Computer Graphics Comprehensive Exam

Computer Science Department
Stanford University
Fall 2004

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] Law of diffuse reflection.

1B [5 points] Gamma.

1C [5 points] Image matte.

1D [5 points] Bump-mapping.

2. [20 points] Homogeneous coordinates.

Computer graphics relies heavily on geometry. One powerful approach represents points using homogeneous coordinates. In 3D, the position of a point in normal coordinates is denoted by a 3-vector (x, y, z). Using homogeneous coordinates, the same point is represented as a 4-vector (xw, yw, zw, w). The 3D position of the point represented using homogeneous coordinates is defined to be equal to (xw/w, yw/w, zw/w).

2A [4 points]. What is the geometric interpretation of a point whose 4th coordinate w equals 0?

2B [8 points]. It is common in computer graphics to transform points using linear transformations. A linear transformation may be represented by a matrix. To transform a 3D point represented in homogeneous coordinates, a 4x4 matrix is used. Write out the 4x4 matrix that translates a point by the amount (tx, ty, tz).

2C [8 points]. Suppose the viewer is placed at the origin, and the image plane is placed at z=1. Write out the 4x4 matrix that performs a perspective projection of the point (x,y,z) from the point of view of the viewer onto the image plane.

3. [20 points] Color.

The human visual system is trichromatic. That means that the perceived color from any visible spectrum may be described by three coordinates.

3A [6 points]. Describe the physiological basis of trichromatic color vision in humans.

3B [7 points]. Cathode-Ray Tubes (monitors) are made using three light emitting phosphors because human vision is trichromatic. Because phosphors emit light, monitors use an additive color space. Suppose you were to use 4 phosphors. Describe the general form of the equation that would relate the brightnesses and colors of the 4 phosphors to the 3 colors perceived by the observer.

3C [7 points]. Color prints use colored inks on white paper. The color inks act as color filters. For this reason, the color space used in color printing is a subtractive color space. Suppose you used 4 inks for color printing. Describe the general form of the equation that would relate the quantities and the colors of the inks to the perceived colors.

4. [20 points] Clipping.

Consider a graphics package that draws 2D line segments. Normally the image is rectangular and one of the first steps is to clip the 2D line segment - returning the portion of the line segment that is inside the image rectangle. This clipped line segment is then drawn into the framebuffer.

Suppose the image is circular, not rectangular. Describe an algorithm for clipping a 2D line segment to a circle. The clipping routine should return the portion of the line segment inside the circle. Assume the line segment is given by the two points (x1, y1) and (x2, y2) and that the circle is the unit circle (radius equal to 1) centered at the origin. Make sure to consider all the cases that can occur. Use pseudocode to describe your algorithm, but work out the mathematics in detail.

5 [20 points] Key-frame Interpolation.

The classic method used to produce animation is key-frame interpolation. In this technique, images are created at certain frames, the key frames, and inbetween frames are interpolated from the previous and next key frames. In the first computer animation systems, the objects in the key frames were represented by polygons and lines.

5A [10 points]. Suppose that two successive key frames have the same number of polygons. Suppose further that each polygon in the first key frame is in correspondence with a polygon in the next key frame (that is, each vertex in one polygon matches a vertex in the corresponding polygon in the other key frame). Suppose further that the first key frame is at frame 0 and the next key frame is at frame 10. How would you create a polygon at frame i using linear interpolation (write out a formula for the positions of the interpolated vertices)? Use the notation Vn for vertex n in key frame 0 and Wn for vertex n in key frame 10.

5B [5 points] Linear interpolation often creates a very mechanical, non-life-like motion. How would you change the interpolation so that it was smoother?

5C [5 points] Suppose that each polygon in one key frame has a matching polygon in the other key frame, but that these polygons have a different numbers of vertices so that vertices are no longer in direct correspondence. Briefly describe an approach to interpolating between two polygons in this case.