CMSC 435/634 Computer Graphics Final Review

These questions are only a study guide. Questions found here may be on your exam, although perhaps in a different format. Questions NOT found here may also be on your exam. Pay attention to homework, project questions, Tamara video, and practical issues in problem solving using computer graphics for data visualization.

Note that there will be questions about OpenGL programming in the final exam.

For the final exam:

- Closed book
- Two double-sided sheet of letter-size notes permitted
- Everything covered in lecture including **Math, Rasterization, Transforms, Viewing, Pipeline, Mesh, Curves, Animation, Ray Tracing, Interaction, and Visualization.**

Before the exam:

- Make sure you understand the concepts related to the key objectives of each lecture.

During the exam:

Strategy: Read through the entire question before you begin it. If you get bogged down on a question, go on and come back later. Even if you don't think you know the entire answer to a question, do what you can in order to get partial credit. If something isn't clear to you, ask.

Odds and Ends, Some OpenGL

1. What is the most amusing bug you've written in this class?
2. Name one graphics fact about Ivan Sutherland (do some research yourself).
3. Where is the default (0, 0) on the screen defined by OpenGL? Where is the point (100, 100) going to appear on a screen with a resolution of (640, 480)? You can answer these questions by drawing the screen coordinates.

Concepts and Terminology

4. Give a short (5 - 10 words) or write an equation if appropriate to define each of the following:

   Dot product; cross product; matrix multiplication; plane normal; triangle normal; line equations; interpolation from a line equation; parametric equation, quadratic equation, homogeneous coordinates; affine transformation; barycentric coordinates; orthogonal (parallel) projection; perspective projection; rasterization; five matrices for computing the pixel coordinates for an object in 3D; vector normalization; graphics pipeline; viewing frustum; Bezier curve; Bezier polygon; line equations; cubic; quadric; composing transform; transform; rotate, scale, translation;

Example questions:

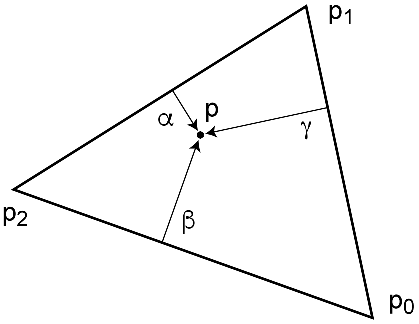
a. Write an implicit equation for a sphere at the origin with radius R.

b. Write a parametric equation for a sphere at the origin with radius R.

c. What is the dot product of two vectors, in terms of the length of each vector and the angle between them?

d. What is the length of the cross product of two vectors, in terms of the length of each vector and the angle between them?

e. Barycentric triangle rasterization:



5.

6. $p = \alpha\, p_0 + \beta\, p_1 + \gamma\, p_2$

e.1 How do you compute α, β and γ?

e.2 What are the conditions on α, β, and γ for a pixel that is inside the triangle?

e.3 What is the characteristic of the edge p1p2.

Display

7. What is an image on your computer screen?
8. What is a pixel?
9. Why do we use RGB color? What do R, G and B stand for?

Rasterization and Pipeline

10. Draw the graphics pipeline.
11. Describe the Bresenham algorithm for line drawing.
12. Describe the rasterization steps for triangles. How would you color a triangle? How would you compute the normal using the Barycentric coordinates? What is a main benefit of doing this? (this one is challenging and you will need to think about it and read the book perhaps.)

Transforms

13. (1) Estimate the 2D affine transformation matrix

$$\mathbf{T} = \begin{bmatrix} \boldsymbol{F} & \boldsymbol{v} \\ 0^T & 1 \end{bmatrix} \in \mathbb{R}^{3\times 3},$$

given its action on three homogeneous points:

$$\begin{pmatrix}1\\1\\1\end{pmatrix} \xrightarrow{T} \begin{pmatrix}2\\1\\1\end{pmatrix}, \quad \begin{pmatrix}1\\-1\\1\end{pmatrix} \xrightarrow{T} \begin{pmatrix}2\\1\\1\end{pmatrix}, \quad \begin{pmatrix}-1\\-1\\1\end{pmatrix} \xrightarrow{T} \begin{pmatrix}0\\1\\1\end{pmatrix}$$

(2) what kind of transformation does this matrix represent?

14. Express the homogeneous 3D transformation defined by the matrix

$$\begin{bmatrix}0 & -1 & 0 & 2\\1 & 0 & 0 & 3\\0 & 0 & 1 & 4\\0 & 0 & 0 & 1\end{bmatrix}$$

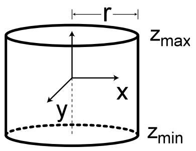
as a sequence of transformations in the following ways:

- A rotation followed by a translation.
- A translation followed by a rotation.

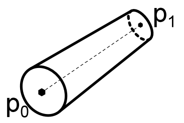
(2) Write the OpenGL code for performing the transformation in (1) using glRotatef and glTranslatef. Note that the order of these function calls matters.

15. Assuming we have drawn a cylinder aligned with the z axis, with radius r from zmin to zmax.

a) How would you build transform functions to create a cylinder of radius r2 between points p0=(x0,y0,z0) and p1=(x1,y1,z1)?



RiCylinder (r, zmin, zmax)



newCylinder(r, x_0,y_0,z_0, x_1,y_1,z_1)

b) Write the exact OpenGL code for your function newCylinder(r, x0, y0, z0, x1, y1, z1).

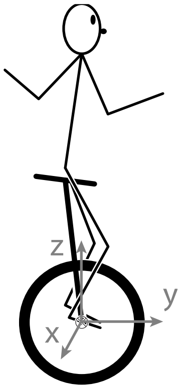
16. The OpenGL call, glRotatef(θ, x, y, z), rotates by θ degrees around the vector (x,y,z) through the origin. The rotation is right handed, so if (x,y,z) points toward you, the rotation is counter-clockwise. Write out the 4x4 transformation matrices for glRotatef(θ, 1, 0, 0), glRotatef(θ, 0, 1, 0) and glRotatef(θ, 0, 0, 1).

17. Why would you use a matrix stack? How is your proposed use implemented in OpenGL?

Viewing

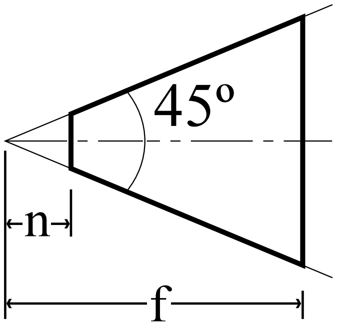
18. You have been asked to model a view from a character on a unicycle. The world coordinates are defined so x and y span the map horizontally and z points up. The unicycle coordinates are centered at the center of the axle, with x pointing right, y pointing forward, and z pointing up.

    It may be useful for this problem to know the standard math library function atan2(y, x). This function computes the arctangent of y/x over the full circle, without singularities when x=0, and using the signs of both arguments to correctly determine the quadrant of the resulting angle.



    c) If you have a translation function Translate(x,y,z), and three functions to rotate around the coordinate axes, RotateX(q), RotateY(q), and RotateZ(q) (but NO lookAt transform), what sequence of calls transform from world-space to unicycle-space, leaving the unicycle at a world-space location of (ux, uy, uz), pointing in the direction (dx, dy)?
    d) If the character's head is at (hx, hy, hz) in unicycle-coordinates with horizontal pan angle of q and vertical tilt angle of f, what sequence of calls will transform view space to world space? In view space, the camera should be at the origin, looking down the –z axis, with x pointing right and y pointing up.
    e) What are the 4x4 transformation matrices for Translate, RotateX, RotateY, and RotateZ?

19. This is a side-view of a viewing frustum, with the eye at (0,0,0), x axis pointing out of the page, y axis pointing down, and z axis pointing to the right. This frustum has a 45º field of view and near and far planes at n and f:



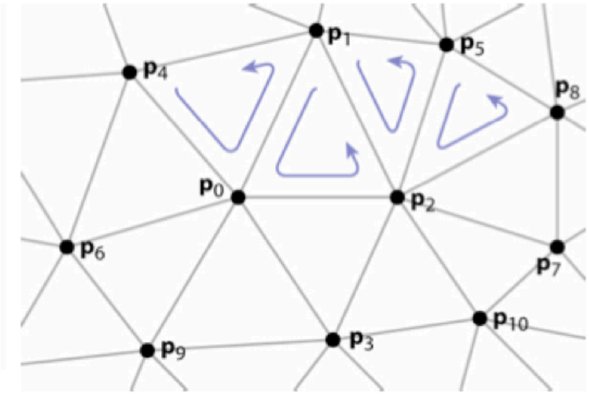
a) What are the eight corners of the frustum?

b) What are the clipping cases? Give an example of each.

c) Write out clipping plane equations for all six clipping planes. Each equation should be positive for points outside its plane and negative for points inside.

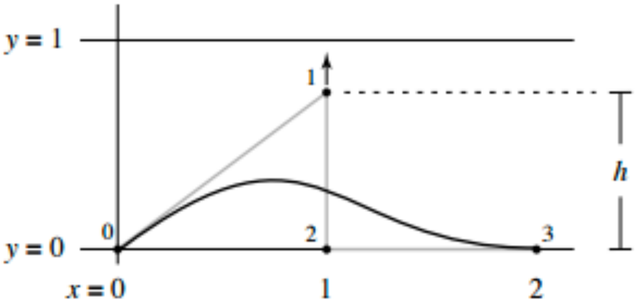
Mesh

20. Describe three applications that make use of mesh.
21. What is the split triangles and index triangles representations? Which one is better and why? (Find out yourself from the textbook).
22. List at least two ways to draw triangles in OpenGL and the amount of memory uses for each method.
23. Given a triangle mesh below, how to define a mesh? How to compute the three adjacent triangles of a triangle? (this is a question which requires quite a bit of thinking.)



Curves

24. Given four control points, know how to draw a cubic curve.
25. What are the two uses of Bezier curves we discussed in class.
26. Assume you have Bezier spline arranged as shown in the figure below. Control points 0, 2, and 3 remain fixed, but point 1 can be moved up and down. For what value of h does the spline become tangent to the line y=1? At what value of the spline parameter t is the tangent point?



27. You have learned about parametric and geometric continuity. For each 2D curve, answer the continuity query as correctly as possible, and provide a brief explanation.

(a) Is a circle C^0 continuous?

(b) Is a circle G^0 continuous?

(c) Is a circle C^∞ continuous?

(d) Is a circle G^∞ continuous?

(e) Is a square C^0 continuous?

(f) Is a square G^0 continuous?

(g) Is a square C^1 continuous?

(h) Is a square G^1 continuous?

Interaction

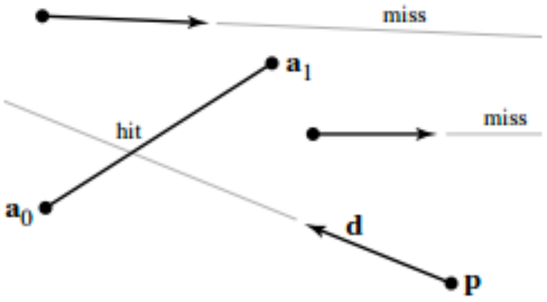
28. What are the four universal interaction techniques in 3D virtual environments?
29. What is virtual environment or virtual reality?
30. What are the two advantages and two disadvantages of using a 3D virtual environment from what you have observed in the class demo?
31. List five major application areas of virtual environments.
32. What are the goals of selection and manipulation? How do you go about analyzing a selection technique in terms of a taxonomical construction?

Ray tracing

33. Page 89 (textbook), Exercises 1, 2, and 3.

34. (Shading) Given a triangle mesh, briefly explain the key differences in how triangle normals are used to evaluate (1) Phong shading, (2) flat shading, and (3) Gouraud shading.

35. We have extensively discussed ray-triangle intersection in 3D; the 2D analog is intersecting a ray with a line segment in the plane. Give pseudocode that takes as input the two endpoints a0 and a1 of a line segment and the point p and direction d defining a ray, and returns a ray parameter t at which the intersection tasks plane, or +inf if the ray misses the line segment.



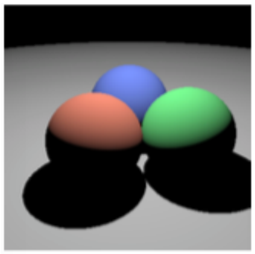
36. Look at each of the three images below that were produced by a Ray tracer with various bugs. The left image is correct and the other three is produced by introducing single-statement bugs into the program.

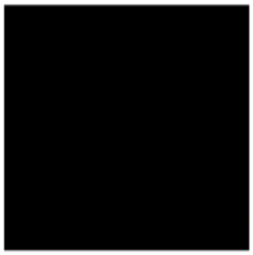
For each one:

(a) Could it have been caused by a problem with ray generation?
(b) Could it have been caused by a problem with ray intersection?
(c) Could you have been caused by a problem with shading computations?

For each "yes" answer, back it up with an example of an error that would cause the observed symptoms. There is no right or wrong explanation; only plausible and implausible ones. But when there is a clearly plausible cause, very far-fetched explanations (which are roughly equivalent to a "no" answer) won't make full credit.

Shadow computations count as part of shading. Computing surface normal's counts as part of ray intersection.


correct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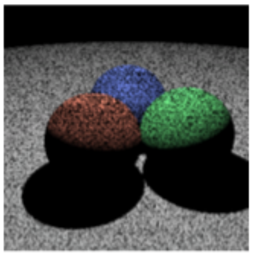
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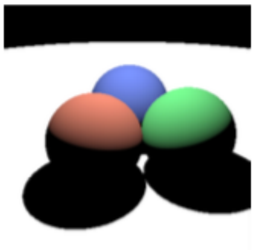
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