Exam Computer Graphics Class

Date: April 6, 2009 Time: 14:00–17:00

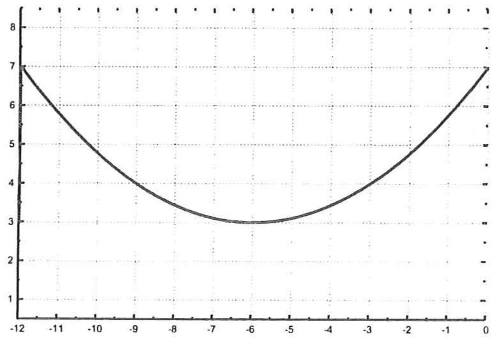
Instructions, read carefully: Fill in your **name and student number** on each of the answer sheets that you hand in. You have 3 hours to answer the questions. Please answer in English if at all possible, write clearly. When in doubt, use a small sketch/illustration to make your point. When deriving an equation, **show all the steps you took** to get to your result **in detail**, otherwise points cannot be awarded.

This exam has a total number of **12 questions** on **3 pages**. The total number of points (100%) is 100. As announced, the final grade for the class will be derived from both this final exam and the tutorials.

Question 1: Bresenham Midpoint Algorithm (20 points)

One important problem in computer graphics is to scan-convert a curve such as a straight line, a circle, a parabola, or a general function, i. e., to compute the pixels to set on a raster display that are to represent this curve. Given shall be the function of your teacher's currently favorite parabola (also shown on the right)

$$f(x) = \left(\frac{x}{3} + 2\right)^2 + 3.$$



Note: The grid above is NOT a pixel raster; one could, e g., use 10 pixels per unit to scan-convert the curve.

Bresenham's midpoint algorithm can be used to scan-convert this function precisely and efficiently. For this purpose, the parabola is first split in half at the symmetry axis ($x = -6$), and each of the sides again into 2 segments which meet where the slope of the curve is equal to 1 or -1.

a) Looking at the positive (right) half of the curve ($x \geq -6$), between which pixels (relative to the pixel previously set, ***use the notation with N, NE, E, SE, S, SW, W, and NW for naming these directions***) is the decision made for each of the above mentioned two segments? (2 points)

b) Derive the decision variable d and the two increments of the Bresenham midpoint algorithm for the first segment ($0 < \text{slope} < 1$) of the positive (right) half of the curve. (14 points)

c) Derive the second order differences for the increments you just derived. I. e., how do the two increments change depending on which decision was made in the previous step? (4 points)

Question 2: Homogeneous Coordinates (4 points)

a) What are homogeneous coordinates and why are they necessary? (3 points)

b) If you would visualize the regular 2D space in the homogeneous 2D space, what would this look like? (1 point)

Question 3: Transformation Matrices (10 points)

a) Give the transformation matrices for 2D translation and non-uniform scaling in homogeneous coordinates. (4 points)

b) Derive the transformation matrix for a 2D counter-clockwise rotation around the coordinate origin by an angle ϕ in homogeneous coordinates. Use a sketch to support your explanations. (6 points)

You can use $cos(a+b) = cos(a)cos(b) - sin(a)sin(b)$ and $sin(a+b) = sin(a)cos(b) + cos(a)sin(b)$ for answering this question.

Question 4: Transformation Order (1 point)

Using column vectors, write the computation of a transformed vertex P' from an original vertex P if you want to achieve first a scaling S_1, then a rotation R, then a translation T_1, then another scaling S_2, and finally another translation T_2 (give it in the form $P' = A \cdot B \cdot \dots \cdot N \cdot P$).

Question 5: Perspective Projection (6 points)

In order to produce an image on the viewing plane, the objects in world space need to be projected onto this plane.

a) Explain (no math, just the general steps, using drawings may help) the steps for perspective projection in which the depth values of coordinates are preserved. (3 points)

b) Why do the depth values of the coordinates need to be preserved? (1 point)

c) What is the name of the resulting volume of space that includes all visible parts of the scene, and what is its shape? (2 points)

Question 6: Backface Culling (10 points)

a) What is backface culling? (2 points)

b) How is it done? (4 points)

c) Why is it used? (2 points)

d) Is it sufficient for general hidden surface removal and why/why not? (2 points)

Question 7: Phong Illumination Model (10 points)

Rendering a scene requires determining how light gets reflected at a location on the surface of an object.

a) Which three aspects of light reflection does the Phong illumination model capture and which phenomena of real physical reflection do these represent? (6 points)

b) Give the formula of the Phong illumination model. (3 points)

c) How do you achieve a smaller but more pronounced highlight, i. e., which parameter do you have to change and how? (1 point)

Question 8: Texture Mapping (5 points)

For rendering detail on surfaces texture mapping is used.

a) What is Mip-Mapping, why is it necessary, and how is it used? (3 points)

b) Why/when is Anisotropic Texture Mapping necessary, and how does it work in principle? (2 points)

Question 9: Color and Color Models (10 points)

In computer graphics, color is being represented using several different color models.

a) Name two different hardware-oriented color models as well as which type of color mixing is used for them. (4 points)

b) Name two different perceptual color models, name the properties (the letters in the abbreviation) they use for representing color. Sketch one of the perceptual color models, pointing out the "axes" of captured properties. (4 points)

c) Why are these perceptual color models necessary in addition to the hardware-oriented color models? (2 points)

Question 10: General Clipping Approach (10 points)

Describe the general process for clipping lines in 2D, i. e., which steps does a line undergo to determine whether it lies in a axis-aligned clipping rectangle to determine its visible parts. You do not need to explain each algorithm in detail, just explain the overall procedure to get from a set of line segments to a set of line segments that are all visible.

Question 11: Radiosity (10 points)

a) What distinguishes radiosity fundamentally from the regular rendering that is typically used for 3D applications? (3 points)

b) Describe the approach of radiosity in general terms, i. e., name the steps that are performed. (4 points)

c) Which aspects of physical light behavior does radiosity capture particularly well, which does it not capture well? (3 points)

Question 12: Object Representations (4 points)

Name the two major classes of 3D object representations discussed in class (2 points) and name two example groups within each (2 points).