CSE 287: Practical Learning Objectives

The following is a list of practical instructional objectives for CSE 287. Each describes some action or task that students should be able to perform. Many include the conditions under which the action or task should be performed.

Chapter One (Introduction)

1. Describe or identify differences, strengths, and weaknesses of image-order and object-order rendering algorithms.

Chapter Two (Mathematics)

2. Use the quadratic equation to find the roots (solutions) or a second order polynomial.
3. Given the value of the “discriminant” in the quadratic equation, state the number of real solutions to the equation.
4. Write code or “by hand” convert radian measures of angles to degrees and degrees to radians.
5. Given the cosine of an angle, use the arccosine to the find the angle.
6. Describe or identify the differences between scalar and vector quantities.
7. Use vector addition and subtraction to solve problems in computational geometry.
8. Use scalar multiplication to change the length of a vector and/or reverse its direction.
9. Given a vector, calculate its length/magnitude.
10. Given two points, calculate the distance between the points.
11. Given a vector, normalize it to unit length.
12. Given a vector, find a new vector that points in the same direction and has a specified length.
13. Given two points, calculate a unit length vector that points from one point to the other.
14. Given two vectors, calculate the dot product of the vectors.
15. Write an expression the represents the geometric interpretation of the dot product. State how this changes when the two vectors are unit length.
16. Use the dot product and the arccosine function to find the angle between two vectors.
17. Given the value of a dot product, state whether the vectors are parallel, perpendicular, less than ninety degrees, or more than ninety degrees apart.
18. Given two vectors, use the dot product to find the parallel and/or perpendicular components of one to the other.
19. Describe how the cross product is geometrically related to the multiplicands in the product.
20. Given two vectors, use the right-hand rule to correctly order the vectors so that their cross product points in a specified direction.
21. Given three points that describe the corners of a parallelogram, use vector subtraction and the cross product to find the area of the parallelogram.
22. Given three points that describe the corners of a triangle, use vector subtraction and the cross product to find the area of the triangle.
23. Given the equation that implicitly describes a surface and the coordinates of a point, calculate a signed distance from the surface to the point.
24. Given three points on a plane, use them to calculate a unit length vector that is normal to the plane
25. Given three points on a plane, use them to create an implicit description of the plane.
26. Given two points on a line, use them to generate a parametric representation a line.
27. Given two points on a line, use them to generate a parametric representation a line in which the direction vector is unit length.
28. Given a parametric description of a line and value of the parameter, t, find the coordinates of that point on the line that is associated with the value of the parameter.
29. Given a parametric description of a line and the coordinates of a point, determine whether or not the point is on the line.

30. Given a parametric description of a line and the coordinates of a point on the line, find the value of the parameter, t, for that point.

Chapter Three (Raster Displays)

31. State what “pixel” is short for.
32. Give or identify a definition for “color depth.”
33. State the values for alpha that are normally associated with totally transparent surfaces and totally opaque surfaces.
34. Given the red, green, blue, and alpha components of two colors, use alpha blending to blend together the two colors.

Chapter Four (Ray Tracing)

1. State whether ray tracing is an image-order or object-order algorithm.
2. Write pseudo code that describes the basic ray tracing algorithm.
3. List or identify the two basic types of projection.
4. Identify the principle characteristics of an orthogonal projection.
5. Identify the principle characteristics of a perspective projection.
6. Write a mathematical expression that defines aspect ratio.
7. Given two rectangles and the dimensions of one or them, set the dimensions of the other to make the aspect ratios equal.
8. Given the heights, widths, and points of origin for two rectangles, create a mapping from one to the other.
9. Given two points, create a ray that will pass through the points going in a specified directions.
10. Given and origin and a direction, create a corresponding parametric description of a ray.
11. Given the parametric description of a ray and a value for the parameter, *t*, describe the location of the point associated with the parameter value relative to the origin of the ray.
12. Given the parametric description of a ray and solutions for the parameter, *t*, that are associated the intersections with a surface, identify which surface is closest to the origin of the ray.
13. Describe the general procedure for determining the point of intersection between a parametric ray and a surface that is described by a quadratic polynomial.
14. Given two points on a line and a third point that is in the same plane as the other points, determine whether the third point is “left” or “right” of the line described by the two points.

Chapter Four (Shading)

15. Identify or give correct descriptions for ambient, diffuse, and specular reflection.
16. Describe how emissive materials impact the results of local lighting calculations.
17. Given the color and intensity of an ambient light source and the material properties of a surface, correctly include the emissive material properties in the total calculation.
18. Given the color and intensity of an ambient light source and the material properties of a surface, correctly calculate the ambient reflection for that surface.
19. Given the color and intensity of a light source, the material properties of a surface, either the direction to the light source or the position of the light source, and a surface normal, correctly calculate the diffuse reflection for that surface.
20. Given the color and intensity of specular light, the material properties of a surface, either the direction to the light source or the position of the light source, either the direction to or the position of the view point, and a surface normal, correctly calculate the specular reflection for that surface.
21. Simulate light attenuation based on constant, linear, and quadratic attenuation factors and the distance to a point of intersection or the distance to a positional light source.
22. Correctly combine the diffuse and specular reflections for multiple light sources, to calculate the total illumination for a pixel (fragment).
23. Given the direction of a ray that intersects a surface and the surface normal at the point of intersection, calculate a reflection vector for the ray.

24. Describe the purpose of a shadow feeler. State under what conditions a light source will not contribute to the illumination for a pixel (fragment) resulting in the rendering of a shadow.
25. Describe how reflection vectors are used to create mirror-like inter object reflections.
26. Correctly combine the results of tracing a reflection vector with the calculations associated with direct illumination for a point of intersection or a fragment.

Refraction and Texture Mapping

27. State how transparent surfaces differ from opaque surfaces in how they interact with light.
28. Name the effect that determines how much light is transmitted and how much light is reflected by a transparent surface.
29. State what occurs when the angle of incidence with a transparent surface is exceeded.
30. State the name of the law that determines the direction of refraction.
31. State the name of the law that determines how light passing through a material is colored and absorbed.
32. State the name of the discrete elements that a texture is composed of.
33. Given a picture of a texture image, identify the s and t coordinates of a specified position.
34. Given an image of a texture mapped object, state whether Planar, Cylindrical, or Spherical Mapping was used to generate the texture coordinates for the object.

Chapter Five (Matrices)

35. Identify the main diagonal of a square matrix.
36. Given a square matrix, create the *transpose* of the matrix.
37. Given two matrices, state whether or not the matrices can be multiplied together based on their dimensions. If they can be multiplied together, state what the dimensions of the product will be.
38. Given two matrices, calculate their product.
39. Given a matrix and a column vector, calculate their product.
40. State whether or not matrix multiplication is communitive.
41. Show how the transpose of the product of two matrices relates to the product of their transposes.
42. Given the dimension, construct an identity matrix with that dimension.
43. State what the product of the identity matrix and a square matrix with the same dimension will be equal to regardless of the order of the matrices.
44. Using matrix multiplication, show how a matrix is related to its *inverse*.
45. State what condition is necessary for a matrix to be invertible.
46. Describe what value the *determinant* of a matrix will be equal to if a matrix is *singular*.
47. Show how the inverse of the product of two matrices relates to the product of their inverses.

Chapter Six (Transformations)

48. Given a description of a desired translation, write a statement that uses a GLM function to construct the 4 x 4 homogenous transformation matrix that can produce the translation.
49. Use the right hand rule to correctly determine the positive and negative directions of rotations in a right handed coordinate system.
50. Given a description of a desired rotation about the x, y, or z axes, construct the 4 x 4 homogenous transformation matrix that can produce the rotation.
51. Given a description of an angle of rotation and the axis about which the rotation is to be performed, write a statement that uses a GLM function to construct the 4 x 4 homogenous transformation matrix that can produce the translation.
52. Given a description of a desired uniform or non-uniform scale operation, construct the 4 x 4 homogenous transformation matrix that can produce the desired scaled coordinate system.
53. Given a description of a desired uniform or non-uniform scale operation, write a statement that uses a GLM function to construct the 4 x 4 homogenous transformation matrix that can produce the translation.

54. Given a description of a position, orientation, and size, write a code fragment that will generate the composite (modeling) transformation that will place the object in that desired position and orientation with the desired size.
55. List, in order, the transformations that must be carried out to produce object coordinates, world coordinates, eye coordinates, clip coordinates, normalized device coordinates, and window coordinates.
56. Given matrices that describe modeling, viewing, projection, and viewport transformations, order them correctly for use in transforming a vertex from Object to Window coordinates.
57. Given a modeling transformation, write an expression of statement that would correctly transform a normal vector to World coordinates.

Chapter Seven (Viewing, Projection, and Viewport Transformations)

35. Given a description of the position and orientation of a view point in world coordinates, write a code fragment containing calls to the GLM translate and rotate functions that creates the composite transformation needed to produce the desired viewing transformation.
36. Given a description of a position and orientation of a view point in world coordinates, use GLM lookat to produce the desired viewing transformation.
37. Given a matrix that describes a viewing transformation use the matrix to transform a given vertex from *world coordinates* to *eye coordinates*.
38. Describe and name the shape of the view volume associated with a perspective projection.
39. Describe and name of the shape of the view volume associated with an orthogonal projection.
40. Define clipping and state the purpose of a clipping plane.
41. Use a simple projection matrix and *perspective division* to transform a given vertex from *eye coordinates* to *clip coordinates*.
42. Describe what relation is required between the aspect ratios associated with the projection view volume and the viewport in order to produce an undistorted view of a “scene”.
43. Given a matrix that describes the viewing transformation, write an expression or a code fragment that gives the location of the view point relative to World coordinates.

Chapter Eight (Graphics Pipeline Algorithms)

44. Given three vertices that describe a triangle and a vector that describes the viewing direction, determine whether or not the triangle faces the viewpoint.
45. Given the description of plane that includes a normal vector and a point on the plane, determine if a given vertex is in “front” or “behind” the plane.
46. Write a code fragment that correctly implements the *depth test* and how it is used to control writing to the color and depth buffers.
47. Write a correct pseudo code description of the depth buffer algorithm.
48. Use the areas of triangles to perform Barycentric interpolation of vertex attributes for a point on the interior of the triangle.

Fog and Alpha Blending

49. Given the values parameters associated with linear, exponential, or exponential 2 fog, the location of the view point, and the fragment color and location, calculate the red, green, and/or blue components that will be written into the color buffer.
50. Define the terms *source* and *destination* as they relate to alpha blending.
51. Given the red, green, blue, and alpha components of two colors, use (source) alpha blending to blend together the two colors.
52. Given the location of the viewpoint in World coordinates, state the necessary rendering order for a group or opaque and transparent objects to correctly simulate transparency with alpha blending.

Memorize

Memorize how to perform the basic vector operations for addition, subtraction, and scalar multiplication.

Memorize the following:

Mapping from one interval to another:

$$x' = (x - fromLow)\frac{toHigh - toLow}{fromHigh - fromLow} + toLow$$

Length of vector:

$$\|\mathbf{a}\| = \sqrt{x_x^2 + y_x^2 + z_x^2}$$

Vector Normalization:

$$\hat{\mathbf{a}} = \frac{1}{\|\mathbf{a}\|}\mathbf{a} = \frac{\mathbf{a}}{\|\mathbf{a}\|}$$

Dot Product:

$$\mathbf{a} \bullet \mathbf{b} = x_a x_b + y_a y_b + z_a z_b$$

$$\mathbf{a} \bullet \mathbf{b} = \|\mathbf{a}\|\|\mathbf{b}\|\cos\alpha$$

Implicit Equation of a Plane:

$$(\mathbf{p} - \mathbf{a}) \bullet \mathbf{n} = 0$$

Implicit Equation of a Sphere:

$$\|\mathbf{p} - \mathbf{c}\|^2 - r^2$$

Parametric Representation of a Line or Ray:

$$\mathbf{p}(t) = \mathbf{p_0} + t(\mathbf{p_1} - \mathbf{p_0})$$

$$\mathbf{p}(t) = \mathbf{p_0} + t\frac{(\mathbf{p_1} - \mathbf{p_0})}{\|(\mathbf{p_1} - \mathbf{p_0})\|}$$

Alpha Blending:

$$color_{fragment} = (1 - \alpha)color_{destination} + (\alpha)color_{source}$$

Aspect Ratio:

$$\text{aspect ratio} = \frac{width}{height}$$

Transformations

Ambient Reflection:

$$\mathbf{color_{ambient\,light}}\ \mathbf{color_{surface}}$$

Vectors used in Lighting Calculations:

If $\mathbf{e}+t\mathbf{d}$ is the traced ray, $\mathbf{n}$ is the surface normal, $\mathbf{i}$ is the point of intersection or fragment, and $\mathbf{p}$ is the position of the light source then:

$$view\,vector = \mathbf{v} = \frac{-\mathbf{d}}{\|\mathbf{d}\|} = \frac{\mathbf{e} - \mathbf{i}}{\|\mathbf{e} - \mathbf{i}\|}$$

$$light\ vector = \mathbf{l} = \frac{\mathbf{p} - \mathbf{i}}{\|\mathbf{p} - \mathbf{i}\|}$$

$$reflection\ vector = \mathbf{r} = \frac{\mathbf{l} - 2(\mathbf{l} \bullet \mathbf{n})\mathbf{n}}{\|\mathbf{l} - 2(\mathbf{l} \bullet \mathbf{n})\mathbf{n}\|}$$

Diffuse Reflection:

$$\max(0, \mathbf{n} \bullet \mathbf{l})\,\mathbf{diffuse\ color_{light}}\ \mathbf{diffuse\ color_{surface}}$$

Specular Reflection:

$$\max(0, \mathbf{r} \bullet \mathbf{v})^{shininess}\ \mathbf{specular\ color_{light}}\ \mathbf{specular\ color_{surface}}$$

Attenuation:

$$attenuation\ \ factor = \frac{1}{k_c + k_l d + k_q d^2}$$

Fog:

$$\mathbf{c_{frag'}} = f\mathbf{c_{frag}} + (1 - f)\mathbf{c_{fog}}$$

$$f = \frac{end - d}{end - start}$$

$$f = e^{-(density \bullet d)}$$

$$f = e^{-(density \bullet d)^2}$$

Matrices:

$$\mathbf{IM} = \mathbf{MI} = \mathbf{M}$$

$$\mathbf{M}^{-1}\mathbf{M} = \mathbf{M}\mathbf{M}^{-1} = \mathbf{I}$$

$$
{}^{\mathbf{window}}\mathbf{v} = \begin{bmatrix} viewport \\ matrix \end{bmatrix} \Leftarrow \underbrace{perspective\ division \Leftarrow \begin{bmatrix} Projection \\ matrix \end{bmatrix}}_{\substack{Projection \\ tranformation}} \begin{bmatrix} view \\ matrix \end{bmatrix} \begin{bmatrix} modeling \\ matrix \end{bmatrix} {}^{\mathbf{object}}\mathbf{v}
$$