CS_217 (2005-2006)

COMPUTER GRAPHICS I: IMAGE PROCESSING AND SYNTHESIS

(*Attempt 2 questions out of 3*)

Question 1

(a) Show, using diagrams, how each of the effects of *shadows*, *reflections*, and *transparency* can be achieved in ray tracing. Describe what recursive ray tracing is. Why does recursive ray tracing lead to *ray explosion*? How are objects defined, and how are ray-object intersections calculated? What is needed to calculate the colour according to the light source at a known intersection point?

[8 marks]

(b) Explain, with an example scene, why ray tracing can be computationally expensive. (You should include some example calculations). How can bounding volumes lead to better computational times? (Again use your example to demonstrate by showing some calculations). Discuss a hierarchy of bounding volumes constructed manually and the automatic method of organising a scene using an *octree*. In your discussion, you may wish to mention, to what depth is an octree created, how the octree accelerates ray tracing, how it can be used to ray trace a scene, what benefits the octree offers and the complexity of the ray-intersection algorithm when an octree is employed.

[8 marks]

(c) We looked at many different ways in which three dimensional objects can be represented digitally. Discuss the different approaches you are familiar with, and describe their advantages and disadvantages (including ease of rendering). Here are some keywords to help you: laser scanning, parametric surfaces, implicit surfaces, polygonal meshes (vertex list, pointers to a vertex list, pointers to an edge list, triangular strips), volume data, distance fields, blobby objects, particle systems. In your answer (of about $1\frac{1}{2}$ to 2 pages), you may wish to develop several approaches in depth, or give a broad overview of all the techniques.

[9 marks]

Question 2

(a) Given a 3x3 sub-image of pixels:

$$I_{ij} = \begin{bmatrix} p_{11} \, p_{12} \, p_{13} \\ p_{21} \, p_{22} \, p_{23} \\ p_{31} \, p_{32} \, p_{33} \end{bmatrix}$$

and a 3×3 filter kernel:

$$M_{ij} = \begin{bmatrix} m_{11} \, m_{12} \, m_{13} \\ m_{21} \, m_{22} \, m_{23} \\ m_{31} \, m_{32} \, m_{33} \end{bmatrix}$$

what is the equation for calculating the new intermediate value at pixel p_{22}?

Given the following 5×5 image (grey-level 0-255 image):

$$\begin{bmatrix} 100 & 110 & 120 & 130 & 140 \\ 120 & 120 & 130 & 130 & 140 \\ 130 & 140 & 150 & 150 & 160 \\ 140 & 150 & 150 & 160 & 170 \\ 150 & 160 & 170 & 180 & 190 \end{bmatrix}$$

and 3x3 filter kernel:

-1	-1	-1
-1	8	-1
-1	-1	-1

what is the result of applying the filter kernel to the image using the process of convolution? Your answer should cover the following items: give the intermediate values for all possible pixels, indicate what choices could be made at pixels the filter cannot be operated on, calculate the maximum and minimum intermediate values, show the normalisation equation, and use the normalisation equation to create the final pixel values.

What differences occur when a 4×4 filter is used, and when a 5×5 filter is used? What difference is made when a colour image needs to be convolved?

Name some applications of convolution. What is a hi-pass filter and what is a low-pass filter and when should they be used? Identify the filter given in the question.

[16 marks]

(b) Write a *detailed* description (1-1$\frac{1}{2}$ pages) about *lossy* compression techniques for still images and for video. You could include some or all of JPEG, JPEG2000, MPEG1, MPEG2, MPEG4, MJPEG, DV, DIVX, or any other *lossy* techniques with which you are familiar. **[5 marks]**

(c) What areas have been the major influences on the development of Computer Graphics? Select one of the areas, and write some details about it.

[4 marks]

Question 3

(a) (i) Show the 2D matrix used for scaling in two-dimensions a point (x, y) by (s_x, s_y) to give a point (x', y'). Also show the translation matrix for translating coordinates by (a, b), and the rotation matrix to rotate coordinates by an angle θ.

[3 marks]

(ii) What are homogenous coordinates? Show the new translation matrix which has changed from an addition with a 2D coordinate to a multiplication by the homogeneous coordinate.

[3 marks]

(iii) Also show the matrices used for rotation and scaling using homogenous coordinates.

[2 marks]

(iv) Multiply the scaling matrix by the translation matrix (such that scaling is applied first, followed by translation) to give P. Show that this one matrix yields an identical result when transforming a point (x,y,1) as applying the 2D matrices separately to point (x, y). Do this by first multiplying the point by your matrix P, and comparing this to multiplying the 2D point by the 2D scaling matrix followed by applying the 2D translation matrix.

[2 marks]

(b) Write precise descriptions ($\frac{1}{2}$ to 1 page each) about *all* three of the following topics:

(i) HSV and RGB colour models (including the diagram for each and the effect of changing parameters within the model);
(ii) Supersampling;
(iii) Event programming.

[9 marks]

Question continues on next page

(c) Discuss when it is useful to use dithering techniques.

Given the following 4×4 pattern dither matrix:

1	9	3	11
13	5	15	7
4	12	2	10
16	8	14	6

and the following 4×4 pixel image where each pixel has a value between 0 and 255:

150	160	160	170
160	160	160	170
150	160	170	150
160	170	180	180

Show the pattern displayed for that 4×4 region when using the pattern dither methods of *halftoning* and *dithering*. Show and explain your workings.

[6 marks]