2IV10/2IV60 Computer Graphics

Examination, January 29 2013, 9:00 – 12:00

This examination consist of **four** questions with in total 16 subquestion. Each subquestion weighs equally. In all cases: **EXPLAIN YOUR ANSWER. Use sketches where needed to clarify your answer. Read first all questions completely.** If an algorithm is asked, then a description in steps or pseudo-code is expected, which is clear enough to be easily transferred to real code. Aim at compactness and clarity. Use additional functions and procedures if desired. Give from each function and procedure a short description of input and output. The use of the book, copies of slides, notes and other material is not allowed.

1 We consider some basic techniques for computer graphics.

a) The depth-sort or painter's algorithm seems simple, but to make it work properly requires effort. Give an example where sorting the polygons for the closest vertex does not give the correct result.

b) What is the characteristic difference between diffuse and specular reflection?

c) Give an advantage and a disadvantage of modeling colors using the RGB-model.

d) Describe two optical effects that can be handled easily with ray-tracing and not with straightforward methods.

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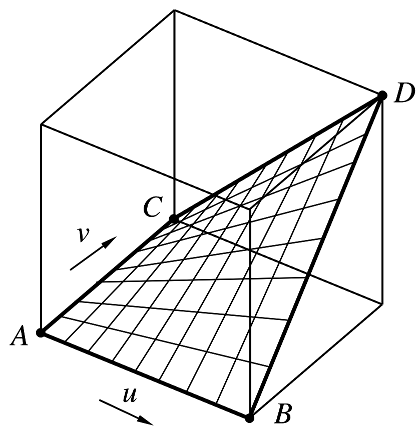
2 We are given a quadrilateral *ABCD* (see drawing) and want to fill in the interior with a smooth surface. We use bilinear interpolation for this. On the edges *AB* and *CD* we construct points $P(u)$ and $Q(u)$ with linear interpolation, next we connect these points with straight lines.



a) Give a parametric description $S(u, v)$ of the surface for arbitrary points A, B, C, and D.

b) Suppose that the four points are located on the vertices of a unit cube, as follows: $A=(0, 0, 0)$, $B=(1, 0, 0)$, $C=(0, 1, 0)$, and $D=(1, 1, 1)$. Give a coordinate-wise parametric description $(x(u, v), y(u, v), z(u, v))$ of the surface.

c) Give an implicit representation $f(x, y, z) = 0$ of the surface of the previous question. Hint: eliminate u and v from your previous answer.

d) Calculate a normal vector $N(u, v)$ on this surface.

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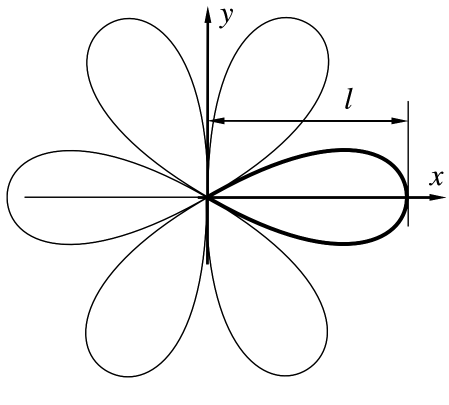
3 We are going to use Bézier cubic splines to draw a flower in 2D. A flower has N leaves, each leaf is mirror-symmetric, and the leaves touch each other in the origin (see figure next page). We model each leaf as a single Bézier segment. We focus on one leaf, aligned with the x-axis, indicated bold in the drawing. The curve that describes this leaf is given by

$$P(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t)P_2 + t^3 P_3 \text{ with } t \in [0,1].$$



a) Give all possible positions of the four control points P_0, P_1, P_2, and P_3, for flowers of arbitrary size and arbitrary N. How many free parameters are left over?

b) How to choose the control points such that the leaf has length l ?

c) Write an algorithm *drawLeaf* to draw a filled-in version of the leaf. (See also generic remarks in the header of this examination). Assume that a function *drawTriangle* (A, B, C) is available, where $A, B,$ and C are the vertices of a triangle in clock-wise order. Use M triangles (where M is an even number) to approximate the leaf.

d) Suppose that we want to use this approach to draw flower leaves in 3D. We want the leaves in the origin to be tangent to the $z = 0$ plane, and to bend them up with increasing distance from the origin, to get a tulip-like shape. Is this possible with the single segment, cubic Bézier spline approach used here? Explain your answer.

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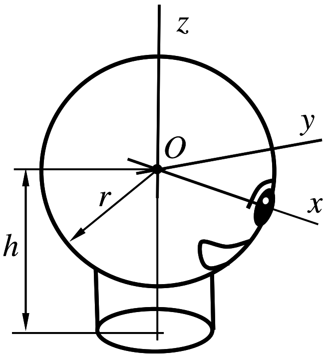
4 We are developing a first person action game, where we see everything through the eye of our hero. Our hero is Freddy the Cyclops, a one-eyed giant. We model Freddy's head in a local coordinate system as a sphere with radius r, centered around the origin, his eye is fixed on the sphere on the local x-axis (see figure). The current position and orientation of his head is fixed by a 4×4 homogenous transformation matrix M, such that a position A in global world coordinates is related to a position B in head coordinates via $A=MB$. The matrix M describes a rigid transformation, no scaling or skewing is applied. In the following, matrices do not have to be specified element-wise. It may be assumed that $T(V)$ gives a translation matrix along the vector V, and that $R_X(a)$, $R_Y(a)$, and $R_Z(a)$ give a rotation matrix of a degrees around the x-, y-, and z-axis, respectively.



a) We use a virtual camera model to specify the viewing projection. This model requires a viewpoint P (origin of the camera), a direction V (direction in which the camera points), and an up-vector W (vector that has to be shown vertically), all in world-coordinates. Give formula's to calculate $P, V,$ and W according to the specification of Freddy's head. Hint: what are $P, V,$ and W in local coordinates?

b) Suppose that Freddy is walking, and that the current transformation is given by $M(t)$, with t the time in seconds. We want to make the motion more lively. Assume Freddy is continuously looking around, looking left and right by rotating his head around the local z-axis over angles of maximally d degrees, where one complete cycle takes T seconds. Give an adapted version $M'(t)$, given $M(t)$.

c) Freddy is standing still. But suddenly, he gets a blow to the center of his head from his left side. As a result, his head rotates over b degrees around a line. This line is parallel with the local x-axis and goes through a point located at a distance h below the center of his head. Give an adapted version M', given M.

d) Freddy senses that his attacker is located at a position Q in world coordinates. He rotates his head around his local z- and y-axis to focus on him. Again, give an adapted version M', given M. For the calculation of angles, assume a function $\arctan(y, x)$ is available, which returns the angle in degrees between the x-axis and a line from the origin to a point (x, y). Hint: Assume that S is the position of Q in local coordinates. How to calculate S?