1. Visualization basics (5p)

a. Describe how image formation takes place in image-order and object order rendering methods and for each category describe two conceptually different rendering methods (4p).

b. For what class of rendering algorithms are hidden surfaces generally an issue? How can this issue be tackled? (1p)

2. Direct volume rendering (5p)

a. The figure below shows images of an implicit model of a vase rendered with a volume ray-caster algorithm and using a gradient-shading method. Explain the reasons for the occurrence of the different visual artifacts and how those can be avoided! (3p)

b. Briefly describe two other rendering modes frequently used in direct volume rendering (use illustrations of the ray traversal and sampling)! (2p)

3. Colors in visualization (5p)

a. Assume a visualization of statistical data related to the countries of the European Union, where one identifying item in the dataset is “Country”. Critically discuss the use of color for the purpose of visualizing the attribute “Country” assuming that the visualization is not based on a geographic map (e.g. Bar charts, Pie charts or Parallel Coordinates)! (2p)

b. Briefly discuss for what kind of visual assessment (visual tasks) it is important to use ordered color sequences (color scales)? (1p)

c. Consider a visualization that is meant to be used collaboratively by several users. Discuss the usefulness of the following colors to identify objects (RGB codes in parentheses for clarification). (2p)

Pink (200,20,200)

Yellow (200,200,0)

Black (0,0,0)

Blue (0,0,200)

4. VTK and the visualization pipeline (5p)

a. Draw a flow diagram of the visualization pipeline we have covered in the course, and describe (briefly) the function and purpose of each stage/step in the pipeline.

b. Suppose that you have a 3D (volumetric) computed tomography (CT) image of a foot. How would you use VTK to visualize the bones in the foot? Please focus on key classes and concepts (that is, what the classes do and how they are connected in the pipeline), not implementation details. You may write simplified pseudocode or, preferably, draw a diagram that shows the data flow and the VTK components you use.

5. Contouring and Marching Squares/Cubes (5p)

a. Explain in detail how an isoline can be constructed using the Marching Squares Algorithm for a simple example of your own choice. Also draw the contour. (3p)

b. What is the problem of ambiguities? Can it be solved? (2p)

6. Interpolation (5p)

a. Explain why linear interpolation can make the Marching Squares algorithm better? Show using examples (3p)

b. What are the main differences between linear interpolation and bi-linear interpolation? What is the difference between linear interpolation and quadratic interpolation? (2p)

7. **Advanced Algorithms (10p)**

Which of these statements are true? And which are false? (The right answer gives 1p and the wrong one gives -1p, but you cannot get less than 0 on the whole question. Leave blank answer if you are unsure.)

a. Volume data can be visualized as points in scientific visualization.

b. The disadvantage of rendering points is that it is orders of magnitude slower to render than polygons

c. The recursive version of the dividing cubes algorithm can produce more points than the procedural version

d. Carpet plots is another way to render 3D data in 2D.

e. Ribbon bands can be used to depict vorticity (twist) in vector field data.

f. Splatting is a concept used for Streamline rendering.

g. Probing is used instead of Phong shading in the rendering process.

h. Hedgehogs is a technique for vector field visualizations.

i. The *Split edge* technique aims at making sharp edges appear on objects as the shading smoothes them out.

j. The *Parallel coordinates* technique is a powerful tool to visualize up to 3 variables only for each data point.