University of California San Diego
Department of Computer Science
CSE167: Introduction to Computer Graphics
Midterm Examination
Thursday, October 27, 2011

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Name:________________________________

Please write your name or initials at the top of every page before beginning the exam.

Please include all steps of your derivations in your answers to show your understanding of the problem. Try not to write more than the recommended amount of text. If your answer is a mix of correct and substantially wrong arguments we will consider deducting points for incorrect statements. You may not use calculators, notes, textbooks or other materials during this exam, except for one single sided, hand-written 3x5 inch index card. There are ten questions for a total score of 100 points.

Good luck!

This space is for grading

Exercise	Points
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total	

1. Linear Algebra (10 points)

1. In the following, assume we are working in 2D and that S(a,b) scales by a in x direction, b in y; that R(a) rotates by the angle a [in degrees], and T(t,s) translates by t in x direction and by s in y.

a) Which of the following pairs of transforms can be reversed (i.e., applied in reverse order) without changing the result? Write Yes if they can be reversed and No if they cannot. (5 points)

T(1,2) T(2,3)

S(2,1) R(45)

R(45) T(1,1)

R(10) R(20)

S(2,2) R(45)

b) Write down a sequence of transformations that has the effect of rotating an object by 45 degrees about the point (1,1). Indicate in which order these transformations have to be applied. (5 points)

2. Matrices (10 points)

Label each of the following 4x4 matrices with what they are. The options are: non-uniform scale, orthogonal projection, perspective projection, translation, rotation. Hint: there is one matrix of each type. (2 points each)

a)

$$\begin{vmatrix} 1 & 0 & 0 & -12 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 7.5 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

b)

$$\begin{vmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.4 & -0.91 & 0 \\ 0 & 0.91 & 0.4 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

c)

$$\begin{vmatrix} 11 & 0 & 0 & 0 \\ 0 & 11 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

d)

$$\begin{vmatrix} 5 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

e)

$$\begin{vmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -11 & 8 \\ 0 & 0 & 1 & 0 \end{vmatrix}$$

3. Projection (10 Points)

a) Name two differences between orthographic and perspective projection? (2 points)

b) What is a view frustum? List a set of parameters which define a view frustum. (3 points)

c) What is the canonical view volume? What range do x/y/z values have in the canonical view volume? (2 points)

d) What is the strategy to map the canonical view volume to the frame buffer? Is this operation reversible? If so, how; if not, why not? (3 points)

4. Rasterization (10 points)

a) The diagram below shows a triangle with vertices labeled a, b, and c. Several locations have been indicated with circles. The list of numbers to the left contains triples of numbers representing the barycentric coordinates of these circles. Draw a line connecting each triple with the correct circle. (1 point each)

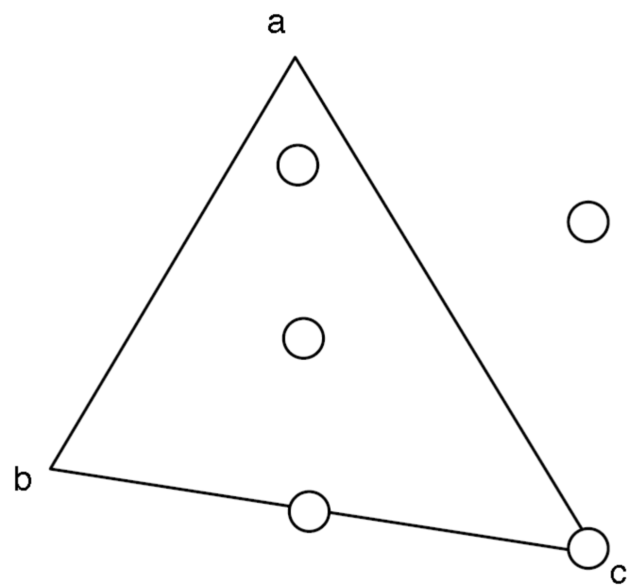
0, 0, 1

0.333, 0.333, 0.333

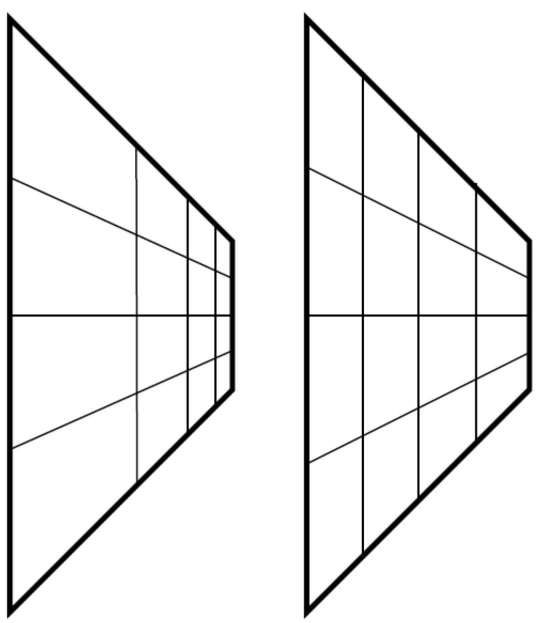
0, 0.5, 0.5

0.75, -0.5, 0.75

0.8, 0.1, 0.1



b) The two diagrams below are supposed to show a perspective square with evenly spaced gridlines. Cross out the one that shows incorrect perspective and explain what the problem is. (5 points)



5. Rendering Optimization (10 points)

a) What is the purpose of triangle backface culling? On average, what percentage of the triangles of a scene can be culled this way? (2 points)

b) Given a triangle with vertices p0, p1, p2, give a mathematical description of how to determine if the triangle is back facing. (3 points)

c) List two ways the points of a triangle could be arranged in which would make it subject to degenerate culling. (2 points)

d) Describe what the general idea of view frustum culling for triangles is. (3 points)

6. Color (10 points)

a) What is at the core of the Trichromatic Theory? (1 point)

b) What did the Tristimulus Experiment aim to determine? (1 point)

c) What experimental setup was used for the Tristimulus Experiment? (3 points)

d) An Experiment done in 1942 was designed to identify regions in CIE xy color space which were perceived as the same color.

What shape did the regions in CIE xy color space have which were perceived as the same color? (1 point)

Given a perceptually uniform color space, what shape would the same regions have in it? (1 point)

e) Circle the correct answer (3 points):

Are the colors in color space CIE RGB perceptually uniform? yes/no

Are the colors in color space CIE XYZ perceptually uniform? yes/no

Are the colors in color space CIE LAB perceptually uniform? yes/no

7. Shading (10 points)

a) Briefly describe what a Bidirectional reflectance distribution function (BRDF) is. Does the light direction have an impact on it? Does the viewer direction have an impact on it? (2 points)

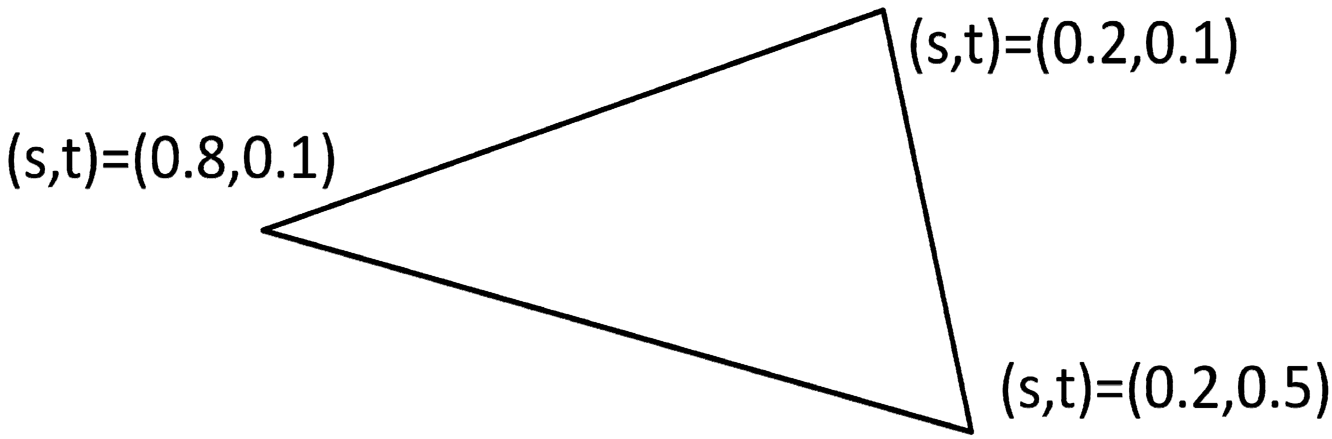
b) What three components does OpenGL's simplified local illumination model consist of? Describe for each of them whether it depends on viewer direction and/or light source direction. Which of them also depends on a shininess parameter, and what does it model? (3 points)

c) Given the following three ways to shade a triangle: per triangle, per vertex, per pixel. Indicate below which image was shaded in which of the three ways. (3 points)

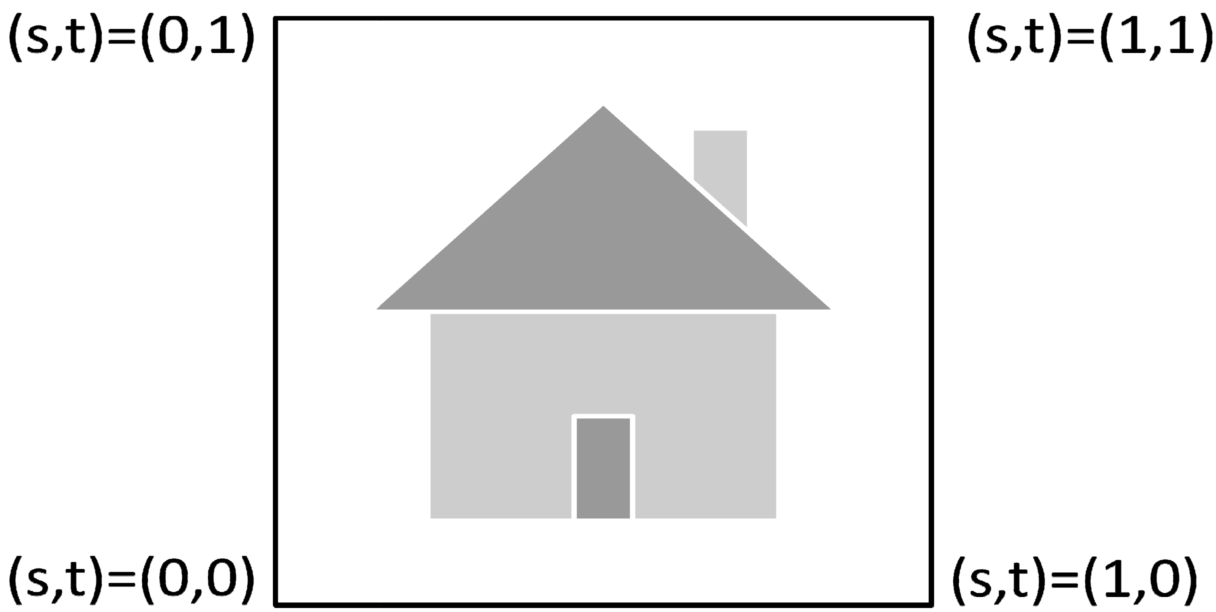
d) Which of the above three shading methods are supported by the fixed function pipeline of OpenGL, which ones require a custom shader? (2 points)

8. Texture mapping (10 points)

Given a triangle with associated texture coordinates (s,t) for its vertices

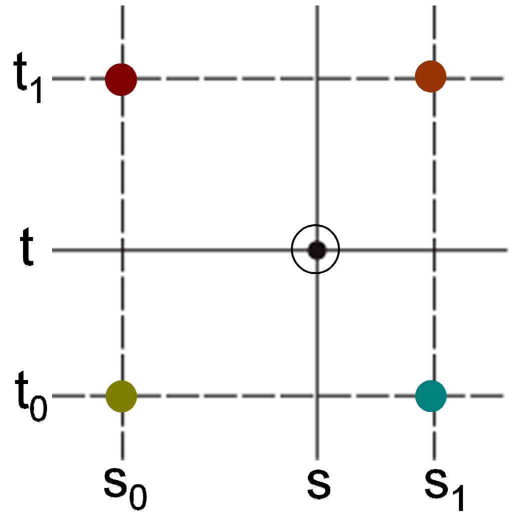


and a simple texture with its corner coordinates given:



a) Sketch into the triangle what it will look like after texture mapping. (4 points)

b) Given interpolated texture coordinates (s, t) at the current pixel, the closest four texels in texture space are at: (s_0,t_0), (s_1,t_0), (s_0,t_1), and (s_1,t_1), as illustrated in the picture below. The colors of the closest four texels are $tex(s_0,t_0)$, $tex(s_1,t_0)$, $tex(s_0,t_1)$, and $tex(s_1,t_1)$.



Derive a formula or pseudo-code for the color c of the pixel when nearest neighbor interpolation is used. (2 points)

Derive a formula or pseudo-code for the color of the pixel when bi-linear interpolation is used. (4 points)

9. Scene Graph (10 points)

a) Name three advantages of using a scene graph compared to flat OpenGL code. (3 points)

b) Name three examples for useful node types in a scene graph. (3 points)

c) Object-level view frustum culling is a performance optimization technique which scene graphs support by providing a hierarchy of bounding spheres or bounding boxes. Outline an algorithm for how object-level view frustum culling can be done on groups of objects in the scene graph. No mathematical formulas required. (4 points)

10. Shader Programs (10 points)

a) Assuming that both vertex and fragment programs have been loaded for rendering a triangle. How many times will the vertex program get executed, how many times the fragment program? (3 points)

b) Name two examples each for what vertex and fragment programs can be used for. (4 points)

c) What is the difference between the storage classifiers “uniform” and “varying” in GLSL? (3 points)