Delft University of Technology
Faculty of Electrical Engineering, Mathematics, and Computer Science

TU Delft

Examination for

IN4003 Geometric Modelling

Wednesday, 25 August 2010, 14:00 – 17:00

This examination has 8 open questions on 4 pages.
All questions have equal weight (10 points/question).
Maximum score = 80 points.
Minimum score required for a passing grade: 44 points.

Use of notes, books and readers is not permitted.
Use of (graphical) calculators is permitted.

Write and draw clearly, avoid verbose explanations, and explain all your answers.

Please use a separate sheet for each question.
Write on each sheet: your name, study number, course code (IN4003), date, and question number. This is important because each question is graded separately.

The examination covers the following materials:
Lecture slides IN4003 2010, Reader IN4003 2010.

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1. a. Explain in your own words the principle of the quadtree representation for 2D figures, making use of an example figure. In this example, at least two levels of subdivision should occur.
   b. Give the tree data structure for the example used in (a).
   c. Give the linear encoding for the example used in (a).

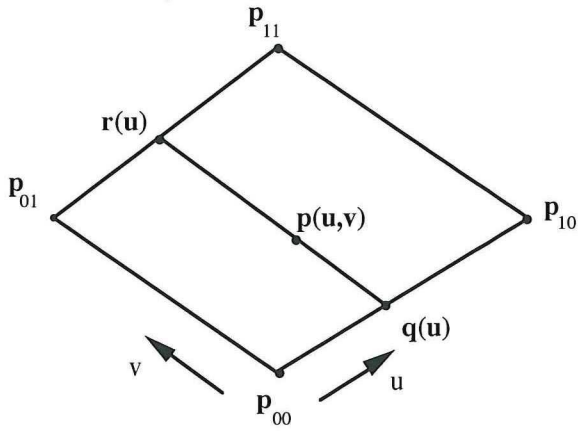
2. a. Describe (in pseudo-code) an algorithm that classifies a line with regard to an object defined by a CSG (Constructive Solid Geometry) model.
   b. What is the major disadvantage of a CSG model compared to a boundary representation?
   c. Given are two objects A and B whose boundaries are not (partially) coincident. Which parts of their boundaries must be combined if the boundary of $A \cup B$, $A \cap B$, A-B and B-A, respectively, has to be determined? Illustrate your answers with a 2D example.

3. a. In which respect is the Delaunay triangulation for a given set of 2D nodes the best possible triangulation?
   b. List the most important steps in the main loop of the algorithm to determine the Delaunay triangulation for a given set of 2D nodes.
   c. Describe, preferably with a formula, how the nodes in an existing mesh are repositioned with Laplacian smoothing. If Laplacian smoothing is applied to a Delaunay triangulation, is the resulting mesh then guaranteed to be a Delaunay triangulation too?

4. a. Given are three 2D control points $\mathbf{p}_0$, $\mathbf{p}_1$ and $\mathbf{p}_2$, and three quadratic basis functions $B_{0,2}(u)$, $B_{1,2}(u)$ and $B_{2,2}(u)$ ($0 \le u \le 1$). A parametric curve $\mathbf{p}(u)$ is defined by these control points and basis functions:

$$\mathbf{p}(u) = \sum_{i=0}^{2} \mathbf{p}_i B_{i,2}(u), \qquad 0 \le u \le 1$$

   Make a sketch of the three quadratic basis functions, if $\mathbf{p}(u)$ *interpolates* the three control points at $u=0$, $u=1/2$ and $u=1$. Give the function values for $B_{i,2}(0)$, $B_{i,2}(1/2)$ and $B_{i,2}(1)$ ($i=0...2$), to achieve the interpolation.
   b. Given are four 3D control points $\mathbf{p}_{00}$, $\mathbf{p}_{01}$, $\mathbf{p}_{10}$ and $\mathbf{p}_{11}$. Derive the equation of the bi-linear parametric surface $\mathbf{p}(u,v)$ ($0 \le u,v \le 1$), with the four control points as corner points, and four linear basis functions.

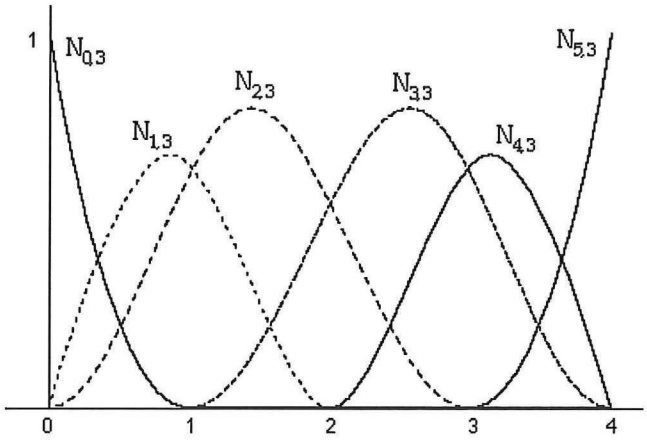


   c. Describe how two adjacent Bézier surfaces can be joined together with continuity of the tangents (C^1).

5. a. Bézier curves in general have three important limitations: (1) the curve degree depends directly on the number of control points, (2) there is no local control, and (3) smoothly joining curves with higher order of continuity than C^1 is difficult. Explain how each of these problems is overcome by B-spline curves.

   b. The figure below shows a graph of the basis functions of a B-spline curve:

$$\mathbf{p}(u) = \sum_{i=0}^{n} \mathbf{p}_i \cdot N_{i,m}(u),$$



   Using this figure, determine the following parameters of the curve: number of control points, order and degree of the curve, and the knot vector. Explain how these parameters are derived.

   c. What causes the shape of the basis functions $N_{0,3}$ and $N_{1,3}$ to be different from the shape of $N_{2,3}$? Explain this difference, and the effect it has for the resulting curve.

6. a. What is the difference between constraint solving and constraint validation?

   b. In a feature class definition, boundary and interaction constraints can be included. For both types of constraints, describe what they can specify and give an example.

   c. A new feature instance is usually added to a feature model with an attach constraint. What does such a constraint specify?

7. a. Explain, using a 2D or a 3D example, the basic idea of the volume decomposition method for feature recognition.
   b. The volume decomposition method initially results in a set of shapes that mostly do not correspond to the usual features. How can the more usual features be determined from these initial shapes? Give two possibilities.
   c. One of the main problems of the volume decomposition method is that it can easily get into a loop. How can this problem be solved?

8. a. What is feature conversion? Why is feature conversion required in multiple-view feature modelling?
   b. Describe how the problems of model consistency and data synchronisation can be solved in a peer-to-peer collaborative modelling system.
   c. Explain the conflict between network load and real-time interactivity in a client-server collaborative modelling system.

End of examination