Example exam questions for EDAN30

"Photorealistic Computer Graphics"

Department of Computer Science, Lund University

Each worth 1.0 point
Allowed aids: none

2011

An actual exam will be made up of 6 questions. The following questions give an idea of the style of type of possible questions in the final exam. The typical exam instructions are as follows:

Remember to answer the questions as thoroughly as you can without diverging from the question. You should strive to give as clear a picture of your understanding as possible. Ensure that you write so that someone other than yourself can read it. Please answer in english.

1: The Rendering Equation
a) [.3p] In a ray tracing-based renderer, explain why and when it is be beneficial (in terms of performance) to split the rendering equation into a direct illumination part and an indirect illumination part.

b) [.3p] Explain how path tracing avoids the combinatorial explosion of shooting new rays that could occur if implemented naively.

c) [.2p] Write down the regular expressions using light transport notation for Whitted ray tracing and full global illumination.

d) [.2p] Explain mathematically how importance sampling is done in Monte Carlo sampling.

2: Ray Tracing
a) [.5p] Compute the distance(s) to the intersection(s) between a three-dimensional ray and an infinitely long cylinder with radius one. The location of the cylinder should be along the z-axis. As a small extension, explain how the length of the cylinder can be limited to a certain length l.

b) [.3p] When computing indirect illumination, it is common to generate uniformly distributed rays over the hemisphere. Describe a foolproof way of doing this around the normal $\mathbf{n}$.

c) [.2p] Can Whitted ray tracing compute some form of indirect illumination? Argue why.

3: Image-Based Lighting and HDR images
a) [.3p] See Figure 1. Assume we want to "merge" these three images into a single HDR image. What is the dynamic range of that image. The answer should be given as $x : 1$, where you should compute a good estimate of x.

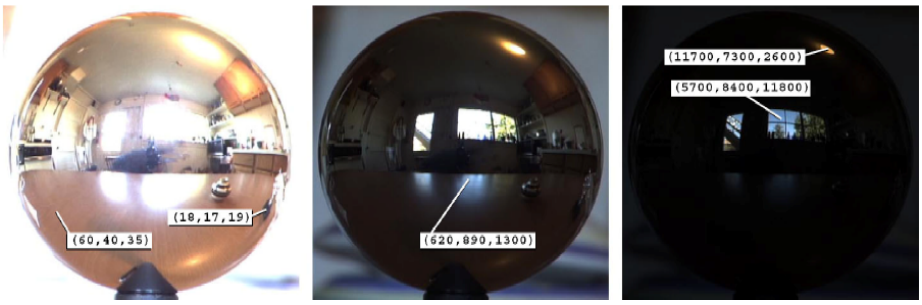

Figure 1: Three images taken of the same scene at different exposures.

b) [.3p] Give an example of how a pixel in an HDR image is stored, and why it is done like that.

c) [.4p] How is a light probe used in image-based lighting using a ray tracer-based renderer?

4: The Rendering Equation
a) [.4p] Write down the rendering equation, and explain all the terms.

b) [.2p] How are Whitted ray tracing and global illumination expressed in light transport notation?

c) [.4p] Assume we want to use Monte Carlo rendering for sampling with n rays to integrate over the hemisphere in the rendering equation. How would that be expressed mathematically?

5: Tracing rays
a) [.4p] A point, $\mathbf{t}$, on a triangle in three-dimensional space can be described as:

$$\mathbf{t}(u, v, w) = w\mathbf{p}_0 + u\mathbf{p}_1 + v\mathbf{p}_2, \tag{1}$$

where $\mathbf{p}_i$ are the three triangle vertices, and for a point inside the triangle, it must hold that: $u \geq 0$, $v \geq 0$, $w \geq 0$, and $u + v + w = 1$. Derive the intersection between a ray and such a triangle in a mathematical way.

b) [.4p] Use C-like code to implement an algorithm of the test in (5a) The code should return a boolean (whether the ray intersects the triangle or not), the distance to the intersection, and the barycentric coordinates, (u, v), of the intersection. (Note: small syntax errors are not important as long as it is apparent what you are trying to achieve)

c) [.2p] If you want to ray trace hair strands, one idea would be to ray trace against the straight line equation from a point, $\mathbf{p}_0$, to another point, $\mathbf{p}_1$. What would be the difficulty with such an approach? In addition, you should propose a better solution.

6: Sampling

a) [.4p] Aliasing can occur at several different major places when rendering images. Write down two of these, along with short descriptions of possible solutions (one solution per "place").

b) [.2p] What does the Nyquist theorem teach us?

b) [.4p] Describe an adaptive super sampling scheme, and explain whether there are any flaws to such a scheme.

7: Ray tracing and photon mapping

a) [.3p] Assume that there are $w \times h$ pixels in the display, and that there are n triangles in the scene description, stored in a linked list. Assume that all objects are perfectly reflective, and that we want to compute one bounce reflections. What would the complexity (O-notation) be for ray tracing such a scene? Motivate your answer.

b) [.4p] Invent an algorithm that improves on the complexity in (7a) without affecting the image quality. Motivate your answer by explaining what the complexity is.

c) [.3p] Describe how photon mapping implements indirect illumination *efficiently.*