LUNDS TEKNISKA HÖGSKOLA Institutionen för datavetenskap

Exam
EDA221 Computer Graphics : Introduction to 3D

2012–10–22, 14.00–19.00, Eden 022/026

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.

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1. Shading
   a) What does the following pixel shader do? *(0.1p)*

```
out vec4 fColor;
void main() {
    fColor = vec4(0.0, 0.0, 1.0, 1.0);
}
```

   b) Give the formula for Phong shading, and define its terms. *(0.4p)*
   c) Use the Phong model defined above and show how you would set the parameters for a shader that represents a "white paper" material. Motivate your answer. *(0.1p)*
   d) Use the Phong model defined above and show how you would set the parameters for a shader that represents a red, "shiny plastic" material. Motivate your answer. *(0.2p)*
   e) If Phong shading is executed per-vertex, it is denoted Gouraud shading. Discuss and motivate any visual differences between Gouraud shading and per-pixel Phong shading. *(0.2p)*

2. Transforms
   A rotation matrix around the z-axis is given by:

$$\mathbf{R}_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

   Given the three matrices **A**: translation along the vector $\mathbf{v} = (4, 0, 2)$, **B**: rotation 90 degrees around the z-axis and **C**: a non-uniform scaling with 2 in x, 3 in y and 4 in z.
   a) Give the (4×4) matrix form of each of **A**, **B** and **C**. *(0.3p)*
   b) Given the point $P = (1, 2, 3, 1)$, what is the location of $P' = \mathbf{CAB}P$? *(0.2p)*
   c) Give an example of two (different) transform matrices **M** and **N** such that $\mathbf{MN} = \mathbf{NM}$. You are not allowed to use the identity or zero matrix as **M** or **N**. *(0.2p)*
   d) Describe the transform needed to transform the triangle from A to B in Figure 1 below, either in RenderChimp syntax or as (a set of) matrices. *(0.3p)*

Please turn the page!

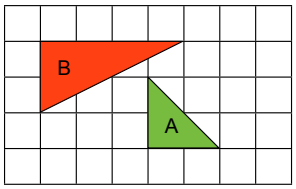

Figure 1: Transform from A to B

3. Mapping techniques and GLSL
   a) Give three examples of how textures are used in shaders. *(0.3p)*
   b) GLSL contains the function `reflect`. Give two examples when that function is useful. *(0.2p)*
   c) What is tangent space and what is it useful for? *(0.3p)*
   d) How do you specify a `float` input parameter which has the same value for all invocations of a shader in GLSL? An example would be the current frame time. *(0.1p)*
   e) How do you pass a `vec3` color that has a unique value for each vertex from a vertex shader to a pixel shader in GLSL? *(0.1p)*

4. The Graphics Pipeline
   a) Describe the responsibility of the vertex shader, rasterizer and pixel shader stage of the graphics pipeline. *(0.3p)*
   b) Mention three coordinate systems (spaces) that you may encounter in a rendering pipeline. Briefly explain the purpose of each system. *(0.3p)*
   c) What is backface culling, why is it useful and where in the graphics pipeline can a backface culling test be executed? *(0.3p)*
   d) A triangle has camera space vertex positions $P_0 = (1, 0, -1)$, $P_1 = (1, 1, -1)$ and $P_2 = (0, 1, -1)$, with normal pointing in the direction $(P_1 - P_0) \times (P_2 - P_0)$. Can this triangle be backface culled? Motivate your answer. *(0.1p)*

5. Hierarchical Modeling
   a) What is a scene graph and what is it useful for? *(0.2p)*
   b) What is the difference between spin and orbit? Explain the two concepts. *(0.2p)*
   c) Show one example of spin and one example of orbit using the objects defined below. Add new nodes if necessary. Exact RenderChimp syntax is not required, but the structure of the scene graph should be clear from your solution. *(0.6p)*

```
world  = SceneGraph::createWorld(...);
sun    = SceneGraph::createGeometry(...);
earth  = SceneGraph::createGeometry(...);
```

6. General Computer Graphics
   a) How is color represented in computer graphics and how does this relate to the Human Visual System (HVS)? *(0.2p)*
   b) Mention three differences between between real-time graphics and offline (photorealistic) computer graphics. In this context, also explain why graphics hardware, e.g., graphics cards, are useful for computer graphics. *(0.3p)*
   c) The *rendering equation* states that the total amount of light arriving at and leaving a point must balance. Why is this equation so hard to solve? *(0.2p)*
   d) In the course, we have described linear and bilinear interpolation. There is also a concept called trilinear interpolation, that we haven't explicitly discussed. Based on the definition of linear and bilinear interpolation, how would you define trilinear interpolation? Motivate your definition. *(0.3p)*

The end.