FINAL EXAMINATION

320322: GRAPHICS AND VISUALIZATION

Fall 2015

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Duration: 115 minutes.

Preliminaries: The following questions build on top of each other. If you are not capable of producing a result for one of them or if the solution you found would make successive computations extremely difficult, make a suitable, non-trivializing assumption for a result and continue with that.

Given a triangle fan with vertices $\mathbf{v}_1 = (0, 4, 2)$, $\mathbf{v}_2 = (0, 0, 2)$, $\mathbf{v}_3 = (4, 0, 2)$, and $\mathbf{v}_4 = (5, 5, 2)$ in 3D Cartesian coordinates. In the same coordinate system, we define a view point $\mathbf{p} = (0, 0, -10)$, the screen by the quadrilateral $\mathbf{v}_1 = (-2, -2, 0)$, $\mathbf{v}_2 = (2, -2, 0)$, $\mathbf{v}_3 = (2, 2, 0)$, and $\mathbf{v}_4 = (2, -2, 0)$. The resolution of the screen shall be 2×2 pixels. The triangles have diffuse reflectance coefficient $(0, \frac{1}{3}, \frac{2}{3})$, specular reflectance coefficient $(0, 0, 0)$, and specular exponent 42. The ambient color is obtained by mapping a 2D texture to the triangle fan. Assuming texture coordinates $(s, t) \in [0, 1] \times [0, 1]$, the texture coordinates for the vertices are given in the respective order by $\mathbf{t}_1 = (0, 0.5)$, $\mathbf{t}_2 = (0.5, 0)$, $\mathbf{t}_3 = (1, 0.5)$, and $\mathbf{t}_4 = (0.5, 1)$. The texture has resolution 6×6, where the s-dimension is given by sampling the hue according to the HSV color model at $\frac{i}{360}$ for $i = 0, \ldots, 5$ and the t-dimension is given by sampling the saturation at levels $\frac{j}{5}$ for $j = 0, \ldots, 5$ (the value can considered to be constant 1). Finally, we have the light source with full-intensity white light (all components) at location $\mathbf{l} = (5, 5, 1)$. Light attenuation shall follow the function $f(r) = \frac{1}{r}$.

Problem 1: Ray Casting. *(10 points)*
Within a ray casting approach to the scene, compute the intersections of the rays with the triangle fan. Make sure that you check whether the intersection points lie inside the triangle fan. If rays and triangles obviously cannot intersect, you do not need to test them, but explain in a mathematically sound way why they cannot intersect.

Problem 2: Texture Mapping. *(10 points)*
Apply 2D texture mapping to determine the HSV texture color at the vertices of the intersected triangles (according to Problem 1). The texture is applied in a clamped way and assuming bilinear interpolation (operating in the HSV color space). Moreover, draw the triangle fan in texture coordinates, and sketch the texture on the triangle fan in Cartesian coordinates.

Problem 3: Color Models. *(10 points)*
Convert the texture colors computed in Problem 2 to the RGB color model. Explain the necessary components of the color models to document your steps.

Problem 4: Illumination. *(20 points)*
Explain all components of the Phong illumination model and apply it to the vertices of the intersected triangles. For the ambient color, assume the RGB texture colors computed in Problem 3 as ambient reflection coefficients.

Problem 5: Shading. *(10 points)*
Explain the idea of Gouraud shading. Compute the color at the intersection points from Problem 1 by applying Gouraud shading to the RGB colors computed in Problem 4. The ray casting approach is now complete such that you can report back the four pixel colors.

Problem 6: Photon Mapping. *(15 points)*
Assume that we replace the diffuse and ambient color computed in Problem 5 with a photon mapping approach. Explain how the photon mapping approach works, in general. Assume a fully opaque surface and consider the diffuse reflection coefficients for the stochastic process. Assume that, for each of the color channels, ten random monochromatic rays reach the surface from a certain direction (we do not consider attenuation). Rolling the dice shall simulate the computation of random numbers (explain how exactly!). Roll the dice ten times and report back the numbers. Then, apply the respective random numbers to all color channels simultaneously to compute the light that leaves the surface (when assuming a perfectly diffuse surface).

Problem 7: Environment Mapping. *(10 points)*
Assume that we want to add a mirror reflection to the rendering without using ray tracing. Explain the concept of environment mapping and how it is applied during rendering.

Problem 8: Scientific Visualization. *(15 points)*
Assume that we replace the triangle fan with a volumetric data set. Explain how ray casting of volumetric data works. In particular, explain the physical concept behind, how the volume rendering integral is obtained, how it can be discretized, what is the back-to-front accumulation, and how the overall volume rendering pipeline looks like (assuming post-classification).