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# THE BRITISH COMPUTER SOCIETY

THE BCS PROFESSIONAL EXAMINATION
Advanced Diploma

## COMPUTER GRAPHICS

18th April 2000 – 2:30p.m. – 5:30p.m.
Answer THREE questions out of FIVE. All questions carry equal marks.
Time: THREE hours.

*The marks given in brackets are **indicative** of the weight given to each part of the question.*

**1.** A drawing package requires the implementation of scan conversion algorithms to display primitive shapes. The algorithms need to be computationally efficient and their output free from visual irregularities. Your answers to each section of this question should take these considerations into account and diagrams should be provided wherever appropriate.

*a)* Two straight lines are displayed using the basic scan conversion algorithm. One line is horizontal and the other has a gradient of 1. Both lines are drawn using 10 pixels. Explain why the two lines have different intensities. Give two mechanisms that can be used to eliminate this difference. **(9 marks)**

*b)* Given that the pixel at co-ordinates (x, y) lies on a circle centred at (0,0), using considerations of symmetry state which other pixel co-ordinate points are known to lie on the circle.

Which values of x and y, which lie on the circle, cannot have their additional points generated in this way? Give the reason why and state the additional points that can be generated from each of these values. **(8 marks)**

*c)* A quarter circle of radius R is scan converted using an equation where x is incremented from 0 to R in unit steps. This scan conversion algorithm fails to meet the requirements of the drawing package. Give a detailed description of each of its failings. **(8 marks)**

**2.** A two-dimensional drafting package makes use of a number of transformations to manipulate primitive shapes. In each of the following, draw a diagram to show the effect on a rectangle of the transformations in question and derive the transformation matrix that needs to be applied to each of its vertices.

*a)* Describe the basic two-dimensional transformations for translation, rotation, scaling and shearing. **(5 marks)**

*b)* Describe the sequence of transformations that are required to rotate an object about one of its vertices. **(8 marks)**

*c)* Define the terms *window* and *viewport*. **(4 marks)**

*d)* Describe the transformations required to display an object which lies inside a window on to a viewport on the display. **(8 marks)**

**3.** A drawing package needs to display complex curves, which are implemented using parametric cubic splines. In each case draw a diagram and clearly label any control points and direction vectors that are required to define the curve.

*a)* Assuming that two spline segments meet at a point $P_1$, describe the conditions that must be met for the curve to be $G^1$ continuous.

What conditions need to be met to make the curve $C^2$ continuous? **(5 marks)**

*b)* Describe the Bézier spline curve and its input controls. **(4 marks)**

*c)* Describe the B-spline curve and its input controls. **(6 marks)**

*d)* Describe the Hermite spline curve and its input controls.

Show how a family of Hermite spline curves, which have the same end points, can be generated by varying one of the controls.

Show how two Hermite spline curves can be combined to produce a $C^1$ continuous curve. **(10 marks)**

**4.** *a)* A PC equipped with a TV tuner receives a colour signal which, once demodulated, results in a colour difference signal. The colour difference model can be converted to the RGB model needed for the monitor's CRT by a mapping matrix, $\underline{M}$, thus:

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \underline{M}. \begin{pmatrix} Y \\ U \\ V \end{pmatrix}$$

[*If you are more familiar with the YIQ model you may treat the YUV model as identical for the purposes of this question.*]

*i)* Describe the components in the YUV colour difference model. **(4 marks)**

*ii)* Explain, giving your reasons, which elements of the mapping, $\underline{M}$, you would expect to be positive and which negative. **(5 marks)**

*b)* Colour models such as YUV and RGB are unsatisfactory from the point of view of a user trying to select a colour.

*i)* Why is this? **(4 marks)**

*ii)* Describe a colour model which would be more intuitive for such a user. **(4 marks)**

*c)* A colour inkjet printer with a separate nozzle for black is to be used to produce hard copies of the images displayed on the PC's monitor.

*i)* Describe a suitable colour model for the printer. **(3 marks)**

*ii)* How would a colour defined in the monitor's RGB model be converted to the printer's model? **(5 marks)**

**5.** *a)* Visual realism can be added to computer generated images by ray tracing.

*i)* Describe the general principle underlying ray tracing. **(3 marks)**

*ii)* Outline an algorithm for simple ray tracing of primary rays. **(5 marks)**

*iii)* Why is a parametric representation of a ray preferable to other vector representations? **(3 marks)**

*iv)* What are secondary rays and what lighting phenomena can be modelled with them? **(4 marks)**

*b)* Radiosity methods provide an alternative approach to visual realism.

*i)* What is the radiosity of a surface? **(2 marks)**

*ii)* How do radiosity methods avoid the main limitation of ray tracing? **(3 marks)**

*iii)* Radiosity methods are computationally very expensive. What paradigm shift enables the progressive refinement approach to generate a first approximation and then gradually increase its accuracy as time permits? **(3 marks)**

*iv)* The early stages in progressive refinement are likely to yield overly dark images. How can this problem be alleviated? **(2 marks)**