Graphics Qualifying Exam

September 2004

- This exam contains six questions.
- **Answer 4 of the first 5 questions, and question 6.**
- All questions are of equal point value.
- Answer each question in a separate blue book.

Question 1:

This question concerns techniques that are now ubiquitous in the graphics community, and were both introduced to the graphics community at SIGGRAPH in 1985.

a. Quaternions, originally developed over a century ago, were introduced to graphics by Shoemake, and are widely used to represent rotations. Choose two other representations for rotation regularly used in graphics. **For each representation** answer the following questions. At the end, you should have two representations, two descriptions, and four problems.

   (i) Describe how the rotation is encoded. How many numbers are used? What is the geometric interpretation, *if any*, of the numbers? For example, quaternions use four numbers. Three of them are the axis of rotation scaled by sin of half the rotation angle, while the fourth number is the cosine of half the rotation angle.

   (ii) Describe **two** problems that arise when using the representation that are made simpler by quaternions. The problems could be common operations that are difficult or costly to perform, or arithmetic problems arising from use of the representation. The problem does not need to be unique to the representation chosen - you may use the same problem for both of your representations.

b. Perlin noise is now found all over graphics, in everything from texture synthesis to fluid animation. Give at least two properties of Perlin noise and explain why each property is important for graphics applications.

Question 2:

The image morphing method of Beier and Neely was significant in part because of the artistic success their company (PDI) had in using it. In fairness, a lot of this artistic success was due to the talented artists that used their system. However, certain features of the algorithm made this possible.

This key algorithm still is known as the Beier-Neely method, and has been the foundation of many other methods (including Seitz and Dyer's View Morphing).

a. Describe the important advances of the Beier-Neely method over the previously available techniques (such as those that used uniform grids). Discuss how these advances helped lead to the artistic successes.

b. Describe how Mipmapping would be used in an implementation of Beier-Neely morphing, or any warping method that employs "reverse mapping."

Question 3:

Algorithms for efficiently rendering complex models, such as visibility and level-of-detail schemes, are designed to overcome limitations in overall rendering system performance. These limitations can be summarized as assumptions about the **relative** costs of rendering, main CPU operations, bus transfers, network transfers, and available memory. The methods also make assumptions about the types of models to be rendered.

For any **two** of the following LOD or visibility techniques, discuss the major assumptions about system performance used in the paper. Also discuss the situations (types of models, applications) that the methods are targeted at.

a. Funkhouser, Sequin and Teller's Walkthrough system.

b. Garland and Heckbert's Quadric Error Simplification.

c. Hoppe's progressive meshes.

Question 4:

Random sampling techniques underly many algorithms for high quality rendering, yet some methods are extremely useful without randomness.

a. State one method that does **not** exploit randomness and yet is capable of generating a physically accurate depiction of some globally illuminated scenes. What properties must a scene have to be suitable for this algorithm?

b. Describe three ways in which randomness or multiple samples can be used to improve the quality of an image of glossy, moving objects rendered using rays traced from the eye. The minimal quality image, on which you must improve, is a ray-tracer that casts a single ray per pixel and at most one reflection, one shadow, and one refraction ray per surface hit.

Question 5:

Painterly style (non-photorealistic) rendering poses two major problems when animated. The first is the "shower door" effect that causes objects to appear as though they are moving behind a textured piece of glass. The second is visible flickering of the painted strokes.

a. Explain the underlying causes of these affects.

b. Describe two ways in which researchers have attempted to overcome the shower door effect.

Question 6:

Seminal systems frequently provide a definitive solution for a specific application domain, which may be completely unsuitable for another. For each of the following pairs of systems, describe the application domain for each system and give two specific tasks. One task should be well suited to one system but not the other, and vice versa for the other task. Explain what it is about the tasks that discriminate between the seminal systems. For example (using information not in the reading list):

The Reyes/*Renderman* architecture versus SGI's *Hardware Graphics* techniques. The Renderman renderer is targeted at *film quality, general scenes*. Hardware graphics is targeted at *real-time rendering* with little flexibility in geometry and shading. For the task of rendering a highly realistic forest scene, the Renderman architecture can capture the complexity of geometry, light and shading through it's flexible modeling primitives and programmable shaders, while SGI hardware graphics cannot perform arbitrary shading operations, nor can it manage the complex geometric shapes in a succinct manner. On the other hand, for an *architectural walkthrough* of a building, Renderman cannot provide the necessary *interactivity* because it uses a scanline rendering architecture tailored for complex shading effects, while hardware graphics can efficiently process the simple geometry and shading requirements.

Now it's your turn:

a. SketchPad and Sketch

b. Facade and Quicktime VR