UNIVERSITY OF LONDON

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1999

BEng Honours Degree in Computing Part III
BEng Honours Degree in Information Systems Engineering Part III
MEng Honours Degree in Information Systems Engineering Part III
BSc Honours Degree in Mathematics and Computer Science Part III
MSci Honours Degree in Mathematics and Computer Science Part III
MEng Honours Degree in Electrical and Electronic Engineering Part IV
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
Associateship of the Royal College of Science

PAPER 3.17 / I 3.16 / E 4.32

GRAPHICS ALGORITHMS

Wednesday, April 28th 1999, 10.00 – 12.00

Answer THREE questions

For admin. only:
paper contains 4 questions

1. Device Normalisation and Rasterisation

a What is device normalisation and what is it used for? Discuss how device normalisation is implemented for both input and output.

b Describe how a line is drawn on the screen in the first octant using the error correction algorithm in floating point form and when the program uses the system routine **PutPixel(x,y,col)**. Show how the floating-point algorithm is turned into the integer (Bresenham) algorithm for increased speed. Finally, discuss the modifications necessary for the integer routine to work with an image buffer rather than drawing the line directly on the screen.

c The general curve-drawing algorithm is used for the function $4x^2 - 2x - 2y = 0$, where the variables x and y are floating-point variables given in pixel coordinates. Starting at $[0,0]$ show how the algorithm calculates the next two points within the neighbourhood of the starting point. Draw the continuous curve in this small neighbourhood at sub-pixel level.

d Describe the simple algorithm (ignoring special cases) for clipping a line by a polygon in the image buffer using integer variables only. What are the special cases for which the simple algorithm may not work correctly?

All four parts carry equal marks.

2. Ray Tracing and Constructive Solid Geometry (CSG)

a What are the rendering effects which can be generated only by ray tracing and not by general rendering methods such as the z-buffer or scan line algorithms? What features of a general 3D scene cannot be rendered exactly even by ray tracing and why? What processing power would you need (approximate number of instructions per second to 10% accuracy) to provide real-time animation when a 3D scene containing 10,000 spheres of radius R is ray traced into an image buffer of 800x800 pixels, and only 1% of the spheres intersect each ray on average?

b Using easy perspective projection, ray tracing is used to render a scene which contains a large number of cylinders, all of the same size. The centre of the front circular disk of a cylinder has coordinates $C0=[x0,y0,z0]$, the radius of the cylinder is 100 pixels, its length is 1000 pixels and its axis is parallel to the z axis. Derive an expression in terms of $x0$, $y0$ and $z0$ for efficiently determining that a primary ray does not intersect the cylinder. Show your work in detail. Estimate the percentage of the cylinders which are not eliminated by your method and still do not intersect the ray.

c A regular tetrahedron is a solid object with four faces which are equilateral triangles. Define the object data required to specify this solid in a convenient form and the program needed to find the intersection points and the normals for using the tetrahedron as a primitive in a CSG system.

The three parts carry 30%, 30%, and 40% respectively

Turn Over ...

3. Visible Edges and Surfaces for Opaque Solid Objects with Planar Faces.

a Explain what the term "self hidden" means. How are the visibility of edges and surfaces connected for a convex object? How are they connected for non-convex objects? Describe the algorithm which can be used for the line drawing of a general scene which contains several non-convex objects without the use of a z-buffer or the scan line algorithm.

b What is the z-buffer and how is it used for rendering three dimensional scenes? An animated three-dimensional scene is made up of a large number of black triangular sheets and very small spheres. The planes of the triangular sheets are parallel to the projection plane and easy perspective projection is used. The small spheres appear as single white dots of one pixel size on the screen. The background is black and the sheets are not visible. Show in detail how the rendering of this scene could be done using a z-buffer.

c How does Warnock's original space-division algorithm work? What type of 3D scenes can be rendered efficiently with Warnock's method? Give a specific example for which Warnock's algorithm would be faster than most other methods. Give a specific example for which Warnock's algorithm would have very poor performance and explain the reasons why it would be slow.

d Describe the main features of the scan line algorithm used for rendering 3D scenes which contain opaque solid objects. It is often the case that in practice scan line algorithms are faster than most other rendering methods. Give reasons for this. Explain why in most cases generally available rendering software systems use the z-buffer algorithm rather than the faster scan line algorithm?

All four parts carry equal marks.

4. Shading and Colour

a i Describe the difference between directly mapped colour and palette-based colour generation. Give examples.

A program generates a colour shade on the screen with integer values in the range 0 to 255 and with colour components Red=50, Green=30, Blue=20.

ii What are the normalised (CIE diagram) component values x, y, z for this colour shade?

iii What are the normalised component values of the pure colour content of the colour shade given in part ii? What visible colour would this represent on the screen?

iv Estimate the saturation value from the normalised component values. Show your work. Will the colour on the screen represented by components in part ii be bright or have a washed-out appearance?

b A quadrangular face is projected onto the graphics window and has projected vertices ***P1****=[X1,Y1]*, ***P2****=[X1,Y2]*, ***P3****=[X2,Y2]*, and ***P4****=[X2,Y1]* where the components are given in pixel coordinates.

i Derive an expression for the Gouraud grey intensity values inside the rectangle $g(x,y)$ in terms of the components $X1$, $X2$, $Y1$, $Y2$ and the grey intensities at the four vertices which are $g1$, $g2$, $g3$ and $g4$ respectively.

ii The intensities at the four vertices of part i are $g1$=0.2, $g2$=0.4, $g3$=0.4 and $g4$=0.0. Determine the two-dimensional coordinates of three separate points within or on the border of the rectangle in terms of $X1$, $Y1$, $X2$ and $Y2$, where the intensity is equal to 0.3.

iii Discuss the difference between Gouraud and Phong shading. What other information is needed to determine the grey shades within this rectangle by Phong shading?

The two parts carry 40% and 60% respectively.

End of Paper