UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2000

BEng Honours Degree in Computing Part III
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the Associateship of the City and Guilds of London Institute

PAPER C317

INTERACTIVE GRAPHICS

Tuesday 2 May 2000, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions

1. Computer Graphics Systems and Graphics Devices

a. What system parameters have to be set for device normalisation and what roles do they play in generating a 2D representation of a perspectively projected 3D scene?

b. Explain shortly what happens to the displayed image when

i. The size of the graphics window is increased.
ii. The size of the graphics viewport is increased.
iii. The focal length is increased.

c. Describe what a frame buffer is and identify a graphics algorithms which must use a frame buffer. What may be a disadvantage when a frame buffer is used instead of drawing directly on the screen?

d. Describe the construction of a hierarchical graphics database by using a practical example. What are the advantages in using a hierarchical instead of a flat graphics database? Does its use have any disadvantages?

e. Define and describe shortly the following graphics terms:

i. Dithering.
ii. 3D Clipping.
iii. Self hidden edges.
iv 2D spline.

(The five parts carry equal marks)

2. Raster Operations and Ray Tracing

a. Describe how a simple seed filling procedure works. What can be done to the algorithm of a seed filling procedure if a system has difficulties in executing it because of stack overflow?

b. Using any clear pseudo code, design an efficient algorithm to draw a straight line in the second octant (x1<=x2, y1<y2, x2-x1<=y2-y1) of the frame buffer when the two end points **P1**=[x1,y1] and **P2**=[x2,y2] are given in (integer) pixel co-ordinates. Show in detail the changes you have to make for this algorithm so that it works in the fifth octant (x2<x1, y2<=y1, x1-x2>=y1-y2).

c. One corner of a rectangular sheet in 3D space is given by the vector **P0**=[x0,y0,z0]. The other three corners are given by two vectors, **A**=[Ax,Ay,Az] and **B**=[Bx,By,Bz] as **P0+A**, **P0+B**, and **P0+A+B**, where **A** and **B** are mutually perpendicular. You have to determine whether the primary ray of easy perspective projection which goes through the origin (centre of view) and the centre of the graphics window ([0,0,1]) intersects this sheet or not.

i. Show the calculations you need using traditional ray/object intersections to determine whether the ray intersects the sheet. Estimate the total number of floating point operations you need for a ray which does intersect the sheet.

ii. Show the calculations you need to determine intersection by using translation and rotation of the vectors **P0, A, B,** and the ray such that the sheet is now in the plane of the graphics window and the sides of the rectangle line up with the *x* and the *y* axes. Estimate the total number of floating point operations you need in this case.

(The three parts carry respectively 20%, 30% and 50% of the marks)

3. Vector Equations and Opaque Solid Objects with Planar Faces (OSOPFs)

a. What is the difference between a convex and a non-convex OSOPF? How do the procedures for rendering a single OSOPF differ for convex and non-convex objects? Would it be an advantage to know in processing a non-convex OSOPF that all faces are made up of convex planar polygons?

b. Given the three vertices of a reflecting triangular sheet in 3D as **V1**=[x1,y1,z1], **V2**=[x2,y2,z2], and **V3**=[x3,y3,z3], show the required vector equations for the calculation of the reflection vector of a ray hitting the sheet at vertex **V1** when the point light source is at the origin. What would this vector be when **V1**=[-3,0,4], **V2**=[0,2,4], and **V3**=[1,3,4]?

c. A plane goes through the origin **O**=[0,0,0], the 3D point **P0**=[x0,y0,z0], and is parallel to the direction vector **d**=[dx,dy,dz].

i. The Cartesian equation of the plane is: A*x+B*y+C*z+D=0. Determine the parameters A, B, C, and D in terms of the known quantities x0, y0, z0, dx, dy, and dz.

ii. Determine the vector equation of the line which is the result of the intersection of the plane defined in c. and the *x-y* plane.

(The three parts carry respectively 30%, 40%, and 30% of the marks)

4. Shading and Colour

a. Show the necessary equation(s) for calculating the image intensities at purely diffuse surfaces in a practical 3D visualisation system in which light is generated only by coloured point light sources. Define all the terms used in your equation(s).

b. A 2D square with sides of 101 pixels is to be rendered by Gouraud shading. The intensity at the lower left vertex, or **V1**=[0,0] is equal to 40, proceeding clockwise, the intensity at vertex **V2**=[0,100] is 80, at **V3**=[100,100] is 100 and at **V4**=[100,0] is equal to 100.

   i. Gouraud shading is performed by dividing the square into two triangles, but there are two ways of doing this. For either one of the possible divisions determine the calculated intensities at five points: **P1**=[50,50], **P2**=[25,25], **P3**=[25,75], **P4**=[75,25], and **P5**=[75,75].

   ii. It is also possible to Gouraud shade the square directly. Calculate the intensities at the five points given in part i. when the square is processed. What would be the visual difference between using triangles and rendering the square as a whole? (Explain in your answer why there is a difference.)

c. Colour calculations are made without using the CIE diagram and the simple linear additive colour model which can be represented by a triangle. A colour shade is produced on a computer terminal screen by using integer intensities of 200 for red, 160 for green and 40 for blue within the 0-to-255 full range of intensities for each basic colour.

   i. What are the normalised *x, y, and z* values for this colour shade?

   ii. What are the *x, y, and z* values of the principal pure colour for this colour shade?

   iii. What are the *x, y, and z* values of the complement pure colour for this colour shade?

   iv. Estimate the saturation value for the original colour shade. (Show your work.)

   v. The original colour shade is to be displayed on the terminal but with maximum brightness. What integer intensities must be used for the three principal colours?

(The three parts carry respectively 30%, 40%, and 30% of the marks)