

UNIVERSITY OF LONDON  
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1997

BEng Honours Degree in Computing 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*

PAPER 3.17

INTERACTIVE GRAPHICS

Wednesday, April 30th 1997, 2.30 - 4.30

*Answer THREE questions*

For admin. only: paper contains 5  
questions

## 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  $1001 \times 1001$  pixels screen from  $x_1$  to  $x_2$  when  $0 \leq x_1, x_2 \leq 1000.0$ , and  $x_2 > x_1$ . (Here,  $x_1$  and  $x_2$  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  $[x_1, y_1]$ ,  $[x_2, y_2]$ , and  $[x_3, y_3]$  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

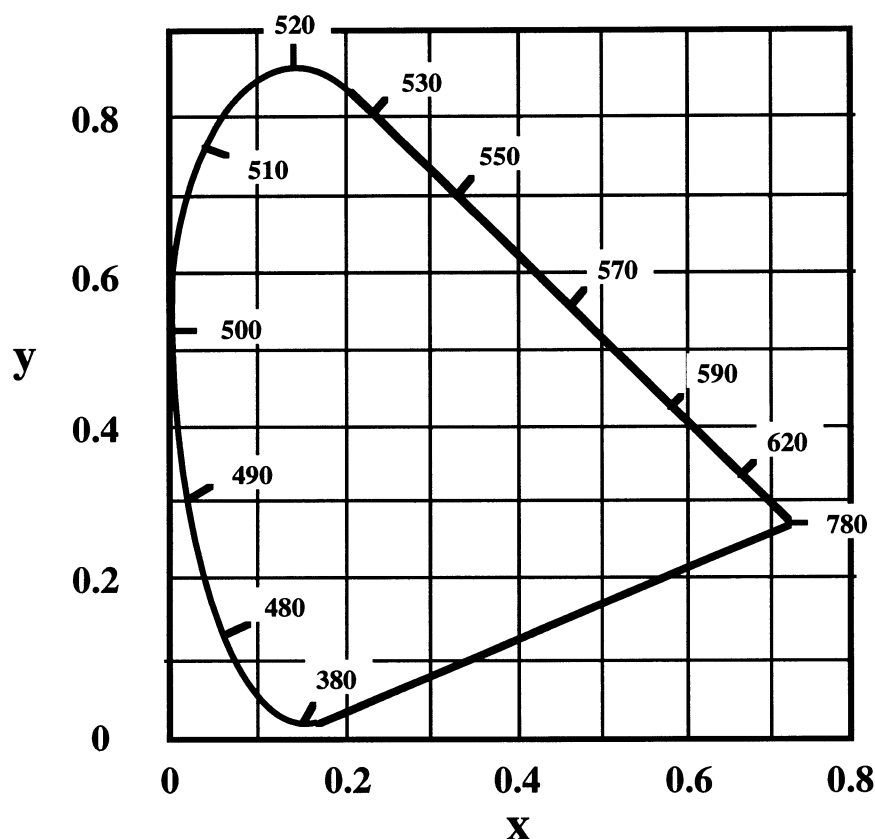
A triangle in an image plane has vertices  $\mathbf{P1} = [x_1, y_1]$ ,  $\mathbf{P2} = [x_2, y_2]$ ,  $\mathbf{P3} = [x_3, y_3]$  and is Gouraud shaded. The intensities at the respective vertices are  $I_1$ ,  $I_2$ , and  $I_3$ . Given  $y_1 = y_2 = 0$ ,  $y_3 \neq 0$ ,  $x_1 \neq x_2$  and  $I_1 = 0$

- a. Express the shading value at point  $\mathbf{P} = [x, y]$  located inside the triangle in terms of  $x$ ,  $y$ ,  $x_1$ ,  $x_2$ ,  $y_3$ ,  $I_2$ , and  $I_3$ .
- b. Prove that the lines on which the Gouraud shaded pixels have constant intensity values are parallel to each other.
- c. The image plane is at  $z=2$ . Show the code or pseudo code of an algorithm which renders this triangle by Phong shading 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 three parts carry respectively 40%, 20%, 40% of the marks.*

### 3. Colour

The standard CIE Chromaticity diagram is shown below.



- 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?
- 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).
- 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?
- 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?

*The four parts carry equal marks.*

*Turn Over ...*

#### 4. Ray Tracing

A primary ray for **orthonormal** (i.e. parallel) projection starts at point  $S=[S_x, S_y, S_z]$  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  $P_0$  and two perpendicular unit direction vectors  $u_1$  and  $u_2$ . Thus the four vertices of the facet are:

$$V_1=P_0 ; \quad V_2=P_0+L*u_1 ; \quad V_3=P_0+L*u_2 ; \quad V_4=P_0+L*(u_1+u_2)$$

- 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.
- 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.
- 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]

- 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.)
  - The combined solid is the union of the two boxes.
  - The combined solid is the intersection of the two boxes.
  - The combined solid is **Box 1** minus **Box 2**.
- 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?
- 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*