EXAM IN

COMPUTER GRAPHICS

TSBK07

(TEN1)

Time:	4th of June, 2016, 8-12
Room:	TER3
Teacher:	Ingemar Ragnemalm, visits around 9 and 11
Allowed help:	None
Requirement to pass:	Grade 3: 21 points Grade 4: 31 points Grade 5: 41 points ECTS: C: 21 points B: 31 points A: 41 points

Answers may be given in swedish or english.

Please make a special note if you followed the course before 2012. Some answers may be slightly different depending on that and I need to know what material you studied (old or new) to make fair scoring.

- Wish us luck!
- I wish you skill!
[Martin Landau, ”Mission Impossible”]

1. OpenGL programming

a) Illustrate the difference between Phong shading and Gouraud shading by writing code for a shader pair performing each of them (diffuse light from one light source only). Make sure the differences between the two are clear. A light source in view coordinates is given as

const vec3 light = vec3(0.58, 0.58m 0.58);

and a normal vector is available in the vertex shader as

in vec3 inNormal;

(3p)

b) Describe how texture access is programmed. You may assume that you have a function that loads a texture to a texture object

GLuint textureObject;
LoadTGA(”mytexture.tga”, &textureObject);

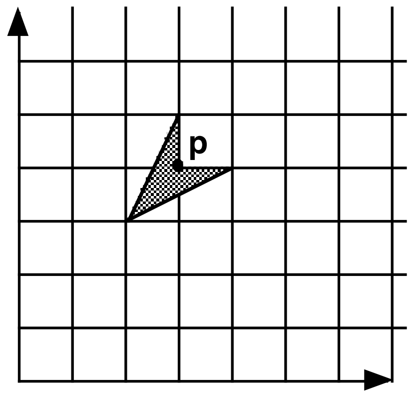
From this point, write code fragments (not a complete program) that shows how you can use this texture for rendering.

Note: Exact function names are *not* important, the task they perform is the important thing!

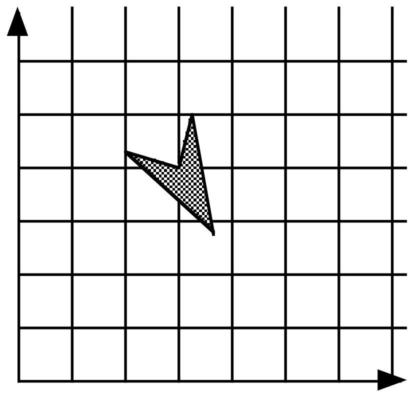
(3p)

2. Transformations

a) In the figure, a 2D shape is shown together with a point **p**. Produce a sequence of 3x3 matrixes that define a transformation that rotates the shape (or anything else) around **p** by an angle ϕ. The contents of each matrix should be given. You don't have to multiply the matrices together.



Original shape and position, and the point **p** that the shape is rotated around



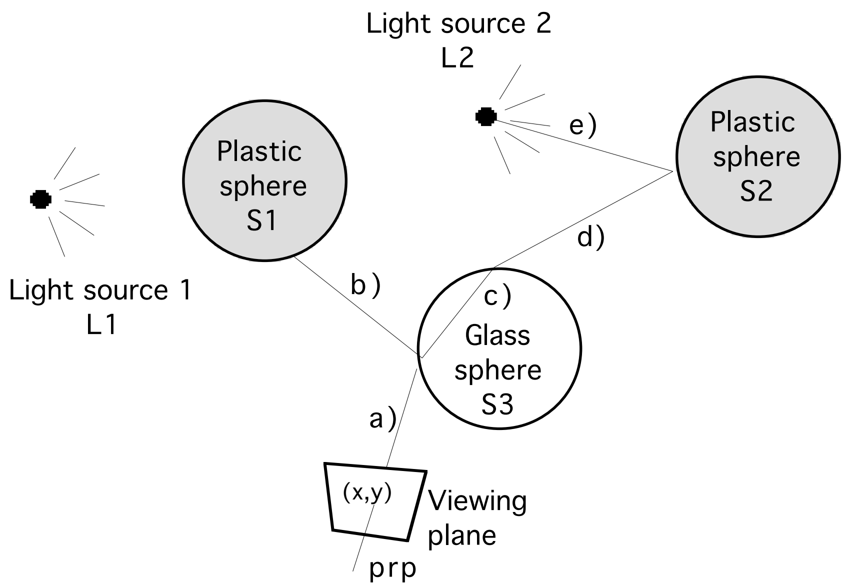
After transformation

(3p)

b) *Trackball controls* means that you can rotate an object by dragging the mouse over it but *not* moving it. Outline, as a sequence of named matrices, how this can be accomplished. This sequence should include any matrices specifically added for performing this rotation as well as related matrices, neighbors in the transformation sequence. As input data, you have a mouse movement vector **v**. The contents of the matrices do not have to be given.

(2p)

3. Light, shading and ray-tracing



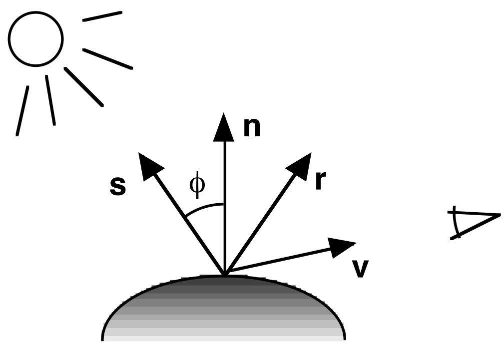
a) A couple of rays (a-e) used to calculate the pixel (x, y) are shown in the figure. Give each ray appropriate descriptive names. How is each ray formed? Are some rays clearly missing? If so, which ones?

(3p)

b) On a written exam, a student gets the task of writing a complete formula for the 3-component light model. The student answers with the following formula:

$$i = \sum \left(k_d i_a + \max(0, k_d \cdot i_s \cdot \cos(\mathbf{s} \bullet \mathbf{n}) + k_{spec} i_s \cdot \cos(\mathbf{r} \bullet \mathbf{v})^{\phi} \right))$$

(sum over all light sources) together with the figure



The examiner is not happy with the answer. Suggest improvements that will give the student full score.

(3p)

4. Surface detail

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

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

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

Only single-argument mathematical functions like $\tan^{-1}$ may be used.

(3p)

b) Outline the principle for bump mapping, assuming that an orthonormal texture space coordinate system (**s**, **t**, **n**) is available, plus a bump map texture.

(2p)

5. Curve generation

a) A quadratic Bezier curve is defined by the following formula.

$$\mathbf{p}(u) = (1 - u)^2\mathbf{p_0} + 2(1-u)u\mathbf{p_1} + u^2\mathbf{p_2},\ u \in [0, 1]$$

If we use this on a sequence of control points $\mathbf{p_0}$, $\mathbf{p_1}$, $\mathbf{p_2}$, $\mathbf{p_3}$, $\mathbf{p_4}$, it will be applied on three at a time, and these sections will be fit together. On what conditions does it fulfill C^1 or G^1 continuity in the intersections of two sections?

Prove mathematically that this is the case. State clearly what the condition means in mathematical terms, that is the relationship that you should prove.

(5p)

b) Show, by using a figure and an appropriate table, how the Bresenham line-drawing algorithm works.

Hint: $p_0 = 2\Delta y - \Delta x$

$$p_{k+1} = p_k + 2\Delta y$$
$$p_{k+1} = p_k + 2\Delta y - 2\Delta x$$

(3p)

6. Miscellaneous

a) Anti-aliasing can be performed by supersampling. Explain why supersampling reduces aliasing, and what behavior you must assume for the signal (the image). The explanation should involve arguments in frequency space.

(3p)

b) Describe, using a figure, how the Diamond-Square noise/terrain generation algorithm works.

(4p)

7. Collision detection and animation

a) There are two fundamentally different ways to perform *picking*. Describe the two and compare them in terms of performance and complexity.

(2p)

b) A line is given by two points $\mathbf{p_1}$ and $\mathbf{p_2}$. A triangle is given by three points **a**, **b**, **c**. Describe how you can test for intersection between the line and the triangle.

(4p)

8. Visible surface detection and large worlds

a) A skybox is an easy way to produce a convincing environent around your scene. Despite the simplicity of the method, there are several problems to consider to make a good skybox. One is simply to have a proper shape with the right texture coordinates... but what else is there to consider? You should be able to give two more problems.

(2p)

b) Describe how a view plane oriented billboard can be implemented.

(2p)

c) Describe how frustum culling can be applied to a scene with a significant number of spherical shapes (shapes with a known bounding sphere). The camera is placed in the point **prp**, given with scalars for near, far, left, right, top and bottom. A sphere i is located around the point $\mathbf{c_i}$ with the radius r_i, in world coordinates. The world-to-view transformation is given as the matrix M.

What operations need to be done for the test? The method should be reasonably efficient.

(3p)