EXAM IN

COMPUTER GRAPHICS

TSBK05

Time:	7th of June, 2005, 8-12
Room:	Ter1
Teacher:	Ingemar Ragnemalm, visits around 10
Allowed help:	None
Requirement to pass:	Grade 3: 21 points Grade 4: 31 points Grade 5: 41 points ECTS: E: 21 points D: 26 points C: 31 points B: 36 points A: 41 points

Answers may be given in swedish or english.

Good luck!

1. OpenGL programming

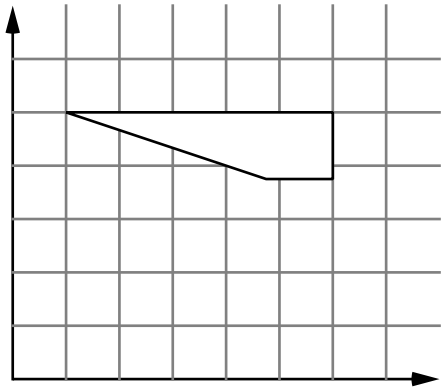
a) Consider a 3D program, where a model is defined in model coordinates, mapped to world coordinates using rotation and translation, and then to camera coordinates defined by the current camera position and rotation. Outline how you implement this in OpenGL. It should be clear in what order you apply transformations for each subproblem, describing both the function calls and the resulting chain of transforms expressed as matrix multiplications. (If you don't remember the exact name of a function call, make up a name that describes its meaning.) The actual drawing of the model in model coordinates can be considered done by a given subroutine, drawmodel().

b) What is GLUT? Describe the role GLUT has for OpenGL, and its relation to other packages (GLU, GLX, WGL, AGL etc).

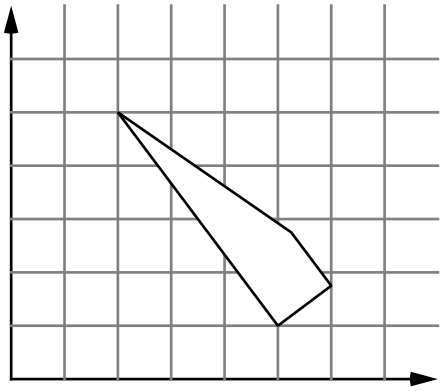
(5p)

2. Transformations

a) In the following figures, a polygon is affected by a transformation. Give that transformation as a sequence of 3x3 matrixes, each defining one basic geometric transformation (translations, rotation around origin, scaling, mirroring). You don't have to multiply the matrices together. Distances and angles may be given as symbols refering to a figure rather than numeric values.



Original position



After transformation

b) The position of the camera is given as a forward vector **n**, an up-vector **v** and a camera position **p**. Form a 4x4 matrix for the world-to-camera transformation. The vector **v** is not guaranteed to be orthogonal to **n** but is in any case not parallel to **n**.

(7p)

3. Curve generation

a) Derive the incremental updating of the decision variable in the midpoint algorithm to plot an 8-connected line. You may assume that the line has a slope within a specified range, but the range must be specified.

b) Show that the algorithm in a) is equivalent to the Bresenham line drawing algorithm.

c) In order to draw an 8-connnected ellipse (as in the book), you must use different expressions for different parts of the curve. At what points must the algorithm switch expressions, and why? Illustrate this in a figure. (You don't have to derive the incremental updating expressions.)

(8p)

4. Miscellaneous

a) Describe in detail how to detect whether a ray intersects a triangle. The ray is given as $p = p_0 + k*v$, and the triangle as three points, A, B, C. Both the calculation of the plane equation, the intersection with the plane and the final check for being inside should be included.

b) A naive flood fill algorithm is descibed by the following pseudo code:

```
startvalue, fillvalue are globals

procedure FloodFill(x, y)
     if GetPixel(x, y) = startvalue then
          SetPixel(x, y, fillvalue)
          FloodFill(x-1,y)
          FloodFill(x,y-1)
          FloodFill(x+1,y)
          FloodFill(x,y+1)

procedure StartFloodFill(x, y, myfillvalue)
     startvalue := GetPixel(x, y)
     fillvalue := myfillvalue
     if startvalue = fillvalue then
          Error
     FloodFill(x, y)
```

This algorithm has at least two significant weaknesses compared to the algorithm we did in the course. What?

(6p)

5. Mapping techniques

a) Spherical coordinates (θ, v) can be defined by

$x = R \cos \varphi \cos\theta$
$y = R \cos \varphi \sin\theta$
$z = R \sin \varphi$

Write formulas for spherical texture mapping, mapping x, y, z to texture coordinates (s, t), normalized to the interval [0, 1].

b) Describe how mipmapping works (in texture mapping). What is the cost, what does it accomplish and what are its limitations?

(6p)

6. Collision detection

a) In a virtual world with a very large number of objects, it is essential that as few objects as possible are tested even in the broad phase. How can that be accomplished? Suggest one method that reduces the number of tests significantly.

b) Describe, using figures, the tests needed in the narrow phase, for testing whether two polyhedra intersect or not.

(4p)

7. Visible surface detection

a) Suggest two different reasons why it is more suitable to store z^{-1} in the depth buffer rather than z. Motivate your answer with appropriate mathematical formulas. You do not have to derive full proofs for your statements, only clarify them.

b) What is a Potentially Visible Set (PVS)? Describe a method for how the PVS can be generated for a given point.

c) Describe how a scene, decomposed to a BSP tree, is drawn. Why will it be correctly rendered from any direction?

(7p)

8. Light, shading and ray-tracing

a) Sometimes, people confuse the Phong model with Phong shading. Describe the two concepts. Is it possible to use one of them without the other? Motivate your answer.

b) A student tries to explain how ray-tracing works, and writes:

A ray starts at the light source, and is traced until it intersects a surface. In the surface, the ray may be reflected or refracted, creating new rays that are traced recursively. The rays are traced until they reach the camera or until they reach the maximum search depth.

Something is wrong in this explanation. Correct the errors. (Language errors are ignored.)

c) A scene is all black except for two surfaces, numbered 1 and 2. Number 1 is a large white lamp. Number 2 is a smaller light grey object.

Surface 1 is a light source with intensity = 1. It also reflects light as a 100% white surface (reflecting all incoming light). Surface 2 is light grey, reflecting 75% of all incoming light.

Since surface 2 is so small, only one third of the total light emitted from surface 1 hits surface 2. Surface 1, however, is larger, so 2/3 of the light emitted from surface 2 hits surface 1.

The radiosity equation is:

$$B_k = E_k + \rho_k \sum_{j=1}^{n} B_j F_{jk}$$

Express the light exchange between the two surfaces above using the radiosity equation. How much light does surface 2 emit?

(7p)