Exam Computer Graphics Class

Date: July 16, 2009 Time: 09:00–12:00

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.

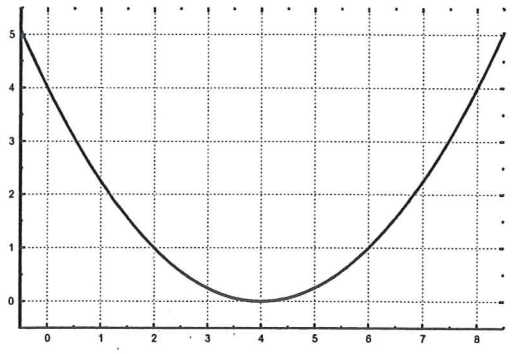
This exam has a total number of **10 questions** on **2 pages**. The total number of points (100%) is 100. As announced, the final grade for the class will be derived from both this final exam and the tutorials.

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)

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

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 ($x = 4$), and each of the sides again into 2 segments which meet where the slope of the curve is equal to 1 or -1.



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

a) Looking at the positive (i. e., right) half of the curve ($x \geq 4$), between which pixels, relative to the pixel previously set, is the decision made for each iteration step (***use the notation with N, NE, E, SE, S, SW, W, and NW for naming these directions***)? I. e., from a previously set point, in which directions can you possibly go to set the next pixel? Give the answer for each of the above mentioned two segments. (2 points)

b) Derive the decision variable d and the two increments for d that the Bresenham midpoint algorithm uses for the first segment ($0 <$ 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 of d 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) Using column vectors, write the computation of a transformed vertex P' from an original vertex P if you want to achieve first a translation T_1, then a scaling S, then a rotation R, and finally another translation T_2 (give it in the form $P' = A \cdot B \cdot \cdots \cdot N \cdot P$). (1 point)

Question 3: Computer Graphics Camera Model (10 points)

To be able to produce images in computer graphics, we need to specify a computer graphics camera model.

a) Describe the typical/basic camera model used in computer graphics, include its parameters, and illustrate these parameters using a small sketch. (5 points)

b) The camera model used in computer graphics differs from that of the typical camera that is used in photography. Name these differences and describe briefly what implications these differences have with respect to the resulting images. (5 points)

Question 4: z-Buffering (10 points)

Explain the z-buffer algorithm (what is it used for, what steps are taken, and which data elements are affected and how, a brief bulleted list is sufficient).

Question 5: 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 6: Shading Techniques (10 points)

a) What is shading in computer graphics? (2 points)

b) Explain Gouraud and Phong shading, comparing the two approaches. Name problems and advantages for each approach. (8 points)

Question 7: Two-pass Texture Mapping (6 points)

For complex shapes, a two-pass technique for texture mapping is used.

a) Explain the general approach briefly. (2 points)

b) Name the four techniques introduced in the lecture and draw sketches to explain their principle. (4 points)

Question 8: Color and Color Representation (10 points)

In computer graphics, color is usually specified using three values.

a) What is color? (1 point)

b) Why do we generally use three values to represent color (biologic & physical reasons)? (2 points)

c) Can the combination of three physical colors (such as done in RGB screens) represent all perceivable colors? Why/why not? (5 points)

d) What are metamers? (2 points)

Question 9: Cohen-Sutherland Clipping (10 points)

Describe the Cohen-Sutherland algorithm for clipping in 2D. Draw a sketch to support your explanations.

Question 10: Raytracing (10 points)

a) Describe the general approach of raytracing using very general pseudo-code. (5 points)

b) Which aspects of physical light behavior does raytracing capture particularly well, which does it not capture well? (2 points)

c) What are ways to speed up raytracing? Name at least three ways. (3 points)