UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2002

MEng Honours Degree in Electrical Engineering Part IV
MEng Honours Degree in Information Systems Engineering 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

PAPER C417=I4.46

ADVANCED GRAPHICS AND VISUALISATION

Wednesday 1 May 2002, 14:00
Duration: 120 minutes

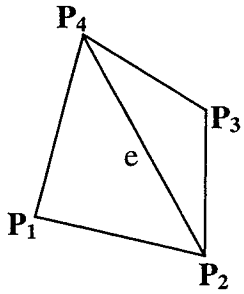
Answer THREE questions

Paper contains 4 questions
Calculators required

1. Delaunay Triangulation

a. In a Delaunay triangulation the objective is to maximise the minimum angle. With the aid of a suitable diagram construct an example where this heuristic rule gives a good result.

b. For the quadrilateral given below explain how you would determine whether the edge e is legal or illegal.



c. A set of points in 3D space is projected onto the XY plane, and a Voronoi diagram is constructed. The first four projected points, in order, are (10,10), (20,10), (20,0) and (0,0). Using these points as examples explain fully how the Voronoi diagram is constructed as each new point is processed. Briefly describe the algorithms and data structures required to implement it.

d. Sketch the Delaunay triangulation for the points given in part c.

e. Under what circumstances does the Voronoi diagram fail to give a triangulation? What must be done to create a Delaunay triangulation.

f. The first step in constructing a three-dimensional Delaunay triangulation is to map the points onto a suitable plane. How would you adapt this step of the algorithm for the case where the points were clustered around the surface of a sphere, for example in building a terrain map of a whole planet.

The six parts carry, respectively, 15%, 10%, 35%, 10%, 55% and 15% of the marks.

2. Spline Curves

A 2D spline curve is defined using the following knots:

	x	y
$\mathbf{P}_0$	1	0
$\mathbf{P}_1$	2	4
$\mathbf{P}_2$	5	1
$\mathbf{P}_3$	6	7
$\mathbf{P}_4$	9	8

A parametric spline curve is to be constructed, in the usual way, with the value of the parameter μ at point $\mathbf{P}_i$ being $i/4$.

a. Make an accurate labelled sketch of the Casteljau construction for the point half way along the Bezier curve.

b. Using the data from part (a) make an accurate sketch of the Bezier Curve. You may use the same diagram as part (a) if you wish, but you may find it neater to draw a new one.

c. Using the Casteljau construction derive the equation pair of the Bezier curve in terms of the parameter μ . ($x=f(\mu)$, $y=g(\mu)$).

d. Using your answer of part (c) find the exact coordinate of the spline for the point given by $\mu = 0.5$.

e. Show that the gradient of the curve at the end is along the direction of the line joining the last two points ($\mathbf{P}_3$,$\mathbf{P}_4$).

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

3. Volume Visualization

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: 230, 250, 320, 20, 175, 340. The opacity transfer and colour transfer functions are defined as follows:

α	C_{red}	C_{green}	C_{blue}	Scalar value
1.0	1.0	0.0	0.0	if $0 \leq x < 100$
0.2	0.0	0.0	1.0	if $100 \leq x < 200$
0.5	1.0	1.0	1.0	if $200 \leq x < 300$
1.0	0.0	1.0	0.0	if $300 \leq x < 400$

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

b. Describe four different ways for accelerating volume rendering with front-to-back ray casting.

c. Consider volume rendering with opacity transfer functions. If the opacity transfer function becomes very narrow and steep, the result is an isosurface rendering. How is this strategy different from marching cubes?

d. In parallel processing, partitioning is used to split a computational problem into separate, mostly independent, pieces for multiple computers to work on simultaneously. Suppose we had a large volume dataset that we wished to visualize using parallel processing. Describe the partitioning schemes which could be used to speed up the following three volume visualization techniques:

   i Marching cubes algorithm.
   ii Volume rendering using ray casting.
   iii Volume rendering using splatting.

The four parts carry, respectively, 40%, 25%, 20% and 15% of the marks.

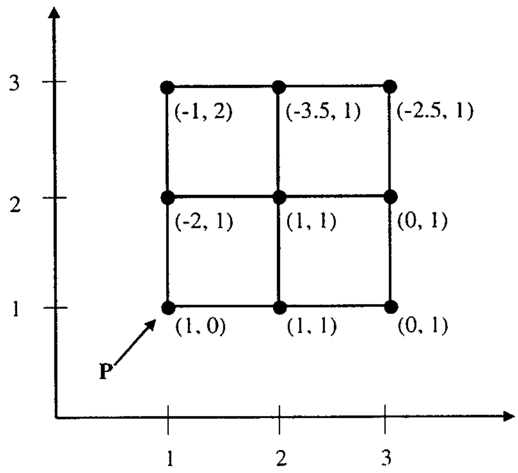
4. Fundamental concepts of visualization

a. Briefly describe the main characteristics of the following four datasets:

i structured points
ii structured grid
iii unstructured points
iv unstructured grid

b. Illustrate the concept of a visualization pipeline for generating isosurfaces from a structured points dataset whose attributes are scalar values. What are the purpose and the key properties of each object in the visualization pipeline?

c. Streamlines are a common visualization technique for vector fields. In the concrete example shown below, a vector field is defined by a 3 x 3 structured points dataset whose vector-valued attributes are shown in brackets for each point. Using Euler integration with a time step of $\Delta t = 0.5$ and linear interpolation, show in detail how you can calculate the path of a streamline starting at point **P** = (1, 1) through the dataset.



d. Describe which characteristics of vector fields cannot be described by streamlines alone. Which modification of streamlines could you use to overcome these shortcomings?

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