FALL 2006
COMPUTER SCIENCES DEPARTMENT
UNIVERSITY OF WISCONSIN-MADISON
PH. D. QUALIFYING EXAMINATION
Computer Graphics
Monday, September 18, 2006
3:00-7:00 PM

GENERAL INSTRUCTIONS:

1. Answer each question in a separate book.

2. Indicate on the cover of *each* book the area of the exam, your code number, and the question answered in that book. On one of your books list the numbers of all the questions answered. *Do not write your name on any answer book.*

3. Return all answer books in the folder provided. Additional answer books are available if needed.

SPECIFIC INSTRUCTIONS:

Answer ALL five questions. Each question has multiple parts-be sure to answer each one.

POLICY ON MISPRINTS AND AMBIGUITIES:

The Exam Committee tries to proofread the exam as carefully as possible. Nevertheless, the exam sometimes contains misprints and ambiguities. If you are convinced a problem has been stated incorrectly, mention this to the proctor. If necessary, the proctor can contact a representative of the area to resolve problems during the *first hour* of the exam. In any case, you should indicate your interpretation of the problem in your written answer. Your interpretation should be such that the problem is nontrivial.

Graphics Qualifying Exam
Fall, 2006

- Answer **ALL** five questions. Each question has multiple parts - be sure to answer each one. There are 100 total points on the exam.
- Please write clearly. If we cannot understand what you have written, we will assume that it is wrong.
- Please write each part on a separate page and be clear which question you are answering.
- 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.
- For essay questions, there may be many correct answers. It is more important that you provide a good argument for the answers you give than that you give the "most correct possible" answer.
- If a question asks for an impossible answer, say so and explain. For example, if you are asked for an example of a situation that could not exist, explain why it can't exist.

Question 1: Basic Graphics Knowledge (25 pts)

1. Consider Brezenham's algorithm (or the very similar midpoint algorithm) for drawing lines. Consider the basic version (for drawing single pixel width lines without anti-aliasing).

   If we draw a line between points (x_1, y_1) and (x_2, y_2),

   What is the lower bound on the number of pixels the algorithm will access?

   What is the upper bound on the number of pixels the algorithm will access?

2. Let $\mathbf{A}$ and $\mathbf{B}$ be 3×3 rotation matrices. Let $\mathbf{C}$ be a matrix created by a convex linear combination of them ($\mathbf{C} = \alpha\mathbf{A} + (1 - \alpha)\mathbf{B}$).

   Under what circumstances will $\mathbf{C}$ be a rotation matrix?

3. A point $\mathbf{p}$ on a surface has associated unit normal vector $\hat{\mathbf{n}}$, and tangent vectors $\hat{\mathbf{t_1}}$ and $\hat{\mathbf{t_2}}$.

   If the surface is transformed by the matrix $\mathbf{M}$ (so the transformed position of the point is $\mathbf{Mp}$), what is the transformed normal vector?

4. The Z-buffer and BSP trees are both common methods for doing hidden surface elimination. Other than efficiency (which depends on many different tradeoffs and is hard to assess in the abstract), give 2 or 3 advantages that BSP trees have over a Z-buffer.

5. Many graphics systems use Mipmapping with tri-linear interpolation as a method for sampling textures. This approach is an efficient approximation to the ideal sampling filter.

Consider drawing a texture mapped triangle (and only "standard" texture mapping), and only consider pixels for which edge effects do not apply (since sampling the edges of the triangle has other issues).

Discuss how mip-map sampling is different than ideal sampling. Describe cases where the approximation would be noticeably different (give a polygon/viewer configuration and a description of the difference in appearance).

Question 2: Tone Mapping (10 pts)

Describe two different methods for tone mapping a high-dynamic range image to a normal (or lower) dynamic range display. For each method, describe a situation where its result might be preferable to the other.

Hint: not all methods need to be complicated.

Question 3: Geometric Modeling (25 pts - 5pts each)

There are many ways to represent 3D objects. For each pair of methods below, discuss the situations under which the first is preferable to the second.

Note: by "point-based" representation, we mean representing a surface by a collection of points on the surface, without any connectivity information.

1. Free form deformations and triangle meshes.
2. Point-based representations and polygonal models (e.g. triangle meshes).
3. Polygonal models (e.g. triangle meshes) and point-based representations.
4. Catmull-Clark Subdivision surfaces and NURBS.
5. NURBS and Catmull-Clark Subdivision surfaces.

Question 4: Ray Tracing (25 pts - 8,8,9 (3,3,3))

Bi-directional ray tracers do a combination of forward (from the light source) and backwards (from the eye) ray casting to create their images.

1. Discuss why a bi-directional ray-tracer is (usually) preferred over purely forward and purely backward ray tracers.
2. A Photon-Map is a clever data structure for storing the results of the first pass of a bi-directional ray tracer. Describe two or three features of the representation and explain why they are important.
3. If a ray tracer under-samples the light paths (that is, uses too few rays), visible artifacts can occur. In a bi-directional ray tracer, under-sampling can occur in either the forward or backwards tracing phase. For each of the following, describe a visual artifact that:

(a) Is indicative that there is under-sampling in the forward pass.

(b) Is indicative that there is under-sampling in the backwards pass.

(c) Could be indicative that there is undersampling in either the forwards or backwards pass.

You should explain why the artifact is indicative of what you say it is indicative of.

Question 5: Seminal Systems (15 pts)

1. 10 years later, the Sketch system (from Zeleznik et al) still serves to inspire graphical interfaces. It provides a fast an easy way to quickly create 3D models.

   Prior to Sketch, many people thought that allowing the user to draw a sketch of a 3D object and using computer vision methods to interpret the drawing as a 3D model was going to be the way to create an easy system for quickly creating 3D models.

   The secret of Sketch is that it solves a different problem than finding a 3D interpretation of a hand-drawn a sketch, but uses a cleverly designed interface that often makes it seem like the user is sketching in 2D and the system is interpreting the drawing.

   Explain these ideas (why Sketch's problem is different, and easier, than sketch interpretation; and how sketch gives the impression that it is performing sketch interpretation).

2. Sketchpad and REYES (the early version of renderman) are two seminal systems that had many ideas that influenced the field for decades.

   Choose *one* of these systems. Pick *one* of its key ideas. Describe how it appeared in the original system, and the influence it has on current systems.