Graphics Qualifying Exam
Fall, 2005

Answer **ALL** six questions in separate blue books. Each question has multiple parts - be sure to answer each one. There are 100 points total on the exam. The questions are not weighted uniformly.

For full credit, an answer must be both correct *and* well-presented (clear and concise).

If you feel a question is ambiguous, state any assumptions that you need to make. Hint: more often than not, this is a sign that you either do not understand the question, or are missing some important insight or piece of knowledge.

Question 1: Image-Based Rendering (18pts)

Image-based rendering systems store a collection of samples of the light of real scenes. If the scene is undersampled, either because there are insufficient numbers of images or insufficient resolution in the images, visual artifacts may occur. For each of the three types of image-based rendering systems listed below discuss the visual artifacts that would occur from *both* types (too few images, too few samples per image) of undersampling.

1A. Quicktime VR

1B. Lightfields and/or Lumigraphs

1C. Façade

Question 2: Surface Representations (18pts)

Over the past few years, subdivision surfaces have become the de facto standard for surface representations in computer graphics. The most common and important subdivision scheme in practice uses Catmull-Clark surfaces. Two papers in the qual reading list that discuss Catmull-Clark surfaces are DeRose et al.'s "Subdivision surfaces for Computer Animation" and Stam's "Exact Evaluation of Catmull-Clark Surfaces for Arbitrary Parameter Values."

2A. Prior to these two papers, the common technique for smooth surface representation was NURBS surfaces. Give 3 brief reasons why subdivision surfaces are preferable to NURBS. (each reason should be a single sentence. If you can think of more than 3 reasons, list only the 3 best ones.)

2B. Are there situations where NURBS surfaces may still be preferable to Catmull-Clark surfaces? Either describe situations where this may be the case, or explain why such situations do not exist.

2C. Among the advancements in subdivision surfaces that made them practical for computer graphics applications were methods for introducing creases into surfaces. (DeRose et al. introduced one in their paper "Subdivision Surfaces for Computer Animation," for example). Describe one method for doing this.

Question 3: Animation (12pts)

3A: Cloth is often simulated using a mass spring system: a lattice of particles connected by springs. This kind of cloth simulation gives rise to stiff differential equations. Stiffness is a mathematical property of differential equations that basically means they are hard to solve. In computer graphics, implicit (or semi-implicit) methods are often used to solve the stiff differential equations that arise in cloth simulation.

Even if the cloth is allowed to be "stretchy" (that is, the spring constants are made smaller so that the cloth can stretch easily, like a rubber sheet) the differential equations to simulate cloth may still be stiff so implicit methods may be advantageous. Explain.

3B: Give 4 reasons why hierarchical (skeletal) representations of motion capture data are preferred to non-hierarchical ones (such as marker clouds).

Question 4: Non-Photorealistic Rendering (15 pts)

While the initial work in Non-Photorealistic Rendering (NPR) was to make pretty pictures, later work had more practical benefits. For 3 different NPR styles/techniques and describe how they achieve something "useful" beyond just making a pretty picture. That is, explain why the methods have practical value beyond simply the aesthetic of recreating a traditional artistic style.

"Gooch shading" (the style presented in the paper "A Non-Photorealistic Lighting Model for Automatic Technical Illustration" by Gooch et al. and in numerous textbooks) must be one of your 3 techniques, however you are free to choose the other two. You may choose methods that appear in the literature that do not appear on the qualifying exam reading list.

Question 5: Rendering (25pts)

For the following four sub-questions (5A, 5B, 5C, 5D), use these definitions:

Radiosity renderer – renders scenes considering only diffuse reflection by encoding light transport into a large linear system that is solved.

"From-the eye" ray-tracer – renders a scene by shooting rays from the eye, and recursing on ray-object intersections.

Traditional ray-tracers – are from-the-eye ray tracers that shoot a small number of rays depending on scene geometry. specifically a *specular reflection ray* (the mirror reflection of the incoming ray) and *shadow rays* (from the intersection point to the light sources). Better ray tracers send out more rays – these are often called *distribution ray tracers*.

Bi-directional ray tracers – start rays at both the eye and at the lights. Many bi-directional ray tracing techniques (such as Photon Mapping) do the from-the-light rays first, followed by from-the-eye rays.

5A: The photon map is a clever data structure for storing the intermediate results of a bi-directional ray-tracer. Describe the key features of this data structure and explain why they are an improvement over the prior state of the art that stores irradiance information on surfaces, such as Heckbert's Radiosity Textures.

5B: A photon map renderer can render lighting effects that cannot be rendered by radiosity renderers, basic ray-tracers, or the combination of a radiosity renderer followed by a ray tracer. Describe two situations where these lighting effects are significant. Describe what would be seen in results of all four (photon-map, radiosity, ray tracer, ray tracer+radiosity).

5C: A student is plans to write a renderer that will render scenes that consist entirely of diffuse reflectors. While a traditional radiosity renderer is an obvious choice, a photon map renderer might be a better choice. Explain why the photon map renderer might be a better choice. Hint: consider how the geometry of the scenes that will be renderered will effect the choice.

5D: In the "from the eye" pass of a photon map renderer some of the rays used in traditional ray-tracing are very important, and others are not needed at all. Explain.

Question 6: Basic Graphics Knowledge (12 pts)

6A: Give two examples where the order that objects are drawn matters when using a Z-Buffer.

6B: What is the difference between Bump Mapping and Displacement Mapping? Describe a situation where you can see the difference.

6C: If Violet was the third primary, many of the color representations we use would change. RGB would become RGV, for example. Describe what would happen to the CIE XYZ color system and the HSV color system.

6D: If you draw lines on a black and white display using Brezenham's algorithm, does a 45° line look brighter, the same, or dimmer than one drawn drawn horizontally? Why? (assume that the display has square pixels that do not overlap and no anti-aliasing)