UNIVERSITY OF LONDON

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2001

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

Thursday 3 May 2001, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

1. Shading

a. What is the difference between Gouraud shading and ray tracing? When is one forced to use more complex algorithms like Phong shading? Explain the difference between shading an object which has large planar faces and one whose smooth surfaces are approximated by small planar facets.

b. Three vertices of a triangle in 3D are given below:

$$\mathbf{P_1} = [4,6,2] \qquad \mathbf{P_2} = [5,8,1] \qquad \mathbf{P_3} = [3,24,3]$$

The calculated image intensities at the three vertices are:

$$I_1 = 10, \qquad I_2 = 20, \qquad I_3 = 15$$

Derive an expression for the Gouraud shaded intensity of a point inside the triangle at the two-dimensional position **P** = [x, y] in terms of x and y. Where would you expect the highest and lowest intensity to be?

c. We place a point light source and the view point (centre of projection) at the origin. Assuming a light source intensity of 100 and a reflection factor of 80%, what would be the intensity at vertex $\mathbf{P_1}$ if it was due entirely to diffuse reflection?

The three parts carry, respectively, 30%, 40%, 30% of the marks.

2. Vector equations and matrix transformations

a. Why do we have to use four-dimensional homogeneous co-ordinates for transforming three dimensional scenes? How are position and direction vectors handled in homogeneous co-ordinate systems and why do they have different forms? Show the homogeneous scaling matrix and explain what its terms do.

b. Derive expressions from which the intersection line between an arbitrary plane and the x-y plane can be calculated. The arbitrary plane is given by one point in the plane **P1** and its normal **n1.** Calculate the parameters of this line by determining its direction **d3** and a point on the line **P3** for the numerical example:

P1 = [1,1,1]   **n1** = [-1, 0, -1]

c. An animation system requires software to perform a flying sequence. The centre of view is at the origin, but unfortunately, the principal direction of view is along the direction vector **v** = [1,1,0]. What homogeneous transformation matrix do you need to transform this system such that you could use easy projection? Describe how you could do the projection calculations without transformations.

The three parts carry, respectively, 30%, 40%, 30% of the marks.

3. Constructive Solid Geometry (CSG) Trees and their Ray Tracing

Two solid objects are in a scene. The first one is a sphere with centre at **C0** = [3,0,10] and radius R=5, the other one is a cube with its centre at **C1** = [2,0,8] and length of the sides L = 10. The faces of the cube are parallel with the x-y, x-z, and y-z planes respectively. The viewpoint is at the origin and the projection plane is parallel with the x-y plane at z=1.

a. A ray is fired from the origin in the +z direction. Calculate all the surface/ray intersections of this scene by the 3D intersection points along the ray and their surface normals.

b. Determine the 3D intersection point and the surface normal which can be seen at the origin when:

   i. The combined solid is the intersection of the sphere and the cube.

   ii. The combined solid is the union of the sphere and the cube.

   iii. The combined solid is created by subtracting the cube from the sphere.

   iv. The combined solid is created by subtracting the sphere from the cube.

c. Calculate the three dimensional min-max box for the union of the two solids. Using this min/max box as completely solid, an octree is constructed for the cubic "world" extending from vertex [-20,-20,-20] to [20,20,20]. How many of the sixty four small cubes at the second recursion level are "black", "white" or "grey"?

The three parts carry, respectively, 40%, 30%, 30% of the marks.

4. Device Normalisation and Raster Operations

a. Using graphics windows and viewports, what values must one know in order to be able to translate a scene in user co-ordinates to the screen? What is the visible effect on the displayed image when the graphics window is made very small? If we click the mouse on the screen which shows multiple viewports, what information must the system have in order to return the mouse position to the application program in user co-ordinates?

b. How does the error correcting line algorithm work? Show the algorithm in a convenient pseudo code in one quadrant for either the simple (REAL) or the Bresenham (INTEGER) case. How is this algorithm modified for a general curve; say for $y = x^2 / 10000.0$ for a 100x100 pixels screen area.

c. A terminal screen has 1201x1001 pixels in the horizontal and vertical directions respectively. A square graphics viewport with normalised corner co-ordinates [0.2,0.4] and [0.6,0.8] is opened. A line is to be drawn within this viewport which has projected pixel co-ordinates [300,200] to [500,700] . Determine the end points of the visible section of the line.

d. Show the seed filling algorithm and describe how it works. Explain how a graphics system would produce a solid white polygon on the screen using the seed filling algorithm with the polygon defined in user co-ordinates. Assume that the system starts with a completely black screen.

The four parts carry, respectively, 30%, 30%, 20% , 20% of the marks.

Candidate Number ______________________________

The CIE Diagram