Computer Graphics Ph.D. Qualifying Exam, October 2008

1. (10%) Give the 3×3 matrix M so that, for any vector v, Mv represents the vector formed by rotating v $90°$ about the vector $(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0)$.

2. (25%) (a) The Phong illumination model can be summarized by the following equation:

$$I = k_e + k_a I_a + \sum_i \left[I_{l_i} \left(k_d (\mathbf{N} \cdot \mathbf{L}_i)_+ + k_s (\mathbf{V} \cdot \mathbf{R}_i)_+^{n_s} \right) \min \left(1, \frac{1}{a_0 + a_1 d_i + a_2 d_i^2} \right) \right]$$

   Draw a diagram to explain the main variables in the above formulation. What effects do the terms of the above formulation intend to model? (b) Describe how to shade a triangle using flat shading, Gouraud shading and Phong shading. Discuss their visual differences.

3. (15%) The Z-buffer and BSP tree are both common methods for hidden surface elimination. Briefly describe both methods and give their pros and cons.

4. (15%) Explain what aliasing is and how it is formed. Suggest two methods for anti-aliasing which can be used along with scan conversion.

5. (10%) Describe the shadow buffer algorithm. What is its main drawback?

6. (10%) Describe the rendering equation proposed by Kajiya in his classic SIGGRAPH 1986 paper.

7. (15%) Assume that there are N triangles in a scene. The rendering resolution is $W \times H$ and the average projected size for a triangle is $M \approx \gamma WH$ pixels, where γ is a constant and $0 < \gamma < 1$. (a) Assume that the shading cost is constant. Please roughly estimate the complexity of rendering the scene using ray casting and traditional scan conversion with a Z-buffer. (b) For a modern scene, it is usual that $N \gg W \times H$. In such a scene, which method is faster, Z-buffer or ray casting? (c) Most commercial renderers still use scan conversion with a Z-buffer; could you give reasons?