UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1996

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
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 I3.16 / M319 / E4.32

GRAPHICS ALGORITHMS

Wednesday, May 8th 1996, 10.00 - 12.00

Answer THREE questions

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

1a The Error Correction Algorithm for line generation in the first octant on a bi-level raster display is given by:

Differential := $(y2 - y1)/(x2 - x1)$;
$x := x1$; $y := y1$;
Set-Pixel(x, y);
Error := 0;
while $x < x2$ **do**
    Error := Error + Differential;
    if Error $>= 0.5$
    then
        $y := y + 1$;
        Error := Error -1;
    end (*if*);
    $x := x + 1$;
    Set-Pixel(x, y);
end (*while*);

Explain carefully what changes are needed to avoid the use of real arithmetic. Write a pseudo-code for the Bresenham algorithm in the first octant.

b Explain briefly how you can modify the Bresenham algorithm for the first octant to generate lines in all octants.

c What is meant by the term anti-aliasing? Explain how the technique of super-sampling can be used for anti-aliasing a line on a screen equipped with gray shades. Illustrate by an example of a straight line segment.

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

2a Describe the z-buffer algorithm for shading the facets of a solid opaque object with planar faces in perspective projection.

b A solid opaque object is bounded by the following five planes with the corresponding colours,

- $z = 10$, red;
- $x + z - 2 = 0$, blue;
- $x - z + 4 = 0$, green;
- $y = 10$, yellow;
- $y = -10$, brown.

The object is viewed with perspective projection from the origin, the plane of projection being the plane $z = 1$.

i) Find the coordinates of the six vertices of the object.

ii) Using the technique in the z-buffer algorithm, determine the colour of the pixel at $(1/2, 0, 1)$.

The two parts carry, respectively, 50%, 50% of the marks.

Turn over...

3a A tetrahedron (a solid opaque object with four triangular facets) is defined by four vertices

$$\mathbf{V1} = (1, 0, 0) \quad \mathbf{V2} = (0, 2, 2) \quad \mathbf{V3} = (0, 0, 3) \quad \mathbf{V4} = (3, 10, 3).$$

Determine a point which is definitely in the interior of the object.

b Determine the outside normal to the facet containing $\mathbf{V1}$, $\mathbf{V2}$ and $\mathbf{V3}$.

c Determine whether or not the facet in part b is visible in the following two cases.

(i) The object is viewed from the origin.

(ii) The object is viewed from the point $(2, -1, -2)$.

d The object is now rotated anti-clockwise around the line $y = z, x = 0$ by 90 degrees. Determine the transformation matrix for this rotation and the new coordinates of the vertex $\mathbf{V4}$.

The four parts carry, respectively, 10%, 25%, 25%, 40% of the marks.

4a The three vertices of a visible facet of a solid object are given by

$$\mathbf{V1} = (0, 0, 5) \quad \mathbf{V2} = (0, 3, 3) \quad \mathbf{V3} = (8, 0, 4).$$

We use perspective projection with the view point at the origin and the plane $z = 1$ as the plane of projection.

Calculate the coordinates $\mathbf{V1}'$, $\mathbf{V2}'$ and $\mathbf{V3}'$ of the projection of the three vertices $\mathbf{V1}$, $\mathbf{V2}$ and $\mathbf{V3}$.

b The calculated light intensities at $\mathbf{V1}$, $\mathbf{V2}$ and $\mathbf{V3}$ are $I1$, $I2$ and $I3$ respectively. Using Gourad shading, compute the light intensity at a two-dimensional point (x, y) on the projection plane which lies in the projected facet.

c Write down, in parametric form, the position vector of an arbitrary point on the projected edge $\mathbf{V1}' - \mathbf{V2}'$ and find its back projection.

d The average normals at the vertices $\mathbf{V1}$ and $\mathbf{V2}$ are $(1, 1, 0)$ and $(0, 1, 1)$ respectively. Using Phong shading with back projection, compute the light intensity at an arbitrary point on the projected edge $\mathbf{V1}' - \mathbf{V2}'$ due entirely to diffuse reflection if the incident light has intensity I and direction $(1, 0, 1)$, and the reflective coefficient is R.

The four parts carry, respectively, 10%, 30%, 30%, 30% of the marks.

Turn over...

5a The base of a cylinder has center at $(0, 7, 0)$ and radius 5. The outward normal to this base is $(0, 0, -1)$ and the cylinder has height 6. A ray originates from the origin in the direction $(1, 1, 1)$.

i) Determine the first intersection of the ray with the cylinder and the contained span of the ray with the cylinder.

ii) Compute the outward surface normal at the first intersection point.

iii) If the cylinder is a perfect mirror, explain in detail how you would determine a secondary ray which starts at the above intersection point and reflects the first ray.

b Explain briefly how ray tracing can be done in a CSG model for the intersection of two primitive objects.

c A solid object is defined as the intersection of the cylinder in part a and the sphere of radius $\sqrt{74}$ centred at $(10, 5, 3)$. Using the CSG model obtain the contained span for the intersection of the ray in part a and this object.

The three parts carry, respectively, 60%, 20%, 20% of the marks.

End of paper