UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1997

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 3.19 / I3.16 / E4.32

GRAPHICS ALGORITHMS

Wednesday, April 30th 1997, 2.30 - 4.30

Answer THREE questions

For admin. only: paper contains 5 questions

Section A *(Use a separate answer book for this Section)*

1 Raster Algorithms

a i) Give code or pseudo-code to implement Bresenham's algorithm to draw a straight line from [0,0] to [x,y] where x and y are integers (pixel numbers) and $0 \leq x \leq y$.

ii) What are the qualitative features of Bresenham's algorithm that contribute to its efficiency?

b It is desired to draw a graph of the equation $y = x^2 / 1000.0$ on a 1001×1001 pixels screen from x1 to x2 when $0 \leq x1, x2 \leq 1000.0$, and $x2 > x1$. (Here, x1 and x2 are expressed as floating point numbers.)

i) Without any efficiency consideration, give the simplest code or pseudo-code that you would use to draw this curve.

ii) Modify your code such that it executes as fast as possible.

c Describe how you would fill a triangle given by vertices [x1,y1], [x2,y2], and [x3,y3] with a solid colour. The vertices are given in terms of pixel numbers.

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

2 Shading

A triangle in an image plane has vertices **P1** = [x1,y1], **P2** = [x2,y2], **P3** = [x3,y3] and is Gouraud shaded. The intensities at the respective vertices are I1, I2, and I3. Given y1=y2=0, y3≠0, x1≠x2 and I1=0

a Express the shading value at point **P** = [x,y] located inside the triangle in terms of x, y, x1, x2, y3, I2, and I3.

b Prove that the lines on which the Gouraud shaded pixels have constant intensity values are parallel to each other.

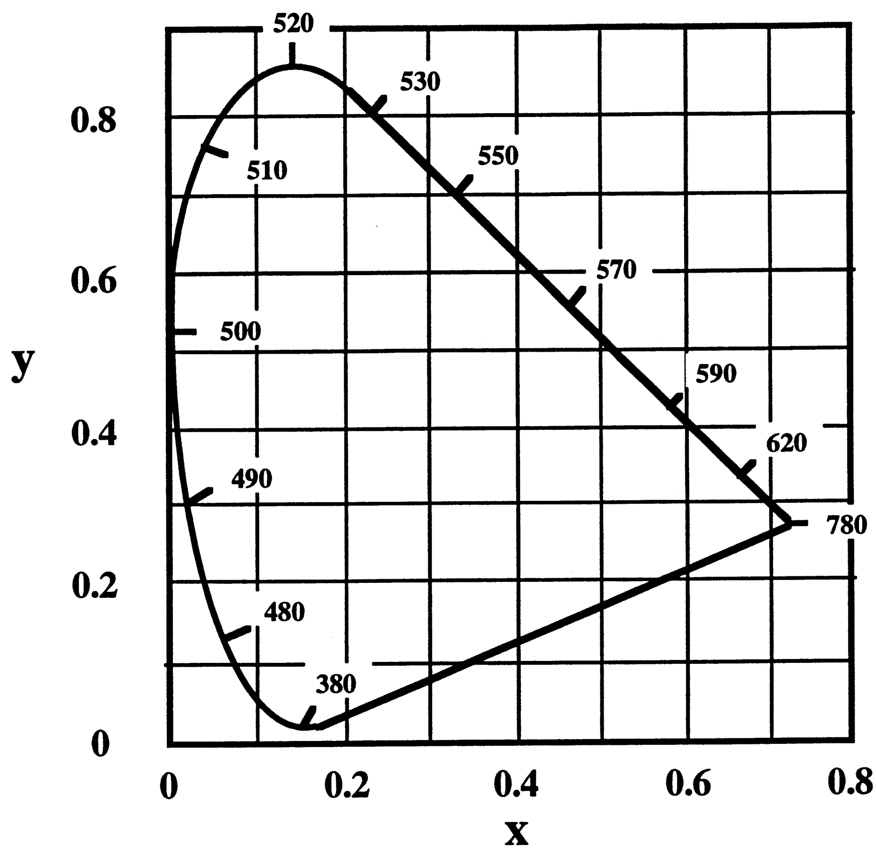
c Describe the difference between Gouraud shading and Phong shading techniques.

d The image plane is at z=2. Using Phong shading instead of Gouraud shading, show the code or pseudo-code of an algorithm that renders this triangle when a point light source with intensity 100 is placed at the origin [0,0,0]. (The speed of the algorithm is not important.)

The four parts carry respectively 40%, 20%, 10%, 30% of the marks.

3 Colour

The standard CIE Chromaticity diagram is shown below.



a What are the normalised x (red) y (green) and z (blue) values for a pure colour defined by physics as having a wavelength of 590 nanometers and what are the [x,y,z] values of its complement colour?

b What are the normalised [x,y,z] values for a colour shade whose principal colour is at 590 nanometers and its saturation is 50%? (Show your work.)

c Explain the reasons why the addition of three practical colour light sources (red, green and blue) cannot match all possible practical colour lights even when the intensities of all the four light sources can be adjusted. Can matching be done by any means?

d The three colour guns of a practical computer display terminal are calibrated by the standard CIE values as:

Red [x,y,z] = [0.8,0.1,0.1] ; Green = [0.2,0.7,0.1]; Blue = [0.2,0.2,0.6].

When executed, the procedure **SetColour(R,G,B:float)** produces a colour shade on the screen with the intensities of the three basic colours ranging from 0 to 1.0. What are the normalised CIE [x,y,z] values of the colour shade which appears on the screen after the call **SetColour(0.1,0.1,0.1)** is executed?

Turn over ...

Section B (*Use a separate answer book for this Section*)

4 Ray Tracing

A primary ray for **orthonormal** (i.e. parallel) projection starts at point S=[Sx,Sy,Sz] and is in the +x direction (unit direction vector [1,0,0]). A square shaped planar facet with length of sides L is defined by one position vector **P0** and two perpendicular unit direction vectors **u1** and **u2**. Thus the four vertices of the facet are:

V1=P0 ; V2=P0+L*u1 ; V3=P0+L*u2 ;
V4=P0+L*(u1+u2)

a Show in detail how one can determine whether the ray intersects the facet and if it does how one calculates the intersection point. Assuming 1 microsecond for a floating point operation, estimate how long the test and the intersection calculations take.

b Show in detail how one may use a bounding box test for rapid determination of those rays which miss the facet. If the bounding box values are pre-calculated and each floating point operation takes 1 microsecond, estimate how long this test takes for N rays and under what conditions the min-max tests save time.

c Describe the needed modifications of the calculations in parts a and b when secondary rays are used. Estimate the time needed to handle secondary rays.

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

5 CSG Trees

Two rectangular solid boxes are present in a graphics scene with all their faces parallel to the x-y, x-z, or y-z planes, respectively. The vertices of the two solid boxes are:

Vertices	Box 1	Box 2
1	[-2,0,0]	[-3,1,1]
2	[-2,4,0]	[-3,3,1]
3	[2,4,0]	[1,3,1]
4	[2,0,0]	[1,1,1]
5	[-2,0,4]	[-3,1,3]
6	[-2,4,4]	[-3,3,3]
7	[2,4,4]	[1,3,3]
8	[2,0,4]	[1,1,3]

For the following questions, assume that *parallel* projection is intended.

a A ray is cast from point [-4,2,2] in the +x direction. Show the solid spans of the ray for the following CSG constructions. (Show your work.)

i) The combined solid is the union of the two boxes.

ii) The combined solid is the intersection of the two boxes.

iii) The combined solid is **Box 1** minus **Box 2**.

b The world cube is defined by opposite corner vertices [-4,0,0] and [4,8,8]. Space subdivision produces eight equal sub-cubes with length of their side equal to 4. Show how these sub-cubes are numbered and then for the "black", "gray" and "white" subdivision tree determine for each sub-cube whether it is "black", "gray" or "white". How many subdivisions do you need for having no "gray" sub-cubes at the lowest level and how many white and black sub-cubes are there at this level?

c Describe how a CSG tree is constructed and how it is pruned.

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

End of paper