UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2000

MSc in Computing Science
MEng Honours Degree in Electrical Engineering Part IV
BEng Honours Degree in Information Systems Engineering Part III
MEng Honours Degree in Information Systems Engineering Part III
BEng Honours Degree in Mathematics and Computer Science Part III
MEng Honours Degree in Mathematics and Computer Science 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
This paper is also taken for the relevant examinations for the Associateship of the Royal College of Science

PAPER M317=I3.16=E4.32

GRAPHICS

Tuesday 16 May 2000, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions

1. Shading of Planar Surfaces

Any point in a triangle can be written in vector form as:

$$\mathbf{P} = \mathbf{P_1} + \alpha(\mathbf{P_2}-\mathbf{P_1}) + \beta(\mathbf{P_2}-\mathbf{P_1})$$

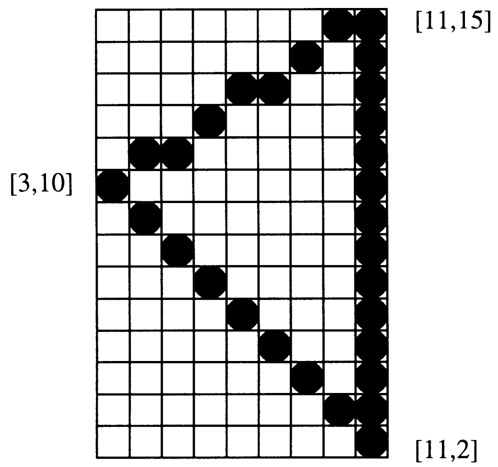
where

$\mathbf{P_1}$, $\mathbf{P_2}$ and $\mathbf{P_2}$ are the vertices of the triangle and α and β are scalar parameters in the range [0..1]

a. Given that the calculated light intensities at the vertices have been found to be I1,I2 and I3 respectively, derive an expression for the intensity at a general point **P** in the triangle using Gouraud (interpolation) shading.

b. Given that the vertices of the triangle are given in two dimensions in integer pixel addresses, explain how a fast algorithm can be used first to calculate the shade values at the edge pixels and then to calculate the shade values of the interior points.

c. A projected triangle has pixel addresses as shown in the figure:



The intensities calculated for the vertices are:

Point	Intensity
[3,10]	90
[11,15]	166
[11,2]	10

Using your algorithm of part b calculate the intensity at pixel [8,9].

d Check to see that your formula in part a gives you a similar result.

e. Explain why Gouraud shading may not be effective for rendering highly specular surfaces.

The five parts carry equal marks

2. Bezier Curves

A two dimensional Bezier curve is to be drawn using the following four knots.

$\mathbf{P_0} = [0,0]$ $\mathbf{P_1} = [2,5]$ $\mathbf{P_2} = [4,3]$ $\mathbf{P_3} = [5,1]$

a. Sketch the curve by constructing the point for which the parameter μ=0.5 using Casteljau's algorithm. Label each construction point on your sketch appropriately.

b. A straight line between two points **Pi** and **Pj** has equation $\mathbf{P} = \mu\mathbf{Pj} + (1-\mu)\mathbf{Pi}$. Use this fact to derive the general equation of a Bezier curve with four knots by working backwards from the point on the Bezier curve constructed with Casteljau's algorithm, writing each construction point in terms of its endpoints.

c. Re-arrange the curve equation as a cubic polynomial in μ and hence find the maximum value of y for the four knots given above.

d. Show that the slope of the curve at the start of the curve is the same as the slope of the line joining points $\mathbf{P_0}$ and $\mathbf{P_1}$

The four parts carry equal marks

3. Ray tracing.

a Explain which effects can be achieved with ray tracing and how these effects are created. Which effects can not be created with ray tracing?

b Explain the difference between primary rays and secondary rays.

c Describe the use of two space subdivision methods for ray tracing and describe how they can be used to accelerate ray tracing.

d A ray originates at point **P** and is parallel with unit direction vector ***d***. A square shaped facet is given by one of its corner points **P1**, two mutually perpendicular unit direction vectors ***u1*** and ***u2*** and the length of the side of the square s. Show in detail how you can calculate the intersection between the ray and the square shaped facet. Note that the other corners of the square can be written as **P2** = **P1** + s ***u1***, **P3** = **P1** + s ***u2***, and **P4** = **P1** + s ***u1*** + s ***u2***.

e. In a concrete example, a ray starts at the origin and has a direction vector ***d***=(0, 0, 1). The square shaped facet is defined by **P1**=(-1, -1, 10) and ***u1***=(1, 0, 0), ***u2***=(0, 1, 0). The sides of the square have length s=5. Calculate whether the ray intersects the square shaped facet.

The five parts carry, respectively, 20%, 10%, 20%, 40%, 10% of the marks.

4. Volume rendering

a Explain the concept of volume rendering. Describe the differences between image-order and object-order volume rendering.

b For an interactive application you need to volume render a volume of size 512 x 512 x 512. Your rendered image should be of size 128 x 128. Decide whether to use image-order or object-order rendering and determine the complexity for the two rendering techniques.

c Describe the problem that can occur with object-order rendering and how "splatting" can be used to solve this problem.

d Explain the role of the ray transfer function in volume rendering and describe four different ray transfer functions.

e In a medical image data set, scalar values from 100 to 200 represent skin, 200 to 300 represent muscle and 300 to 400 represent bone. Define a color transfer function which will show skin as green, muscle as red and bone as white.

f In the example of part e, what kind of artifact may appear in your image if you first perform interpolation and then classification? How can it be avoided?

The six parts carry, respectively, 20%,10%, 20%,25%,15%, 10% of the marks.