Midterm Review
CSCI-4965: Three-Dimensional Computer Graphics
Fall 2000

1 Midterm Exam

The midterm exam will be held in class (CII 3039) on Thursday, October 19, 2000 at 10:00 am. The duration of the exam will be 2 hours. The exam will be closed book and closed notes.

2 Topics

Topics for the midterm exam include all material covered in class upto and including the lecture of October 12, 2000. The list of topics will be available on the course web page.

3 Review Questions

These review questions and problems are intended to improve your understanding of the material and to help you prepare for the midterm exam.

1. Suppose an RGB raster system is to be designed using an 8 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 12 bits per pixel in the frame buffer, how much storage (in bytes) do we need for the frame buffer?
2. Consider two raster systems with resolutions of 640 by 480 and 1280 by 1024. How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second? What is the access time per pixel in each system?
3. Assuming that a certain full-color (24 bit per pixel) RGB raster system has a 512 by 512 frame buffer, how many distinct color choices (intensity levels) would we have available? How many different colors could we display at any one time?
4. List three geometric primitives supported by OpenGL.
5. True or False: The order in which rotation and translation transformations are performed does not matter.
6. Compare the Digital Differential Analyzer (DDA) and Bresenham line drawing algorithms. What are the advantages of the Bresenham algorithm?

7. Compare the Sutherland-Hodgman and Weiler-Atherton polygon clipping algorithms.

8. Give three two-dimensional transformation operations that can be performed on points using a 2×2 matrix. Which important operation cannot be expressed in a 2×2 matrix?

9. Consider a point $p = (2, 5)$ in the plane. Assume the point is rotated counterclockwise in the plane by 90 degrees about the origin. Compute the coordinates of the resulting point $p^{'}$. Note that $\cos(90) = 0$ and $\sin(90) = 1$.

10. Consider an orthonormal world frame W in the plane. Let there be another orthonormal frame F located at p_0, at an angle of α with respect to W. Write the composite matrix to transform coordinates from the world coordinate system W to the coordinate system F. (The matrix can be expressed as the product of matrices.)

11. Consider a transformation that maps a square into a trapezoid. Is this an affine transformation? Justify your answer.

12. True or false:

    (a) Rotations in the plane are commutative.
    (b) Perspective transformation is an affine transformation.
    (c) For a perspective projection, size varies inversely with distance.
    (d) Parallel projections are good for exact measurements.

13. Under perspective projections, any set of parallel lines that are not parallel to the projection plane will converge to a "vanishing point". Vanishing points of lines parallel to a principal axis X, Y, or Z are called "principal vanishing points." What is the number of principal vanishing points that can be present in a perspective drawing?

14. Does nonuniform scaling preserve orthogonality?

15. True or false:

    (a) Hermite splines are interpolating splines.
    (b) Catmull-Rom spline has C^1 continuity.
    (c) Every third order Bezier curve can be subdivided into two other third order Bezier curves.
    (d) Every C^2 continuous spline is also C^1 continuous.

16. For a Bezier spline curve with $n+1$ control points $p_0, p_1, \ldots, p_n$, show that $P(0)^{'} = n(p_1 - p_0)$.

17. Show that sum of blending functions for Bezier curve is 1.

18. Give the 3 blending functions for a Bezier curve of degree 2.

19. Compute the matrix representation for a Bezier curve of degree 2 from its blending functions.

20. Suppose that we join two Bezier curves of degree 2, using the control point sequences p_0, p_1, p_2 and p_2, p_3, p_4 respectively. What conditions must be satisfied by these five points for the combined curve to have C^1 parametric continuity at the point at which they are joined?

21. Let the number of control points for a b-spline curve be 10, and the number of knot points be 15. What is the order of the resulting b-spline curve? Degree of the b-spline?

22. B-splines possess a property called local support. What is local support, and why is this property desirable?

23. State one advantage of using NURBS.

24. Consider a triangle in 3-space, defined by its vertices p_0, p_1, p_2. Derive a formula for a unit normal vector $\hat{n}$ that is normal to this triangle. The normal vector should be directed so that for a viewer on the same side as the unit normal vector, the points appear in counterclockwise order.

25. The implicit equation for the sphere of radius 5 with center at (0, 1, 2) is given by
$f(x, y, z) = x^2 + (y-1)^2 + (z-2)^2 - 25 = 0$.
Compute and express the unit normal to this sphere in terms of x, y, z.

26. An ellipsoid centered at the origin is described by the equation
$f(x, y, z) = (x/r_x)^2 + (y/r_y)^2 + (z/r_z)^2 - 1 = 0$.
Compute and express the unit normal to this ellipsoid in terms of x, y, z.

27. In parametric form, the ellipsoidal surface can be written:
$x = r_x \cos(\phi)\cos(\theta)$, $-\pi/2 \leq \phi \leq \pi/2$, $-\pi \leq \theta \leq \pi$
$y = r_y \cos(\phi)\sin(\theta)$, $-\pi/2 \leq \phi \leq \pi/2$, $-\pi \leq \theta \leq \pi$
$z = r_z \sin(\phi)$, $-\pi/2 \leq \phi \leq \pi/2$
Compute the unit normal to this surface.

28. Consider the quaternion (0.5, 0, 0.5, 0). Is this a unit quaternion? Is it a pure quaternion? What is the conjugate of this quaternion?

29. Find the product of two quaternions $q_1 q_2$ where $q_1 = (s_1, v_1)$ and $q_2 = (s_2, v_2)$.

30. Using quaternions, compute the resulting point p' when the point $p = (1, 2, 3)$ is rotated by 90 degrees about the $(1, 1, 1)$ axis passing through the origin. Note that if $q = (s, v)$ represents the unit quaternion corresponding to the rotation, $p' = s^2 p + v(p.v) + 2s(v \times p) + v \times (v \times p)$. Also $\sin(45) = \cos(45) = 1/\sqrt{2}$.

31. True or false: BSP-trees always use orthogonal splitting planes.

32. What do the leaf nodes of a CSG tree contain?

33. Lambert's law for diffuse reflection is written $I = k_d I_l (N.L)$. What are I, k_d, I_l, N, L?

34. The combined illumination model can be described by the following equation:
$I = k_e + k_a I_a + \sum_i \frac{1}{(a_0 + a_1 d_i + a_2 d_i^2)} [I_{l_i} [k_d (N.L_i) + k_s (V.R_i)^{n_s}]]$.
The variables used are: $I, a_0, a_1, a_2, d_i, k_e, k_a, k_d, k_s, n_s, I_a, I_{l_i}, L_i, R_i, N, V$.
Which of the quantities above are affected if :
    - the position of the ith light changes?

- the material changes?
- the orientation of the surface changes?

35. What is the effect on the highlights due to specular reflection as n_s is increased?

36. How is the unit normal vector at a polygon vertex computed for Gouraud or Phong shading?

37. True or False:

    (a) The Phong specular reflection model is a physical simulation of the behavior of real-world light.

    (b) For polished metal, the specular exponent n_s would be large.

    (c) Gouraud shading, also known as smooth shading, linearly interpolates the normal vectors at the polygon vertices.

    (d) A rough surface with many tiny microfacets is likely to have a large diffuse reflection coefficient.

38. In OpenGL, what is the reflected light when a surface with RGB color $(R_{material}, G_{material}, B_{material})$ is illuminated by a light with intensity $(R_{light}, G_{light}, B_{light})$?