UNIVERSITY OF EDINBURGH

FACULTY OF SCIENCE AND ENGINEERING

MASTER OF SCIENCE IN COMPUTER SCIENCE

COMPUTER GRAPHICS

Thursday 20 April 2000

9:30 to 11:00

Examiners:

I. Watson (External)

R.N. Ibbett (Chairman)

INSTRUCTIONS TO CANDIDATES

Answer any TWO questions.

All questions carry equal weight.

1. (a) An application renders photorealistic exterior elevations of buildings for the purpose of architectural evaluation, the model for the building consisting of both planar polygons and curved surfaces. The application is required to be used both in an interactive manner and for the generation of high quality still images for printing.

Outline the main features of the following methods of image synthesis with respect to suitability for this application.

- Scanline rendering with Z-buffer
- Ray casting with local illumination method
- Radiosity method

[9 marks]

(b) What problems might the limited numerical precision of a Z-buffer cause in this application? *[2 marks]*

(c) The innermost loop of a ray tracer involves computing the intersection point of a ray and a surface. This question concerns the calculation of the intersection of a ray and a cone.

The equation of a cone is $x^2 + y^2 - z^2 = 0$.

This equation describes an infinite double cone whose apex is at the origin, and whose sides extend toward infinity in the positive and negative z directions.

Suppose a ray is given by the equations :

$$x = x_0 + tx_1$$
$$y = y_0 + ty_1$$
$$z = z_0 + tz_1$$

Show that the intersection of the ray and cone may be computed by solving for the roots of the quadratic equation $at^2 + bt + c = 0$. To show this derive expressions for a, b, c in terms of ray parameters x_0, y_0, z_0, x_1, y_1, and z_1. *[6 marks]*

(d) Suppose the cone corresponds to our common intuition of what is a cone; that is, is not doubled and does not extend to infinity. To make such a cone, we will form a base to the the cone with a unit disk at $z = -1$ and cut off the cone in the positive z halfspace. How would you modify your calculation to handle this more realistic situation? (Sketch out the algorithm, do not attempt to work out the mathematics). *[8 marks]*

2. (a) For objects consisting of a polygonal mesh, describe the key idea behind the following shading techniques.

    - Flat shading
    - Gouraud Shading
    - Phong Shading [*8 marks*]

   (b) With the aid of a diagram, indicate a situation where the assumptions that Gouraud shading makes about the behaviour of the surface normal do not apply. How can this problem be resolved? [*4 marks*]

   (c) Environment mapping is a process that can be used to render approximate reflections in an object. Describe the method and indicate the approximations made to true reflections. [*6 marks*]

   (d) A Fisheye lens camera has the property that the radial distance along the image plane from the origin to the projection of an object point is linearly proportional to the angle between a perpendicular line through the image plane origin and a line from the origin to the object point. This implies the fisheye lens samples the scene uniformly, or put another way a pixel at the centre of the image has the same angular size as a pixel at the edge of the image. Compare the fisheye lens camera with a photograph of a reflecting sphere for the purpose of generating environment maps, bearing in mind for a practical fisheye lens the field of view is usually 180 degrees. [*7 marks*]

3. (a) Define a measure for smoothness of 2 connected line segments, and use this to compare the smoothness of the Bezier and B-spline approximations. [*3 marks*]

(b) What is the convex hull property of a Bezier curve and what is its practical relevance? [*3 marks*]

(c) In this part, you are going to invent a special cubic spline curve $g(x)$ to approximate the function $f(x)$ on the unit interval between 0 and 1.

You are given 4 pieces of information:

$$
\begin{aligned}
v_0 &= f(0) \\
v_1 &= f'(0) \\
v_2 &= f''(0) \\
v_3 &= f(1)
\end{aligned}
$$

Here f' is the first derivative, and f'' is the second derivative of the function. Find the set of cubic basis functions that allow g to be written in the following form :

$$g(x) = \sum_{i=0}^{3} v_i B_i(x)$$

[*12 marks*]

(d) Show how the path of a B-spline curve can be constrained to pass through a specified line or point with the use of multiple knots. In general, what is the effect of using multiple knots? [*7 marks*]