Name: ___________________________

CS559 2010 Final Exam

Closed Book and Closed Notes.

You will have the entire exam period (until 2:25pm) to complete the exam. The exam is designed to take less time (yes, really this time!)

Please write your name on every page!

Write numerical answers in fractional form or use radicals (square root symbols) – we would prefer to see $\frac{\sqrt{3}}{2}$ than .866. You should not need a calculator for this exam.

Unless otherwise noted, assume that everything is a right-handed coordinate system and that angles are measured counter clockwise (i.e. to find the direction of rotation, point your thumb along the axis and curl your fingers).

Please keep your answers concise and readable. Answers that are excessively wordy or illegible will be considered incorrect. If you need more space, use the back of the page, but put a note telling us to look there.

Note: there are some questions at the back of the exam for which there a lots of possible right answers.

There are 11 Questions on this exam.

There are 100 points on this exam.

Name: ___________________________

Question 1: I told you I'd ask (4pts)

(this is in the book, but we talked about it at the beginning of a Lecture and I said it would be on the exam)

1A: An object with surface normal **n** (which is a 3 vector) is transformed by the 3x3 Matrix **M** (which is the upper 3x3 part of the 4x4 transform in homogeneous coordinates).

Give an expression for the transformed surface normal.

It's the inverse transpose (also known as the adjoint) $n' = (M^{-1})^T$

1B: In some circumstances, the answer is the matrix itself, that is:

$\mathbf{n}' = \mathbf{M}\,\mathbf{n}$

What is the important special case when this is true?

When M is a rotation, it is its own inverse transpose.

Name: ___________________________

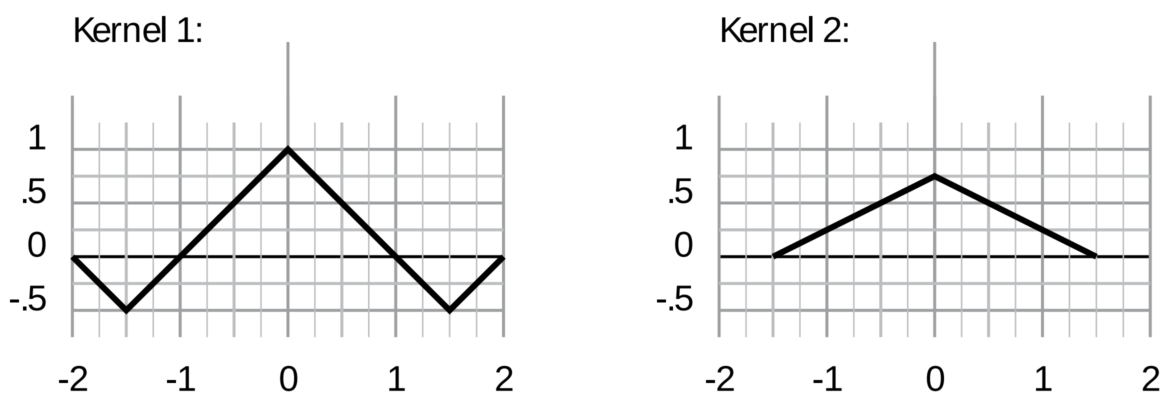
Question 2: (10 pts)

(note: there are actually 6 parts to this question, each is a single number)

Given the following sampled signal:

[0 4 4 8 8 4 0] (the first sample is for t=0, and the second sample is t=1). Assume any sample outside of the range 0-6 is 0.

Here are two reconstruction kernels (the grid units are ¼):



2A: If kernel 1 is used to reconstruct the signal, what will the value be at:

t=1.5 (-.5) * 0 + (.5) * 4 + (.5) * 4 + (-.5) * 8 = **0**

t=3 8 (the kernel interpolates)

t=4.5 (-.5) * 8 + (.5) * 8 + (.5) * 4 + (-.5) * 0 = **2**

2B: If kernel 2 is used to reconstruct the signal, what will the value be at:

t=1.5 (.5) * 5 + (.5) * 4 = 4

t=3 (.25) * 4 + (.75) * 8 + (.25) * 8 = 9

t=4.5 (.5) * 8 + (.5) * 4 = 6

Name: ___________________________

Question 3: (22pts)

Please define the following terms. A sentence or two should be sufficient.

The first four are worth 4 pts each. The last one is worth 2pts – it was a term that I told said in class would be on the exam.

Metamer:

Two colors that have different spectral distributions but the same perceptual response

Limit Surface:

The surface that is obtained after an infinite number of subdivision operations

Depth-of-Field: (your answer should explain the conditions required to create it – why most graphics doesn't have it)

When parts of an image away from the focal depth appear out of focus because there is a finite aperature (most graphics cameras have a pinhole model - inifitessimal aperatures).

Technically, depth of field refers to the range of distances that appear sharp (or in focus).

MIP-Map: (your answer should include what it is used for)

A data structure that holds copies of an image in a pyramid of reduced sizes, each half as big. Done to allow for fast sampling (usually for texture mapping) by pre-computing.

Environment Map:

A texture map that surrounds an object/scene so that texture lookups tell what a reflection would see. It is used to create reflections using texturing hardware.

Persistence of Vision: (you may want to contrast this with the other term that people confuse this with)

When you are temporarily "blinded" by a bright flash of light (that causes all of your photo-receptors to discharge and need to regenerate). This is **not** the "flicker fusion" effect used to see movies as a continuous image.

Name: ___________________________

Question 4: (8pts)

In class, and in the book, we described 4 things that *Distribution Ray Tracing* gives over a basic ray tracer. One of those four is *Depth of Field*.

4.A. Describe **2** things that *Distribution Ray Tracing* gives over a basic Ray-Tracer **besides** Depth of field. You should give a sentence explaining why Distribution Ray Tracing can give you this.

If you'd like to give a third answer as a backup (in case one of your first two are wrong), we'll let you write 3 of them. But if we have to look at #3, you'll lose some points for getting 1 or 2 wrong.

4.A.1. Soft Shadows (rays shot to sample the finite light size)

4.A.2. Anti-Aliasing (rays shot to sample the finite pixel size)

4.A.3. Glossy Reflections (rays shot to sample the range of directions the reflections might go in)

4.B. Give an example of something that you get by increasing the recursion depth of a ray tracer, rather than increasing the ray distribution.

A reflection of a reflection. (or more iterations of the same). Or a reflection of a refraction. Or Shadows in a reflection. Etc.

Name: ____________________________

Question 5: Convolution Boundaries (12pts)

Convolve the signals

```
f(x) = 6 0 6 0 6 0 6 0
for the range of x 0..7

g(x) = 1/3 1/3 1/3
for the range -1..1
```

Assume that g is zero outside of its range (-1 to 1 inclusive), but that f is only defined over the range 0 to 7.

Only consider the result over the range of f (f has 8 entries, so f*g should have 8 entries as well).

5A: Compute f*g assuming f is zero outside its range

2 4 2 4 2 4 2

5B: Compute f*g using clamping of f outside its range

4 4 2 4 2 4 2

5C: Compute f*g using mirroring (a.k.a. reflection)

4 4 2 4 2 4 2 (there is another right answer if you do the reflection differently)

5D: Compute f*g using kernel re-normalization

3 4 2 4 2 4 2 3

Question 6: What did that word mean and why did we use it (12pts)

For each part (A,B,C) there are two subparts. Please be clear where your answers are for each part. A sentence or two is sufficient for each.

6.A.1) The XYZ color system uses "**imaginary** colors" as its primaries. Why are these colors "**imaginary**"?

6.A.2) Why would you need a color system with **imaginary** primaries (rather than one with non-imaginary primaries)?

An "imaginary" color is a spectral distribution (color) that is not physically realizable (that is, it involves negative energy at points in its spectra).

Imaginary colors are useful because they allow created color systems that isolate particular photo-receptors (which have overlapping sensivities).

These color systems are really useful in analyzing the range of perceptual responses.

6.B.1) What are the three things referred to by the "tri" in **tri-linear** interpolation?

6.B.2) Where is **tri-linear** interpolation used, and why would you prefer it to "less than tri-" linear interpolation (like bi-linear or uni-linear)?

Tri-linear interpolation interpolates position in 2D (since they are images), and the level of the mipmap.

It is useful since it allows for using interpolation of images (so we don't need to sample at pixel boundaries) and mip-map level (so we don't need to restrict ourselves to the power-of-2 images sizes in a mipmap).

If you just did bi-linear interpolation, you would either have to use a single blurred image (so it would be either too blurry, or not blurry enough) , or switch between them, which would cause discontinuities.

Name: ___________________________

Question 7: (8pts)

In class (and in the book), we discussed a number of ways that we perceive depth in a scene.

List 4 of these "depth cues":

Stereo, Accommodation, Relative Size, Known Objects, Perspective, Parallax, Occlusion, …

Question 8: (8pts)

The idea of pre-filtering is that you filter before you do something else (that's why its called pre-filtering). Explain what pre-filtering does for re-sampling, and why the pre-filter has to be a pre-filter (not a post-filter)

The pre-filter removes high-frequencies so that the subsequent down-sampling won't alias.

Once you downsample, things will have aliased, so filtering won't help. So "post-filtering" doesn't work.

(example: if you downsample a black/white checkerboard by a factor of 2, you'll either get all black or all white – filtering one of those won' get you gray)

Name: ___________________________

Question 9: (10pts)

In the graphics hardware pipeline, what are the stages between the "Vertex Processor" (the thing that transforms the vertices, computes per vertex lighting, …) and the "Fragment Processor" (the thing that decides what color each fragment should be, …)?

Name the stages, and give a brief description of what they do.

There should be at least two stages in your answer (more if you consider a fancier version of the pipeline).

Assembly – puts the vertices back together into triangles

Rasterization – figures out which pixels/fragments are generated by triangles

Other possible things to add:

Geometry Shaders – alters the set of triangles

Clipping/Culling – throws away triangles (or parts of triangles) that cannot be seen

Name: ___________________________

Part of the idea of giving a final exam is to make sure that you do some review/study at the end of the semester to help the material sink in. So, here are some questions that try to check that more directly.

Question 10: (3 points)

Name a topic that we discussed in class in the second half of the course that did not appear on the exam:

Compression, Parts of the Eye, Radiosity, Histogram Equalization, Compositing, Nyquist theorem, GLSL, …

Question 11: (3 pts)

Give three of the most interesting facts about graphics that you reviewed while studying, that were not asked about on the exam. (These should be things that you learned in class, either from the lectures or the readings).

11A)

11B)

11C)