

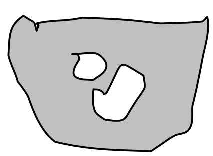
ANSWER IN THIS BOX

$R_D = 1 - 1/C_R$

where $C_R = n_1/n_2$

(e) Calculate the Euler Number of the following figure giving steps of the calculation.

(04 marks)



ANSWER IN THIS BOX

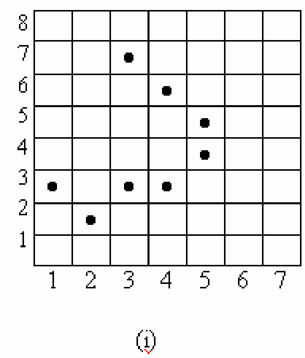
Euler Number (E) = number of connected components (C) - Number of holes (H)

= 1 -2

= -1

(f) The following figure (i) represents a boundary segment and figure (ii) represents a chaincode. How could one represent this boundary using the given chain code?

(04 marks)



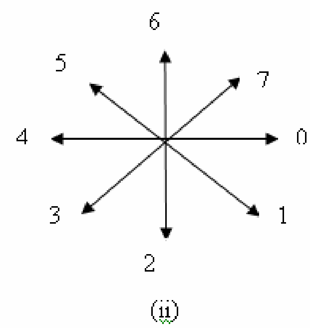


Figure (i) – Boundary segment

Figure (ii) - Chain code

ANSWER IN THIS BOX

(3,7) (1, 1, 2, 3, 4, 3, 5)

or

(1,3) (1, 7, 0, 7, 6, 5, 5)

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