ICS 186A: Computer Graphics
Spring 2002
Gopi Meenakshisundaram

Written Assignment 3
Assigned: Sunday, April 28, 2002
Due: Friday, May 3, 2002
Estimated Time: 6 hrs

Consider the tetrahedron with the following vertices:
A=(-10,0,-10), B=(0, 0, -20), C=(0,0,0), D=(-5, 10, -5). The faces of the tetrahedron are ABC, DBA, DCB, DAC (all vertices ordered in anticlockwise direction around the face). First I rotate the tetrahedron about the Y axis in the counter clockwise direction by 90 degrees. Then I translate the tetrahedron in the positive X direction by 20 units.

I look at this transformed tetrahedron at vertex D from (15, 50, 5), and the view-up vector is parallel to the positive Z axis. The perspective transformation vertical field of view is 45 degrees, the aspect ratio 1.0, near plane is at 1.0, and far plane is at 100.0.

Tetrahedron's material properties are as follows: O_a=(0.8, 0.7, 1.0), O_d = (0.2, 0.3, 0.4), O_s = (0.5, 0.5, 0.5), k_a =0.8, k_d = 0.25, k_s = 1.0, and the specular exponent n=3.

There is one light in the scene at (15,-20,5) with diffuse component I_d =(1.0, 1.0, 0.0) and the specular component I_s =(1.0, 1.0, 1.0). The ambient light in the scene is black, I_a=(0.0, 0.0, 0.0).

1. Compute the Euler characteristic and genus of the tetrahedron.
2. Compute the normal vectors of all the four faces.
3. Compute the normal vectors of all the four vertices.
4. Compute the rotation matrix R in the given transformation.
5. Compute the translation matrix T in the given transformation.
6. Choose the correct answer: If P is a vertex (one of A, B, C, or D, but in homogenous coordinates), then after transformation, the transformed vertex is computed as (a) RxTxP (b) TxRxP.
7. Compute the transformed vertices A, B, C, and D after rotation and translation.
8. Compute the normal vectors of all the four faces after transformation
9. Compute the normal vectors of all the four vertices after transformation.
10. The homogenous coordinate of a **point** (p_x, p_y, p_z) is $(p_x, p_y, p_z, 1)$ and the homogenous coordinate of a **vector** (v_x, v_y, v_z) is $(v_x, v_y, v_z, 0)$. Transform the normal vector of vertex A computed for Question 3, the same way you transformed vertex A in Question 7. Compare your result with the normal vector computed for Question 9. If the transformation matrix had just the rotation matrix R, would you get the same result?
11. Which normal vectors do you use for lighting computation? (a) The ones computed for Questions 2 and 3. (b) The ones computed for Question 8 and 9.

12. After the transformation (computed for Question 7), which of the faces are facing *away* from the light? (Which faces have normal vector making angle more than 90 degrees from the light vector?) Remember, since these faces are facing away from the light, there is no contribution of color from the light source on these faces (Neither diffuse nor specular. Only ambient contribution is present, as there is no light source associated with ambient light.) This applies to vertices also. Vertices with normal vectors making angle more than 90 degrees from the light vector will not have diffuse and specular components of light.
13. Compute the centroid of all the four faces. Name them E,F,G, and H. Interpolate the normal vectors at the vertices of the tetrahedron (computed for Question 9) to compute the normal at each centroid.
14. Compute the color at the four vertices (A,B,C, and D) using the lighting equation. Use the normal vectors computed for Question 9.
15. Compute the color at the centroids by (a) Gouraud shading (interpolating the color at the vertices computed in Question 14.) (b) Phong shading (applying the lighting equation at the centroids using the normal vectors computed in Question 13.) (These are not exactly "OpenGL" Gouraud or Phong shading, as these shadings are actually done in OpenGl in 2D after perspective transformation of the triangles. In this assignment, you are doing this interpolation in 3D. But the concepts are same.)
16. Compute the three **unit vectors** in the **orthogonal** eye coordinate system. (Eye to the center ***u***, the computed view-up vector ***v***, and the vector perpendicular to both these vectors ***w=u***x***v***. Remember, ***u,v,w*** should be perpendicular to each other since it is an orthogonal coordinate system.)
17. Let the transformation E bring the eye coordinate to the origin and then rotate the eye coordinate system such that the ***u*** vector aligns with the negative Z axis, ***v*** vector aligns with the positive Y axis, and the ***w*** vector aligns with the positive X axis. Since the eye coordinate has to be brought to the origin, E is a combination of a translation and a rotation matrix. Let P be one of the transformed vertices (one of A,B,C, or D computed after Question 7), and the matrix E be applied to P as ExP. If T_2 and R_2 are the translation and rotation components of E as discussed above, choose the correct answer. (a) E = T_2xR_2 (b) E = R_2xT_2.
18. Compute E. Pay attention to the fact that ***u*** aligns with the negative Z axis when computing the rotation matrix.
19. Compute the new vertices of the tetrahedron after the view transformation (E).
20. Compute the perspective transformation matrix M with the given parameters.
21. Compute the new vertices of the tetrahedron (Computed after Question 19) after the perspective transformation (M). Remember, the range of values for x, y, and z after perspective transformation (and after division by homogenous coordinate) should be between -1 and +1.
22. Let N be the composition of all the matrices (model transformation, view transformation, and perspective transformation). If P is a vertex (P is one of A, B, C or D of the *original* vertices given in the beginning of the problem), then the transformed vertex is NxP (the results you got in Question 21). If $N=M_1xM_2xM_3xM_4xM_5$, assign each M_i is one of T, T_2, R, R_2, or M.