Computer Graphics Comprehensive Exam

Computer Science Department
Stanford University
Fall 2003

NAME:

Note: This is exam is *closed-book.*

The exam consists of 5 questions. Each question is worth 20 points. Please answer all the questions in the space provided, overflowing on to the back of the page if necessary.

You have 60 minutes to complete the exam.

1. [20 points] Computer graphics definitions.

Define in a few sentences each of the following computer graphics terms. Some of these terms may be used in other fields, so be sure to give the computer graphics meaning.

1A [5 points] Alpha channel.

1B [5 points] Phong reflection model.

1C [5 points] Spline.

1D [5 points] Gouraud shading.

2. [20 points] Transformations.

Computer graphics relies heavily on transformations. Most common are linear transformations such as rotations and translations. In the following, T(dx,dy,dz) refers to a translation by (dx,dy,dz), Rx(a) refers to a rotation about the x-axis by a degrees, Ry(a) and Rz(a) refer to rotations about the y- and z-axis, respectively.

The order of transformations may matter. Also, sometimes the order may be rearranged, but the arguments will change. Describe whether the following statements are true or false.

T(1,0,0) Rx(360) = Rx(720) T(1,0,0)?

T(1,0,0) T(0,2,0) = T(0,1,0) T(1,1,0)?

Rx(45) Ry(30) = Ry(45) Rx(30)?

Rx(45) Rx(30) = Rx(15) Rx(60)?

T(1,0,0) Rz(180) = T(1,0,0) Rz(-180)

Transformations have inverses. State whether the following formulas for the inverse transformations are true or false.

$Rz(45)^{-1}$ = Rz(-45)?

$Rz(180)^{-1}$ = Rz(180)?

$[T(1,0,0)T(0,2,0)]^{-1}$ = T(-1,0,0)T(0,-2,0)?

$[Rz(45)\ T(1,0,0)]^{-1}$ = T(-1,0,0) Rz(45)?

$[Rx(45)\ Ry(30)]^{-1}$ = Rx(-45) Ry(-30)?

3. [20 points] Ray tracing.

One of the most general methods for rendering is ray tracing. At the core of a ray tracer is a procedure to find ray-surface intersections. The inputs to the procedure are a ray and a description of a surface; the output is the point of intersection.

Assume a ray is given by the following parametric equations:

$$x = x0 + t * x1$$
$$y = y0 + t * y1$$
$$z = z0 + t * z1;$$

(x0,y0,z0) is the origin of the ray, and (x1,y1,z1) is the direction of the ray. As t increases, the points on the ray move from the origin along the direction.

The simplest surface is a plane. The following equation defines a plane:

$$Ax + By + Cz + D = 0.$$

A plane also defines a half-space: $Ax + By + Cz + d < 0$.

A set of planes may be used to define convex polyhedra. Each face i of the convex polyhedra is associated with a plane (Ai, Bi, Ci, Di). A convex polyhedra is defined to be the intersection of the half-spaces created by the planes making up its faces.

Work out a procedure for computing the point of intersection of a ray with a convex polyhedra defined as the intersection of n half-spaces. In general, a ray intersects a convex shape in two points. Your procedure should return the closest point of intersection in the direction of the ray.

4. [20 points] Hidden-surface elimination.

Hidden-surface elimination is one the classic algorithms in computer graphics. The goal of hidden-surface elimination is to draw a picture where each point in the image shows the surface visible at that point; hidden points and surfaces are not shown.

4A [5 points] Describe succinctly the z-buffer algorithm for hidden surface elimination.

4B [5 points] What is the complexity of the z-buffer algorithm?

4C [5 points] Is the z-buffer algorithm optimal? What would be the complexity of an optimal algorithm?

4D [5 points] Suppose you are given a scene consisting of a set of polygons. You can draw polygons as lines (i.e. as an outlined polygon) or as a filled polygon. How would you create a line drawing of the scene with hidden lines removed? Hint: Consider enhancing the basic z-buffer drawing mode slightly.

5 [20 points] Intensity and Gamma.

Cathode-Ray Tubes (CRTs), or monitors, convert voltage to light. However, the relationship between the amount of light energy produced and the input voltage is nonlinear:

$$L = V^{\gamma}$$

In this equation, L is the amount of light output and V is the input voltage. Gamma γ characterizes this non-linear relationship. A typical value for γ is 2.2. This means, that if the input voltage is doubled, the output light increases by more than a factor of four.

The framebuffer stores pixel values. These pixel values can be converted to voltages in various ways.

5A [5 points] Suppose the voltage is set to be proportional to the framebuffer values. Call this V-space. What are some advantages of working in this V-space?

5B [5 points] Suppose that it were possible to store values in the framebuffer in such a way that the amount of light energy produced were directly proportional to the value stored in the framebuffer. Call this L-space. What are some advantages of working in L-space?

5C [5 points] What hardware would be required to convert framebuffer values to voltages if the framebuffer values are stored V-space?

5D [5 points] What additional hardware would be required to convert framebuffer values to voltages if the values are stored L-space?