EXAM IN

COMPUTER GRAPHICS

TSBK07

(TEN1)

Time:	31th of May, 2017, 8-12
Room:	TER1
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) Outline the steps needed to draw a rotating polygon in modern OpenGL (3.2 and up, core profile), given only an array of vertices in the main program.

It was tricky to set up everything in the labs. Why don't we just use a simple API like this?

```
vec3 poly[3] = {{0, 0, 0}, {1, 0, 0.5}, {1, 1, 1}};
RotateVertices(poly, 3, angle);
DrawTriangleStrip(poly, 3);
```

Why isn't this a good approach?

(3p)

b) Write code for Gouraud shading of an object. Write GLSL or GLSL-like code showing how this is programmed. Both vertex and fragment shaders should be included and it should be clear where calculations are made and how information passes between shaders.

A few variables are given below. No color or texture is involved. Geometry operations (vertex location etc) can be ignored here.

Vertex: in vec2 inNormal; uniform vec3 light; uniform mat3 normalMatrix;
Fragment: out vec4 outColor;

(2p)

2. Transformations

a) One of the projects 2017 was about mountain biking, where the participants realized that they needed to base the orientation of the bike on a fixed *side* vector in order to give it the desired behavior when running a bike up and down a hill.

They had some constraints on the side vector, but we will here solve the problem in a somewhat more general way, accepting (almost) any side vector.

Thus, you need to produce a transformation for a model which should be placed at position **p**. You have a fixed side vector which defines the direction of the model's x axis (its right vector), **r**, and an approximate up vector **v**. The resulting matrix should place and rotate the model according to the given vectors.

Note that we are not producing a camera matrix but modify the orientation of a model, regardless of where the camera is located.

(4p)

b) Which one(s) of the following statements are true (given names and symbols used in the course, T = translation, R = rotation, S = scaling)?

(1) Translation: $T(p)^{-1} = T(p)^T$
(2) Rotation: $R(\phi)^{-1} = R(\phi)^T$
(3) Mirroring: $M = R(\pi)$
(4) Composite transformations: $T(p)*S(a) = S(a)*T(p)$
(5) Composite transformations: $R(\phi)*S(a) = S(a)*R(\phi)$
(6) Cross product: $\mathbf{a} \times \mathbf{b} = \mathbf{b} \times \mathbf{a}$
(7) Dot product: $\mathbf{a} \bullet \mathbf{b} = \mathbf{b} \bullet \mathbf{a}$

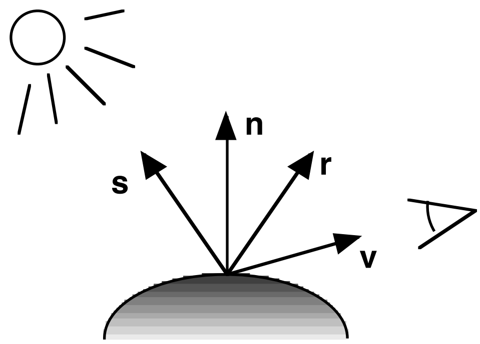
(2p)

3. Light, shading and ray-tracing

a) A farly large scene is lit from two different light sources, the sun and a light bulb. In what way can, or even should, we handle these light sources differently? At least two significant differences, including any significant mathematical differences, should be stated for full score.

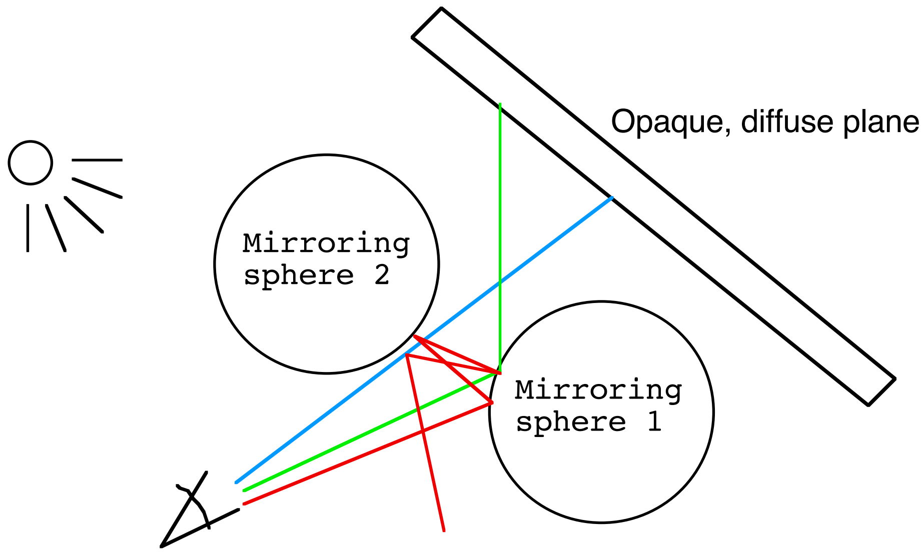
(3p)

b) Write a formula for the 3-component light model allowing for multiple light sources. Use the symbols of the following figure:



(3p)

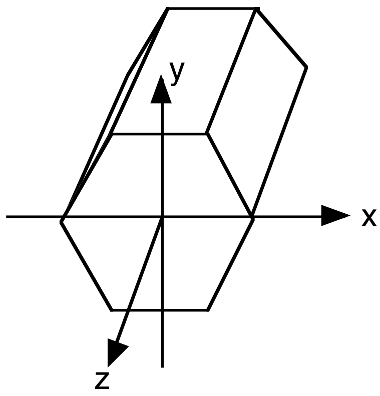
c) Two mirroring spheres, a diffuse non-transparent surface and the camera are placed as in the figure. An image is rendered using ray-tracing. Outline how the ray-tracer works. Three rays are shown as red, green and blue. Are there any special considerations for any of them?



(3p)

4. Surface detail

a) Cylindrical mapping is used to map a texture (by vertex) onto a shape that is roughly cylindrical, with six sides. The height of the cylinder is in the z direction. The six edges along the z axis are at angles 0, $\pi/3$, $2\pi/3$, π, $4\pi/3$ and $5\pi/3$. We don't consider the texture on the end sides.



A six-sided approximation of a cylinder

However, this mapping produces an error. What error? Suggest how we can overcome it.
(2p)

b) A skybox is an easy way to get an illusion of an environment at (for practical purposes) infinite distance. Altough the principle is simple, mapping a texture on a cube which works as a backdrop, there are several important issues that have to be considered in order to make a good skybox. Give *three* important issues. A brief sentence for each should suffice.
(2p)

c) Give one example of an operation that a *texture unit* performs (apart from reading texels from memory).
(1p)

5. Curve generation

a) Two segments of a 2D spline is given by the following functions:

$p_x(u) = u^3 - u^2 + 2u$
$p_y(u) = 4u^2 - 2u$
$q_x(v) = v^2 + v + 2$
$q_y(v) = v^3 + 2v^2 + 2v + 2$

What continuity criteria do these segments fulfill for u=1, v=0?
(3p)

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) A self-squaring fractal works with a certain radius parameter. What happens if the algorithm starts outside this radius?

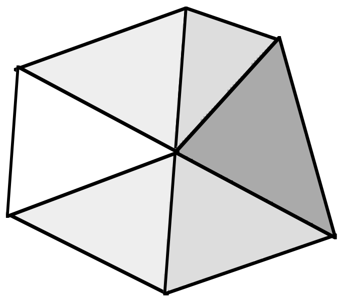
(2p)

b) Supersampling and multisampling are two closely related methods for anti-aliasing. Outline how they work. How are they different?

(2p)

c) Given a vertex and six adjacent polygons according to the figure (but with 3D coordinates, not flat), suggest a good method to calculate a normal vector for the vertex. Describe your solution mathematically, and with a figure with symbols as needed. Is your method a good approximation to the ideal vector? If not, is it still "right" in some sense?

Note: The grayscales in the figure are only there to remind us that this is part of a 3D model, not a set of triangles in a plane.



(2p)

7. Collision detection and animation

a) Outline the principles for an efficient collision detection system based on broad and narrow phase tests. There are really three phases, which ones? List, by name and a brief explanatory comment with a figure, a typical solution for each phase.

(3p)

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

(2p)

8. Visible surface detection and large worlds

a) Frustum culling is essential for efficient large world handling. Describe mathematically how frustum culling can be applied for separate objects. The description should reflect the coordinate systems involved. In what coordinate system do you test frustum culling?

(4p)

b) A common VSD method has problems with transparency. Describe the problem and a remedy.

(2p)

c) Describe the cells and portals method with a figure. For what kind of environment is this suitable?

(2p)