UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2003

MEng Honours Degree in Information Systems Engineering Part IV
MSci Honours Degree in Mathematics and Computer Science Part IV
MEng Honours Degrees in Computing Part IV
MSc in Advanced Computing
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 C417=I4.46

ADVANCED GRAPHICS AND VISUALISATION

Monday 12 May 2003, 14:30
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

1 Volume rendering

a. Sketch the contour cases for the marching squares algorithm. Describe what kind of ambiguities can arise and how these ambiguities can be resolved.

b. Consider the over operator for compositing colours and opacities. What is the colour of the result of compositing two polygons, each with an opacity of 0.5? What is the opacity of compositing three of these polygons?

c For volume rendering using the method of splatting, we must choose an appropriate footprint or splatting kernel.

(i) What kind of general shape should this kernel have and why?

(ii) What happens to the rendered image if the kernel is too big?

(iii) What happens to the rendered image if the kernel is too small?

(iv) Roughly how big should this kernel be?

d With a careful choice of transfer functions, direct volume rendering can be made to emulate isosurfacing.

(i) What is the ideal transfer function that theoretically achieves isosurface rendering?

(ii) In practice, an exact isosurface rendering is difficult to achieve. Why?

(iii) Given that you know which isovalue you want to see, which transfer function would you choose to approximate that isosurface rendering and why?

(iv) What would be the visual differences between isosurface rendering with the transfer function from the previous answer and conventional isosurface rendering, e.g. via marching cubes?

e In a medical image dataset, scalar values from 100 to 200 represent skin, 200 to 300 represent muscle, and 300 to 400 represent bone.

(i) Define a colour transfer function that will show skin as green, muscle as red and bone as white.

(ii) What kind of artifact may appear in your image if you first perform interpolation and then classification, and how can it be avoided?

The five parts carry, respectively, 25%, 15%, 20%, 20% and 20% of the marks.

2 Image-based rendering

a The plenoptic function plays a key role in many image-based rendering techniques.

(i) Briefly explain the idea of a 7D plenoptic function in image-based rendering and describe its parameters.

(ii) In the lightfield approach, the plenoptic function is reduced to 4D. Briefly explain how this is achieved and what consequences this reduction from 7D to 4D has?

b The lightfield rendering approach is fundamentally different from traditional rendering and modelling approaches in computer graphics.

(i) Describe how in the lightfield rendering approach the data is acquired, stored, and used for rendering novel views.

(ii) Give one example for which rendering graphical scenes with lightfield rendering is not suitable. Explain why lightfield rendering in this case would be problematic.

(iii) Give one example for which rendering graphical scenes with lightfield rendering is particularly suitable. Explain why lightfield rendering in this case would be advantageous.

c You have been asked to design a light-field based rendering which enables the observer to view a sculpture from all sides. In an approximate 2D diagram, show a configuration of uv- and st-planes that is suitable for this purpose. In another 2D diagram show the ray space coverage obtained by this configuration of uv- and st-planes. What resolutions should the uv- and st-planes have?

d Explain how geometric information about graphical scenes can be used in lightfield rendering to improve the quality of the rendering.

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

3 Implicit Surfaces

a An implicit surface h(x,y,z) is defined as a combination of two spheres f(x,y,z) and g(x,y,z) with equations:

$$f(x,y,z) = \sqrt{(x^2 + y^2 + z^2)} - 5 = 0$$
$$g(x,y,z) = \sqrt{((x-5)^2 + y^2 + z^2)} - 5 = 0$$
$$h(x,y,z) = f(x,y,z)*g(x,y,z)$$

Sketch the intersection of the surface with the plane z=0 and indicate which points are inside the surface and which are outside.

b An implicit surface is constructed by combining a vertical cylinder and a horizontal plane. The equations are as follows:

$$f(x,y,z) = \sqrt{(x^2 + z^2)} - 10 = 0$$
$$g(x,y,z) = y = 0$$

The surfaces are to be blended using elliptical blending over a distance of 2 units using the blending equation:

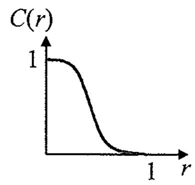
$$h(f(x,y,z),g(x,y,z)) = (f(x,y,z) - 2)^2/4 + (g(x,y,z) - 2)^2/4 - 1$$

(i) Calculate the surface coordinates in the plane z=0 for y = 0, 0.5, 1, 1.5, 1.

(ii) Sketch the intersection of the surface with the plane z=0 in the region around the origin (-15<x,y<15)

c Describe how you would render the surface of part b using ray tracing.

d An implicit surface is defined as an iso-surface. There are three control points at positions (0,0,0), (0,1,0) and (1,1,0). The potential field around each of these three points, in terms of the radial distance, is defined by a non-parametric cubic spline ($C(r) = ar^3 + br^2 + cr + d$) shown below.



The surface is defined as $\Sigma_i C_i(r) - 0.16 = 0$ where the index i indicates the control points.

(i) Find the equation of the function C(r)
(ii) Determine whether the point (0.5,0,0.5) is inside or outside
(iii) Sketch the intersection of the surfaces with the plane z=0 assuming that C(0.75)=0.16.

The four parts carry, respectively, 20%, 25%, 25% and 30% of the marks.

4 Uniform, Non-uniform and Rational B-Splines

The B-Spline blending curve is defined by the following four cubic splines:

$$b_1(\gamma) = (1/6)*\gamma^3$$
$$b_0(\gamma) = (1/6)*(1 + 3\gamma + 3\gamma^2 - 3\gamma^3)$$
$$b_{-1}(\gamma) = (1/6)*(4 - 6\gamma^2 + 3\gamma^3)$$
$$b_{-2}(\gamma) = (1/6)*(1 - 3\gamma + 3\gamma^2 - \gamma^3)$$

They are combined to form the curve as follows:

$$B(\tau) = \begin{cases} 0 & |\tau| \geq 2 \\ b_1(\tau+2) & -2<\tau\leq -1 \\ b_0(\tau+1) & -1<\tau\leq 0 \\ b_{-1}(\tau) & 0<\tau\leq 1 \\ b_{-2}(\tau-1) & 1<\tau<2 \end{cases}$$

A curve is to be drawn using the following five knots:

$\mathbf{P}_0 = [0,0]$, $\mathbf{P}_1 = [2,2]$, $\mathbf{P}_2 = [4,1]$, $\mathbf{P}_3 = [3,-1]$, $\mathbf{P}_4 = [5,0]$

a Given that the curve is a uniform B-Spline with equation:

$$P(\mu) = \sum_{i=-1}^{5} \mathbf{P}_i \, B(4\mu - i)$$

(i) Calculate the values of the two phantom knots, $\mathbf{P}_{-1}$ and $\mathbf{P}_5$, that will make the curve interpolate the end points $\mathbf{P}_0$ and $\mathbf{P}_4$.

(ii) Sketch the curve

b The curve is changed to a non-uniform B-Spline with the following equation:

$$P(\mu) = \sum_{i=0}^{4} \left\{ \mathbf{P}_i \, B(4(\mu - \mu_i)) \right\} \Big/ \sum_{i=0}^{4} B(4(\mu - \mu_i))$$

The knots located at the following intervals of the parameter μ.

	Knot location μ_i
P_0	0
P_1	0.125
P_2	0.25
P_3	0.5
P_4	1

(i) Compute the coordinate of the spline for the parameter $\mu = 0.5$.

(ii) Calculate the values of μ for which the curve passes exactly through the start point. (Hint: It will be negative.)

c The curve is changed to a Non-Uniform rational B-Spline with equation:

$$P(\mu) = \sum_{i=0}^{4} \left\{ W_i \mathbf{P}_i B(4(\mu - \mu_i)) \right\} / \sum_{i=0}^{4} B(4(\mu - \mu_i))$$

The weights and knot spacing defined by the following table.

	Knot location μ_i	Weight
P_0	0	1
P_1	0.125	1
P_2	0.25	2
P_3	0.5	1
P_4	1	1

Calculate the co-ordinate of the curve for $\mu = 0.5$.

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