UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2001

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
BSc Honours Degree in Mathematics and Computer Science Part III
MSci 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

Wednesday 16 May 2001, 10:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators required

1. Transformations of Graphics Scenes

a. In a computer graphics animation scene an object is defined as a planar polyhedron. The object is located at position P = [0,0,20], and the scene is drawn, as normal, in perspective projection with the viewpoint at the origin and the view direction along the z-axis. Calculate the transformation matrix that will shrink the object in size by a factor of 0.8 towards its centre point.

b. In a different animation, the object defined in part a is required to rotate clockwise while shrinking. In each successive frame it is to rotate by 15^{o} while shrinking to 0.8 of its original size. The rotation axis is to be the z axis, and the shrinkage is, as before, towards the object's centre. Given that $Cos(15^{o}) = .97$ and $Sin(15^{o}) = .26$, what is the transformation matrix that will achieve this animation?

c. For another sequence the object is to shrink, as defined in part a, and to drop vertically downwards by 1 unit each frame. If the animation sequence is made up of a number of frames, numbered consecutively from zero, what is the transformation matrix that should be applied at frame n?

d. The scene is to be viewed from a moving viewpoint specified by its position **C** and a left handed viewing coordinate system [***u,v,w***]. At one point in the animation the view direction is ***w*** = [-1, 0, 0], and the viewpoint is given by **C** = [50,10,-10]. Given that the view is in the horizontal plane (***v*** = [0,1,0]) find the value of ***u***.

e. Hence, or otherwise, find the viewing transformation matrix.

The five parts carry equal marks

2. Colour Representation

A special page marked *the CIE diagram* will be provided for your answer to parts of this question. Please ensure that you write your candidate number on it and hand it in with your answer book.

A graphics card is set to a colour representation where 24 bits are used for each pixel. These are configured normally with 8 bits representing the red value, 8 bits representing the green and 8 representing the blue. A polygon in the scene is coloured using: r=150, g=99 and b=51.

a. Calculate the corresponding [x,y] coordinate in the CIE diagram and plot the point on the diagram provided, labeling it P.

b. By constructing a line on the CIE diagram, estimate the wavelength of the fully saturated colour, which when mixed with white will produce the colour of part a.

c. Using your CIE diagram estimate the saturation of the colour of part a.

d. Using your CIE diagram estimate the wavelength of the complement colour to that found in part b.

e. A monitor has the following [x,y] CIE coordinates for its phosphors:
   Red = [.6,.35]
   Green = [.27,.6]
   Blue = [.15,.07]

   Plot the area that includes all possible colours that can be displayed on the CIE diagram.

f. Explain briefly why the shape of the CIE diagram must be convex.

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

3. Ray tracing and CSG

A scene contains the following three geometric primitives:

A sphere **A** with center $\mathbf{p}_s = (0, 0, 8)$ and radius $r = 5$
A sphere **B** with center $\mathbf{p}_s = (0, 0, 9)$ and radius $r = 3$
A sphere **C** with center $\mathbf{p}_s = (0, -3, 8)$ and radius $r = 2$

A ray originates at the viewpoint $\mathbf{p}_v$ and passes through the viewing plane at $\mathbf{p}_i$.

a. Show in detail how you can calculate whether a ray has any intersections with a sphere with radius r centered at $\mathbf{p}_s$.

b. In a concrete example the viewpoint is at $\mathbf{p}_v = (0, 0, -10)$ and the ray passes through the viewing plane at the origin $\mathbf{p}_i = (0, 0, 0)$. Calculate the intersections of the ray with the spheres above.

c. Describe how a CSG tree is constructed and how it can be pruned during ray tracing.

d. Calculate the intersections and surface normal vectors of the ray for the following objects, assuming the spheres defined above.

i $A + B + C$
ii $A - B$
iii $(B - A) \cap C$
iv $A + (B \cap C)$

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

4. Volume-rendering

A volume is rendered using an image-order volume rendering algorithm. A ray sent out from a pixel on the viewing plane encounters the following scalar samples with increasing distance from the viewpoint: 22, 80, 45, 40, 120, 100. The opacity transfer and colour transfer functions are defined as follows:

α	C_{red}	C_{green}	C_{blue}	Scalar value
1.0	0.5	0.6	1.0	if $30 \leq x < 70$
0.5	0.5	0.2	0.5	if $70 \leq x < 90$
0.5	1.0	1.0	0.0	if $90 \leq x < 150$
0.0	0.7	0.3	1.0	if $10 \leq x < 30$

a. Calculate the pixel colour using back-to-front rendering as well as front-to-back rendering.

b. Explain how the marching cubes algorithm can be used to generate isosurface data.

c. Sketch the contour cases for the marching triangles algorithm. How many different cases are there? Are there any ambiguities?

d. Describe the main problem that can occur using the marching cubes algorithm? How would you try to avoid this problem? What are the advantages and disadvantages of your approach?

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

Candidate Number ________________________________

The CIE Diagram