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

TU Delft

Examination for

IN4086 Data Visualization

Wednesday, 28 January 2009, 14:00 – 17:00 h.

This examination has 6 open questions on 3 pages.
All questions have equal weight (10 points/question). Maximum score = 60 points.
Minimum score required for a positive grade: 33 points.

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

Write and draw clearly and 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 (IN4086), date, and question number. This is important because each question is graded separately.

The examination covers the following materials:
Course sheets 2008/2009, Reader IN4086, edition 2008/2009.

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1. a. Scientific data sets for visualization are generated by numerical simulations or by measurements (data acquisition). Give a typical example of each of these, and explain why the size of these data sets is often very large. *(3)*

   b. Given a point P(x,y) in global coordinates, located inside a 2D regular rectangular (Cartesian) grid, with base point (x_0,y_0), and cell size (dx,dy). Determine the indices (i,j) of the cell that contains P, and the relative position (α,β) of P in the cell $(0 \le \alpha,\beta \le 1)$. *(3)*

   c. Four data points P_1 ... P_4 are the corner points of a 2D rectangular grid cell. The data values at P_1 ... P_4 are d_1...d_4 respectively. Inside the cell lies an arbitrary point $P(\alpha,\beta)$ with: $\alpha,\beta \in [0...1]$, and data value d_p. Derive the expression for determining d_p by *bi-linear interpolation. (4)*

2. a. Describe in pseudo-code the global structure of the Marching Cubes algorithm. One step in this algorithm is "*Process Cell*" *(3)*

   b. Describe in pseudo-code (6 steps) the structure of "*Process Cell*" mentioned above. *(3)*

   c. Sometimes two configurations of the triangles in a cell are possible in the Marching Cubes algorithm. Under which condition for the INSIDE / OUTSIDE classification for the cell and a neighbouring cell will this problem occur? Make a drawing of a situation (two cells) showing the problem. *(4)*

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10 3. a. What is the main difference between a surface fitting method and a direct volume rendering method for producing an image of a volume dataset? Give an advantage and a disadvantage of using surface fitting (relative to direct volume rendering) when making an animation with a moving camera through a static volume dataset. *(4)*

b. Front to back or back to front color compositing between the volume entry point and the volume exit point is one way to calculate a color from an intensity profile along a ray in volume ray casting. Describe shortly three alternative ways to calculate a color for a pixel from the intensity profile along the ray. *(3)*

c. The ray casting integral $I(N,X) = \int_N^X g(s) e^{-\int_N^s T(x)dx} ds$ determines the intensity of a pixel. Convert this integral into a discrete version (sum of contributions of all samples) that can be use to calculate the pixel color in front to back order from a finite number of samples along the ray. Explain the meaning of all variables in the formula. *(3)*

10 4. In virtual colonoscopy, CT data is acquired of the patient colon. The colon is primarily filled with air but also contains some stool. Due to tagging, the stool has the highest intensity.

If one were to draw a straight line in the volume data starting in air, going through the tagged stool and ending in the soft tissue of the colonic wall, one could plot a graph of gradient magnitude versus CT intensity, sampling values at regular intervals along the straight line. This graph has a very characteristic shape.

a. Draw the graph and explain briefly what you see. You do not need to give exact values on any of the axes, only the general shape and relative positions of intersections with the axes are important. *(2)*

b. How can this graph be used to eliminate the false border between stool and air caused by the partial volume effect? *(2)*

Other medical visualization questions:

c. Explain image registration in the context of medical image processing and visualization. Give one or more applications of registration. *(3)*

d. Briefly define three medical visualization application types and give an example of each type. You do not have to limit yourself to the examples discussed in class. *(3)*

10 5. a. A 3D stationary velocity field is defined on a structured curvilinear grid. Describe a technique for computing a particle path directly in the curvilinear grid (without transformation to a Cartesian grid). Which step in this calculation is more complex than in a Cartesian grid? *(4)*

b. What are *time lines* in a velocity field? How can time lines be determined using the particle path computation? How can this be extended to time surfaces? *(3)*

c. A possible improvement of the particle path calculation is the use of a variable time step instead of a fixed time step. Why can this be an improvement? Describe a technique for adjusting the time step. *(3)*

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6. a. Describe the basic principle of *spot noise* for visualization of a 2D velocity field. What is the effect of the *magnitude* of velocity on the visualization? *(3)*
   b. What is the main characteristic of a *vortex* in a flow field? Briefly describe a method for detection of regions in a flow field where vortices will occur. *(4)*
   c. What is the essential difference between *active* and *passive* stereo display systems for projection-based Virtual Reality? *(3)*

End of examination