CS 248: Introduction to Computer Graphics

Final Examination
Tuesday, March 19, 1996

Note: This is exam is *closed-book.* No written materials or notes are to be used while taking this exam.

Note: Please print your name in the space provided on every page.

The exam consists of 6 questions. Each question is worth a different number of points. Please answer all the questions in the space provided, overflowing on to the back of the page if necessary. We estimate that this exam should take 1 hour, but you will have the entire 3 hours to complete the exam.

Honor Code Statement

The Honor Code is an undertaking of the students, individually and collectively:

1. that they will not give or receive aid in examinations; that they will not give or receive unpermitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;

2. that they do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of the Honor Code.

The faculty on its part manifests its confidence in the honor of students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code. While the faculty alone has the right and obligations to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.

I acknowledge and accept the Honor Code.

Printed name____

Signature____

NAME:

1. The innermost loop of a ray tracer involves computing the point of intersection of a ray and a surface. This question concerns the calculation of the intersection of a ray and a cone.

The equation of a cone is $x^2 + y^2 - z^2 = 0$. This equation describe an infinite double cone whose apex is at the origin, and whose sides extend toward infinity in the positive and negative *z* directions.

Suppose a ray is given by the equation $\vec{P} = \vec{O} + t\vec{D}$, or alternatively:

$$x = x_0 + tx_1$$
$$y = y_0 + ty_1$$
$$z = z_0 + tz_1$$

1A. [15 points] Show that the intersection of the ray and cone may be computed by solving for the roots of the quadratic equation $at^2 + bt + c = 0$. To show this, derive expressions for *a, b, c* in terms of the ray parameters x_0, y_0, z_0, x_1, y_1, and z_1.

1B [5 points] Suppose the cone corresponds to our common intuition of what is cone; that is, is not doubled and does not extend to infinity. To make such a cone, we will cap the cone with a unit disk at z=-1 and cut off the part of the cone in the positive z halfspace. How would you modify your calculation to handle this more realistic situation? (Sketch out the algorithm in detail, but do not attempt to work out the math.)

NAME:

2. [10 points] Match up the following 4x4 matrices with the corresponding type of 3D transformations. Answer the question by drawing lines connecting the phrase on the left to matrix on the right.

Identity (no effect)

$$\begin{bmatrix} \sqrt{2} & -\sqrt{2} & 0 & 0 \\ \sqrt{2} & \sqrt{2} & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix}$$

Uniform scale

$$\begin{bmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Non-uniform scale

$$\begin{bmatrix} 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Reflection

$$\begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

Rotation about z

$$\begin{bmatrix} 3 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

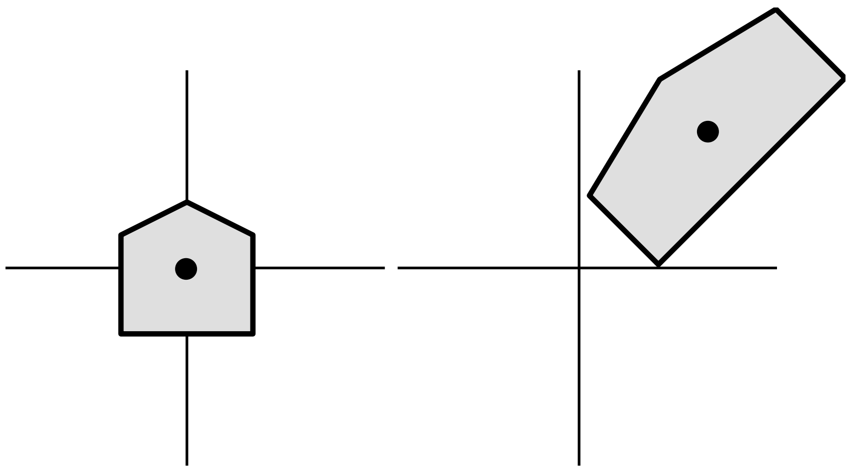
Rotation

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}$$

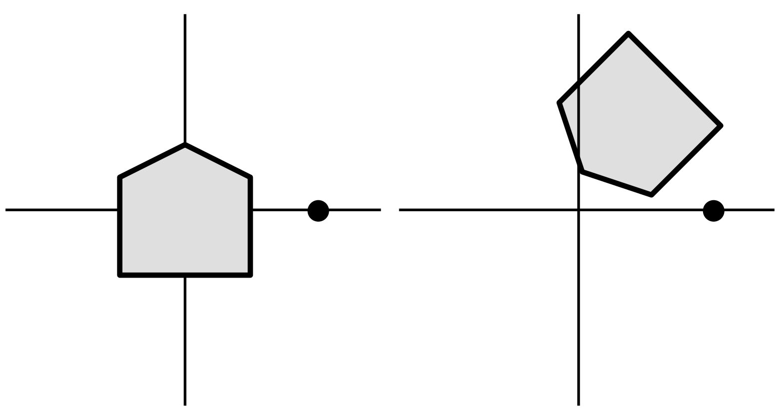
NAME:

3. Suppose you have created a drawing of a house centered at the origin as shown below. In the following two questions, derive the sequence of transformations that place the house at the new position. Answer the question by writing down a sequence of the form T(1,1) S(2,3) R(45). In your answer use T to represent a translate, S to represent a scale, and R to represent a rotation about the origin; also use the convention that the rightmost transformation is the first to be applied.

3A:[5 points] Position the house centered at the point (2,2), scaled by 2 in the horizontal direction, and rotated by 45 degrees, as shown.



3B. [5 points]. Rotate the house about the point (2,0) by 45 degrees, and flip it as shown.



NAME:

4. An axonometric parallel projection can be produced by a sequence of two rotations: $R_x(\theta)R_y(\phi)$.

4A. [10 points] Symbolically calculate the 4x4 transformation matrix produced by this sequence of transformations.

4B. [5 points] Transform the unit interval on the x, y, and z axes by this matrix and project them onto the x-y plane. Derive the coordinates of the transformed endpoints. What is the length of each transformed vector (this is the amount of foreshortening caused by the projection)?

4C. [5 points] Find the angles θ and ϕ that generate an isometric projection where the x, y, and z directions are equally foreshortened; that is, have the same length.

NAME:

5. [20 points] In this problem, you are going to invent a special cubic spline curve *g(x)* to approximate the function *f(x)* on the unit interval between 0 and 1.

You are given 4 pieces of information:

$$v_0 = f(0)$$
$$v_1 = f'(0)$$
$$v_2 = f''(0)$$
$$v_3 = f(1)$$

Here *f'* is the 1st derivative and *f''* is the 2nd derivative of the function..

Find the set of cubic basis functions that allow the *g* to be written in the following form:

$$g(x) = \sum_{i=0}^{3} v_i B_i(x)$$

NAME:

6. Shading

6A. [10 points] Describe the difference in appearance between two objects: the first exhibiting primarily diffuse reflection, the second exhibiting primarily specular reflection. (By specular, we do NOT mean ideal specular reflection like that produced by a mirror).

6B. [10 points] There are three common “shading” techniques used in 3D graphics system: Flat shading, Gouraud shading, and Phong shading. Explain the key idea behind each technique.

Flat shading:

Gouraud shading:

Phong shading:

Which of these three techniques is most expensive to implement and why?

Course Evaluation

In order to help us improve future offerings of CS 248, please use the"Comments to the Professor" section of your School of Engineering course evaluation to inform us of your opinion of the course. Specific written comments are very helpful to us.

In particular, we would like to know your opinion on the following specific aspects of the course; if you run out of space on your evaluation, please write your comments on this page and turn it in along with your final:

1. Were each of the following: the class WWW pages, the cs248tas@graphics.stanford.edu email account, the class-wide mailing list (cs248students@graphics.stanford.edu), and the su.class.cs248 newsgroup, helpful?

2. Were each of the following assignments: 1 game, 2 environment map viewer, 3. modeling and animation.

- instructive?
- "fun"?
- time-consuming?
- well-supported in terms of class software (sample viewer and MOAN)?

3. Were each of the following: the OpenGL Programming Guide, the textbook "Computer Graphics: Principles and Practice," the course reader, and the lecture slides,

- clear?
- relevant to the course material?
- helpful for completing coursework?

4. Was our policy on late days fair?

Teaching evaluation form: **Andrew Beers**

Please answer each of the following questions with a rating from 1 to 5, where 1 indicates poor performance (much below average), 3 indicates average performance, and 5 indicates excellent performance (much above average). If you have no opinion, please select "N/A".

1. is well prepared for office hours:

1 2 3 4 5 N/A

2. presents material with clarity:

1 2 3 4 5 N/A

3. selects good examples to illustrate points:

1 2 3 4 5 N/A

4. is responsive to student questions:

1 2 3 4 5 N/A

5. makes the students feel comfortable to ask questions:

1 2 3 4 5 N/A

6. avoids being sidetracked:

1 2 3 4 5 N/A

7. provides helpful comments on assignments:

1 2 3 4 5 N/A

8. imparts enthusiasm for the subject:

1 2 3 4 5 N/A

9. is sensitive to diversity in the classroom:

1 2 3 4 5 N/A

10. holds office hours at convenient times:

1 2 3 4 5 N/A

11. is available outside office hours:

1 2 3 4 5 N/A

Rate the overall performance of Andrew Beers

1 2 3 4 5 N/A

Any other comments?

Teaching Evaluation Form: **Homan Igehy**.

Please answer each of the following questions with a rating from 1 to 5, where 1 indicates poor performance (much below average), 3 indicates average performance, and 5 indicates excellent performance (much above average). If you have no opinion, please select "N/A".

1. is well prepared for office hours:

1 2 3 4 5 N/A

2. presents material with clarity:

1 2 3 4 5 N/A

3. selects good examples to illustrate points:

1 2 3 4 5 N/A

4. is responsive to student questions:

1 2 3 4 5 N/A

5. makes the students feel comfortable to ask questions:

1 2 3 4 5 N/A

6. avoids being sidetracked:

1 2 3 4 5 N/A

7. provides helpful comments on assignments:

1 2 3 4 5 N/A

8. imparts enthusiasm for the subject:

1 2 3 4 5 N/A

9. is sensitive to diversity in the classroom:

1 2 3 4 5 N/A

10. holds office hours at convenient times:

1 2 3 4 5 N/A

11. is available outside office hours:

1 2 3 4 5 N/A

Rate the overall performance of Homan Igehy

1 2 3 4 5 N/A

Any other comments?

Teaching Evaluation Form: **Apostolos "Toli" Lerios.**

Please answer each of the following questions with a rating from 1 to 5, where 1 indicates poor performance (much below average), 3 indicates average performance, and 5 indicates excellent performance (much above average). If you have no opinion, please select "N/A".

1. is well prepared for office hours:

1 2 3 4 5 N/A

2. presents material with clarity:

1 2 3 4 5 N/A

3. selects good examples to illustrate points:

1 2 3 4 5 N/A

4. is responsive to student questions:

1 2 3 4 5 N/A

5. makes the students feel comfortable to ask questions:

1 2 3 4 5 N/A

6. avoids being sidetracked:

1 2 3 4 5 N/A

7. provides helpful comments on assignments:

1 2 3 4 5 N/A

8. imparts enthusiasm for the subject:

1 2 3 4 5 N/A

9. is sensitive to diversity in the classroom:

1 2 3 4 5 N/A

10. holds office hours at convenient times:

1 2 3 4 5 N/A

11. is available outside office hours:

1 2 3 4 5 N/A

Rate the overall performance of **Apostolos "Toli" Lerios**

1 2 3 4 5 N/A

Any other comments?