UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1996

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

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

PAPER 3.17

INTERACTIVE GRAPHICS
Tuesday, May 7th 1996, 10.00 - 12.00

Answer THREE questions

For admin. only: paper contains
5 questions
3 pages (excluding cover page)

1. Vectors, Matrices and Transformations

1a. What are homogeneous coordinates, how are they used for 3D graphics and what is the relationship between a vector given in homogeneous coordinates and its 3D equivalent?

1b. A line goes through the origin and the point $\mathbf{P_1} = [4,0,3]$. Determine the homogeneous matrix which rotates this line into the y axis.

1c. Determine the intersection point between the line given in part 1b. and a plane which goes through the point $\mathbf{P_2} = [0,2,0]$ and contains the two direction vectors $\mathbf{d_1} = [\ 1,-1,0]$ and $\mathbf{d_2} = [0,0,1]$.

1d. The plane given in part 1c. is rotated by the 3D rotation matrix given below.

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

What is the Cartesian equation (Ax+By+Cz+D=0) of the rotated plane?

2. Ray Tracing

2a. Explain why ray tracing usually takes a long time and when primary rays are not sufficient for ray tracing. What are the best known methods of reducing computer execution time for ray tracing? Give one example when ray tracing is not sufficient for producing a realistic image.

2b. A ray starts at the origin and is parallel with direction vector $\mathbf{d}$. A square shaped facet is given by one of its corner points $\mathbf{P_1}$, two mutually perpendicular unit direction vectors $\mathbf{u_1}$ and $\mathbf{u_2}$ and the length of the side of the square L, all in 3D. Show in detail how the intersection between the ray and the square facet can be determined.

Hint: the other corners of the disk are at $\mathbf{P_2} = (\mathbf{P_1}+\text{L}\ \mathbf{u_1})$, $\mathbf{P_3} = (\mathbf{P_1}+\text{L}\ \mathbf{u_2})$, and $\mathbf{P_4} = (\mathbf{P1}+\text{L}\ \mathbf{u_1} + \text{L}\ \mathbf{u_2})$.

2c. You have written a procedure which determines the intersection between a ray and a square shaped disk based on the method above with calling sequence:

```
procedure InterSect(d, P1, u1, u2 : vector; L : real; var NIntersect : int;
                                               var IntsctPoint : vector)
```

where the integer variable "NIntersect" is set to 1 if there is an intersection and is set to 0 if there is no intersection. Describe how you could use this procedure to determine the intersection of a ray and faces of a cube whose one face is given by the square disk described above and whose other four vertices are:

$$\mathbf{P_{i+4}} = \mathbf{P_i} + \text{L}\ (\mathbf{u_1} \times \mathbf{u_2}) \qquad \mathbf{i = 1,2,3,4}$$

(Hint: You may assume that useful procedures such as translation, rotation of vectors and points are available).

3. Objects, Projection and Visibility

3a. The four vertices of a tetrahedron (a solid with four triangular planar faces) are: $\mathbf{P_1} = [6,4,2]$, $\mathbf{P_2} = [2,6,1]$, $\mathbf{P_3} = [24,16,4]$, and $\mathbf{P_4} = [12,24,3]$. We view this tetrahedron from the origin using perspective projection and a projection plane which is perpendicular to the x and y axes and which cuts the z axis at z=1. Sketch the wire frame of the projected object with properly labeled and scaled axes. Determine an internal point $\mathbf{P_{int}}$ and show where its projected 2D point is on your sketch.

3b. Determine by vector methods whether the triangular face formed by vertices $\mathbf{P_1},\mathbf{P_2},\mathbf{P_3}$ is visible from the origin or not. Show that if the visibility of one face is known then the visibility of the other three faces can be determined without any further calculations. Sketch the proper view of the object.

3c. How are min/max boxes in 3D and min/max rectangles in 2D used? What is the min/max box of this object in 3D and what is its min/max rectangle in 2D?

The three parts carry, respectively, 40%, 40%, 20% of the marks.

4. Raster Algorithms and Clipping

4a. Describe the general form of an error correcting differential curve generating algorithm. How was this general form used by Bresenham to develop an efficient algorithm for drawing lines?

4b. Using pseudo code, show a simple line drawing algorithm which is not an error correcting algorithm described in part 4a. and which will draw a line on the screen from pixel [500,500] to [502,506]. Which pixels will be turned on by your algorithm?

4c. The vertices of a polygon are stored in two real arrays X[] and Y[]. Describe how the line filling algorithm would work with this data.

4d. What is the difference between 2D and 3D clipping? Give one example when 2D and one when 3D clipping is necessary. In ray tracing both 2D and 3D clipping are used regularly. Show how the order of using 3D and 2D clipping could influence the execution time of the ray tracing calculations.

Turn over ...

5. Rendering Algorithms

5a. Assume that you have to render by Gouraud shading a large number of planar faceted objects. Describe how the painter's algorithm works and discuss its efficiency compared to a general direct method of rendering which always works. Under what conditions does the painter's algorithm give correct results? Sketch a situation when the painter's algorithm would fail and show both the result it produces and the correct one.

5b. Describe the simple Warnock subdivision algorithm. For what kind of scenes would you expect this algorithm to work well? What extensions and improvements can be made for the simple Warnock algorithm and thus improve its efficiency?

5c. Describe how the scan line algorithm works for rendering planar faceted objects. What do you attribute the known fact that scan line algorithms work efficiently for general scenes?

5d. Space division methods are used for speeding up ray tracing. Describe one method and show under what conditions you would expect it to be very efficient.

End of paper