

Exam

EDA221 Computer Graphics : Introduction to 3D

2013–10–21, 08.00–13.00, MA08

Answers may be given in Swedish or English.

Dictionaries for English (and the native language for each student) are allowed.

Electronic calculators are **not** allowed.

Grading: The maximum score is 6.0. A score of 3.0 or above is needed to pass.

1. Shading

- a) Give the formula for the diffuse and specular terms of Phong shading (0.3p)
- b) Use the Phong model defined above and show how you would set the parameters for a shader that represents a yellow, mostly diffuse material with a small specular peak. Motivate your answer. (0.2p)
- c) A large triangle has vertex normals $\mathbf{n}_0 = (1, 0, 0)$, $\mathbf{n}_1 = (0, 1, 0)$ and $\mathbf{n}_2 = (1, 1, 1)/\sqrt{3}$ at vertex \mathbf{p}_0 , \mathbf{p}_1 , and \mathbf{p}_2 respectively. The vertex and pixel shaders are:

Vertex shader:

```
in vec4 vPos;
in vec3 vNormal;
out vec3 fN;
uniform mat4 MVP;
void main()
{
    fN = vNormal;
    gl_Position = MVP*vPos;
}
```

Pixel shader:

```
in vec3 fN;
out vec4 fColor;
void main() {
    fColor = vec4(fN, 1.0);
}
```

If all vertices are placed at the same depth after vertex shading, what color will the pixel shader return for a pixel at the middle of the triangle edge between \mathbf{p}_0 and \mathbf{p}_1 ? (0.1p)

- d) Write a vertex shader that, when applied to a sphere model, makes the sphere grow and shrink repeatedly over time. Exact GLSL syntax is not necessary, but specify the inputs needed, the transform applied, and the output of the shader. (0.4p)

2. Transforms

Given the three matrices **A**: translation by the vector $\mathbf{v} = (1, 1, 1)$, **B**: rotation 90 degrees around the z-axis and **C**: a non-uniform scaling with 2 in x, 4 in y and 3 in z.

- a) Given the point $P = (1, 2, 3, 1)$, what is the location of $P' = \mathbf{ABC}P$? (0.2p)
- b) If the matrix **B** is used to transform points of an object, what matrix is used to transform the corresponding surface normals? What is the direction of the normal $\mathbf{n} = (1, 0, 0)$ after this transform? (0.2p)
- c) Derive the view matrix for a camera placed at $E = (2, 2, 2)$ looking at the point $C = (2, 0, 2)$ and with an up-vector $(1, 0, 0)$. (0.3p)

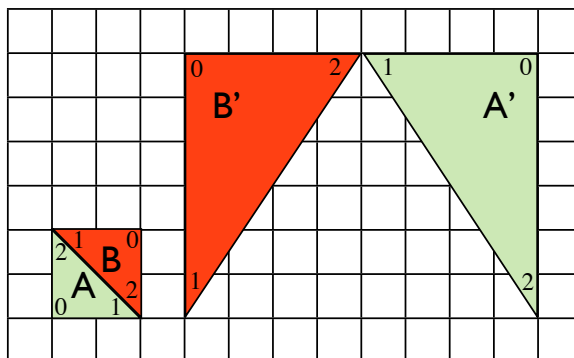


Figure 1: Transform from A to A' and B to B'

- d) Describe the transform \mathbf{M} needed to move the triangle A to A' and the transform \mathbf{N} that moves B to B' in Figure 1 below, either in RenderChimp syntax or as (a set of) matrices. Assume that the origin is placed at the lower left corner of triangle A. (0.3p)

3. Interpolation and Graphics Techniques

- a) Smoothstep is cubic interpolation between $[0,1]$ on the interval $x \in [a,b]$, with the constraint that the derivative is zero at $x = a$ and $x = b$. Derive the cubic interpolant. (0.3p)
- b) Explain the bump mapping algorithm. (0.4p)
- c) Reflection mapping is an approximation of true reflections. Why? Motivate your answer. (0.2p)
- d) What is the difference between an orthographic and perspective projection? (0.1p)

4. The Graphics Pipeline

- a) Describe the stages in a real-time graphics pipeline; from input to a resulting image. Include the different stages of the pipeline and their responsibilities. (0.4p)
- b) What are the most computationally costly parts of the graphics pipeline? Motivate your answer. (0.3p)
- c) In Figure 2, three primitives are rendered in order: A,B,C. Explain how depth buffering works, and how it can correctly render the three primitives. If the primitives were instead rendered in order C,A,B, with depth test active, what would the image look like? (0.3p)

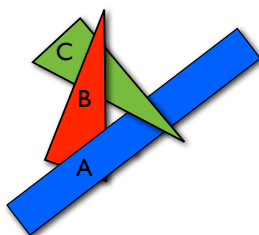


Figure 2: Three overlapping primitives.

5. The Rendering Equation

- a) The rendering equation is given as

$$I(\mathbf{p}_c, \mathbf{p}_s) = v(\mathbf{p}_c, \mathbf{p}_s) \left[\epsilon(\mathbf{p}_c, \mathbf{p}_s) + \int_S \rho(\mathbf{p}_c, \mathbf{p}_s, \mathbf{p}) I(\mathbf{p}_s, \mathbf{p}) d\mathbf{p} \right]$$

Describe and discuss each term of this equation. Also describe why the equation is so hard to solve. (0.5p)

- b) Describe how the rendering equation can be simplified in order to arrive at the Phong shading model (0.3p)

- c) Mention at least two effects that are hard to reproduce in real-time graphics, but needed for high quality offline rendering. Motivate your answer. (0.2p)

6. Hierarchical Modeling, Toon Shading and Shadows

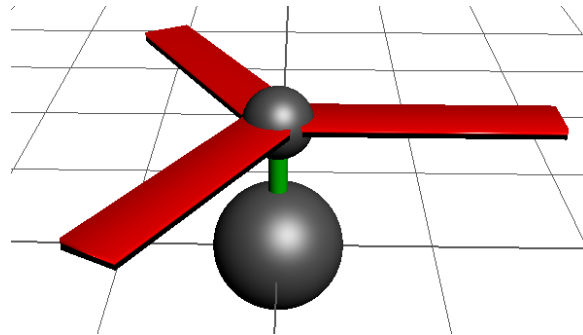


Figure 3: A simple helicopter model.

- a) Figure 3 shows a simple helicopter model. It contains a body, a vertical axis, a top sphere (to hold the main propeller) and three rotor blades. Describe a scene graph for the model and use the scene graph to animate the vertical ascent (take-off) of the helicopter. As the helicopter lifts, the three rotor blades should rotate around the vertical axis. (0.2p)
- b) *Toon shading* is a technique where the silhouette is enhanced, and a three-dimensional object appears to look flat, similar to a cartoon character. One example is shown in Figure 4 below. Notice the black border along the silhouette, the lack of 3D perception and the constant-colored specular peak.

Design a pixel shader in GLSL that performs this effect. Exact syntax is not required, but it should be clear which inputs the shader needs and how the effect is obtained. Motivate your answer. (0.3p)

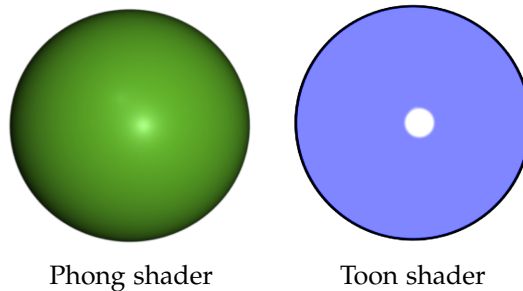


Figure 4: Two different shaders are applied to a sphere.

- c) Shadows add realism to rendered images. A shadow appears at a point P if there is an object O between P and the light source. Discuss how you could simulate shadows, both in a ray tracer and in a rasterization pipeline. Focus mostly on the latter.

Hint: In a rasterizer, one could first place a camera at the light source and render the scene from that perspective. For each pixel, both a color and/or a depth value can be obtained. In a second pass (when rendering from the real camera), use information from the first rendering pass to obtain shadows. (0.5)

The end.