Exam Computer Graphics Class

Date: April 5, 2011 Time: 9:00–12:00

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 possible, **write clearly** (parts that are unreadable will not be awarded any points). 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.

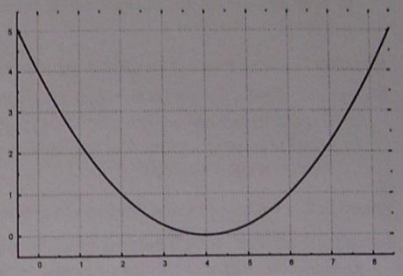
This exam has a total number of **10 questions** on **2 pages**. The total number of points (100%) is 100. As announced, the final grade for the class will be derived from both this final exam and the tutorials.

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. Show the detailed steps! (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 (5 points)

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

b) What is the geometric equivalent of a 2D coordinate point in regular space (for example, use the 2D point $(1,1)^\top$) in the homogeneous 2D space (you may add a drawing to illustrate your answer)? (1 point)

c) 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 $P' = A \cdot B \cdot \cdots \cdot N \cdot P$). (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: 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 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 larger but less pronounced highlights, i. e., which parameter in the equation 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 (5 points)

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

a) Explain the general approach briefly. (2 points)
b) Name at least three of the four techniques (of O Mapping) introduced in the lecture and draw sketches to explain their principle. (3 points)

Question 8: 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 (**this does NOT mean the ones used for TV broadcast such as PAL or NTSC**) as well as which type of color mixing is used for them. (4 points)
b) Name two different perceptual color models (NOT the ones used to understand human color vision), 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 9: Cohen-Sutherland Clipping (10 points)

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

Question 10: 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)