Technische Universiteit
Eindhoven
University of Technology

Examination cover sheet

(to be completed by the examiner)

Course name: Computer Graphics Course code: 2IV60

Date: January 26, 2015

Start time: 9:00 End time: 12:00

Number of pages: 3 (including Examination cover sheet)

Number of questions: 4, with 16 subquestions

Maximum number of points/distribution of points over questions: Each subquestion maximally 4 points

Method of determining final grade: grade = (1 + 9*P/64), where P is the total number of points scored

Answering style: See instructions in exam.

Exam inspection:

Other remarks:

Instructions for students and invigilators

Permitted examination aids (to be supplied by students):

None

Important:

- examinees are only permitted to visit the toilets under supervision
- it is not permitted to leave the examination room within 15 minutes of the start and within the final 15 minutes of the examination, unless stated otherwise
- examination scripts (fully completed examination paper, stating name, student number, etc.) must always be handed in
- the house rules must be observed during the examination
- the instructions of examiners and invigilators must be followed
- no pencil cases are permitted on desks
- examinees are not permitted to share examination aids or lend them to each other

During written examinations, the following actions will in any case be deemed to constitute fraud or attempted fraud:

- using another person's proof of identity/campus card (student identity card)
- having a mobile telephone or any other type of media-carrying device on your desk or in your clothes
- using, or attempting to use, unauthorized resources and aids, such as the internet, a mobile telephone, etc.
- using a clicker that does not belong to you
- having any paper at hand other than that provided by TU/e, unless stated otherwise
- visiting the toilet (or going outside) without permission or supervision

2IV60 Computer Graphics

Examination, January 26 2015, 9:00 – 12:00

This examination consist of **four** questions with in total 16 subquestions. 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 a short description of input and output for each function and procedure. The use of the book, copies of slides, notes and other material is not allowed.

1 We consider some basic concepts of computer graphics.

a) Draw examples of a non-simple, a convex, a concave, and a regular polygon.

b) Suppose that we use a standard set-up of a virtual camera: an eye-point, a center-point, and a view-up vector. What is the effect on the screen if we change the view-up vector?

c) Give the equation for the standard model of diffuse reflection, and a sketch and a description of the parameters.

d) What are three optical effects that can be simulated with ray-tracing and not with a basic shading model?

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2 A *ruled surface* can be described as $S(u, v) = P(u) + vQ(u)$, with $u_0 \le u \le u_1$ and $v_0 \le v \le v_1$: a line segment with direction $Q(u)$ is moved along a curve P, sweeping out a surface. We use this to model surfaces that result from twisting flexible strips.

a) Take a flexible strip with length d and width w and align its center-line with the positive z-axis. Next, fix the bottom of the strip and rotate the top around the z-axis over 180 degrees. Give $P(u)$, $Q(u)$, and the associated values for u_0, u_1, v_0, and v_1 for the resulting surface.

b) The figure on the right shows a *Moebius strip*, obtained by gluing the begin and end of a twisted strip with length d and width w. For the curve P we use again the centerline, which is now a circle in the plane $z = 0$. Give $P(u)$, $Q(u)$, and the values for u_0, u_1, v_0, and v_1.

c) A Moebius strip has one single boundary, a curve $B(t)$ with $t_0 \le t \le t_1$. Give $B(t)$ and the associated values for t_0 and t_1 for the model of question b).

d) We want to decorate the Moebius strip with a pattern of tiles via texture mapping. We want M tiles along the strip and N tiles across the width of the strip. We use a standard unit square texture, representing one tile, and use texture wrapping in all directions to get a pattern of tiles. Give the texture parameters $s(u,v)$ and $t(u, v)$ for this.

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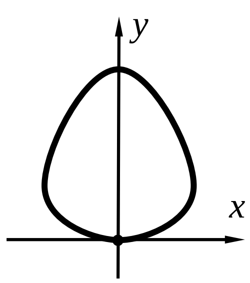
3 We want to draw a closed, *smooth* curve. The curve must be tangent to the x-axis at the origin, and left-right symmetric across the y-axis. We use Bézier segments, and one of these starts at the origin. Answer the following questions, with formal definitions of the points *and* sketches:



a) Suppose we use two cubic Bézier segments for the curve, where a segment is given by $P(t) = (1-t)^3 P_0 + 3t(1-t)^2 P_1 + 3t^2(1-t)P_2 + t^3 P_3$.

Give the possible positions of the control points. How many degrees of freedom remain?

b) How to select the points in this cubic case such that a circle with radius r is approximated?

c) Suppose we use three quadratic Bézier segments for the curve. Give the possible positions of the control points. How many degrees of freedom remain?

d) Suppose we use one fourth-degree Bézier segments for the curve. Give the possible positions of the control points. How many degrees of freedom remain?

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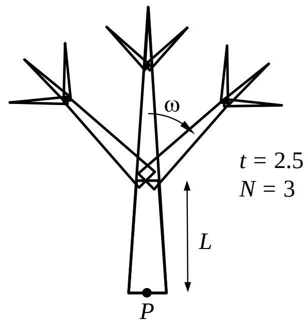
4 We want to draw a growing tree in 2D. The root of the tree is at a point P, the age of the tree is t years. The tree consists of branches, where each branch is modelled as a trapezium (older branches, $t > 1$) or a triangle (young branches, $t < 1$). The length of each branch increases linearly to L cm in its first year. The width of a branch at a position l ($0 \leq l \leq L$) increases with D cm per year, starting from the time that the branch reaches length l. When a branch is one year old, N subbranches are created. The directions of these subbranches are distributed over angles in the interval $[-\omega, \omega]$, $0 < \omega < \pi / 2$, where an angle of 0 radians is a continuation in the same direction as the original branch.



We want to define a function *DrawTree*(float t) that draws such a tree, and which gives a nice animation when called with small increments of t. We assume that a function *DrawTrapezium*(float a) is available to draw trapeziums, where the coordinates of the four vertices of this trapezium are (1, 0), (a, 1), ($-a$, 1), and (–1, 0). The use of a=0 gives a triangle. The trapezium is defined in a local coordinate frame; global positions X are derived from local coordinates X' by $X=MX'$, where M is a homogenous transformation matrix, initially equal to the identity matrix. Furthermore, suppose that a standard set of functions to define transformation matrices is available, *i.e.*,

- $T(V)$ gives a translation matrix over a vector V;
- $S(s_x, s_y)$ gives a scaling matrix with scale factors s_x and s_y for the axes; and
- $R(a)$ gives a counterclockwise rotation over a radians around the origin.

An incomplete version of *DrawTree* is given below:

```
Matrix M ;    // current transformation matrix, similar to the model matrix of OpenGL

DrawTree(float t);     // Recursively draw a tree, where the age of the root is t.
{
    Matrix MS;
    MS = M ;                          // Save the current transformation
    w0 = …; w1 = …; b = …;            // Question a)
    M = …;                            // Question b)
    DrawTrapezium(…);                 // Draw the current branch

    if t < 1 then exit;               // A young branch has no subbranches
    for i = 0 to N–1 do               // Draw N subbranches
    {
       M = …. ;                       // Question c).
       DrawTree(t – 1);               // Recursively draw subtree
    }
    M = MS;                           // Restore the current transformation
}
```

Answer the following questions:

a) Calculate the widths w_0 and w_1 at the start and end of the current branch, as well as its length b.
b) Give the transformation matrix M needed to draw the first branch of this tree, and the value of the parameter a of *DrawTrapezium.*
c) Give the transformation matrices M to produce the N subbranches/subtrees.
d) What is the height $H(t)$ (the maximum y coordinate for all branches) of a tree of age t ? Take into account whether N is odd or even.