Assignments 2IV35 – Visualization

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Contents

Chapter 1

Overview

The assignments for the course are spread over three sets. For each set, you should:

- Complete several exercises concerning visualization techniques.
- Extend a JAVA and/or D3 application to include various visualization techniques.
- Evaluate your results.

Practical support (questions, feedback on your intermediate results, etc.) is provided during the practical work sessions by the instructor(s). The assignments are sometimes quite specific, but we encourage you to *explore* the possibilities for extending the applications in different directions, and not to stay limited to the letter of this document. Visualization is much about designing creative solutions to the (given) problem of displaying complex data to gain different insights.

1.1 Deliverables

The following deliverables will have to be submitted via OASE before each assignment set deadline:

- A report that contains solutions to the exercises. Make sure that you explain your approach and evaluate your work, and that you include images that demonstrate your approach.
- Depending on the assignment: a D3-based website or executable JAR files of the extended applications.

1.2 Some report writing guidelines

1.2.1 General guidelines

- Do not underestimate the difficulty of technical writing, so reserve enough time for writing the report.
- Be precise. It is not sufficient that you understand what you mean. If the reader cannot understand it, it is usually your fault and not the reader's.
- Use illustrations and screenshots to clarify methods and results.

- Each figure and table should be numbered and accompanied by a caption text that explains what the reader sees in the picture or table.
- Refer to figures and tables in the text by using their numbers, for example, "Figure 1 shows...". Furthermore, each figure and table must be referenced in the text somewhere.
- Use proper expressions, for example, "don't" should be written as "do not", "it's" as "it is", and so on. The pronoun that goes with "it" is "its" without an apostrophe.
- Spell check, grammar check, and proof read the document before handing it in. Most readers, in particular examiners, will be irritated by poor spelling and poor grammar.
- Do not use material that you did not write yourself. Copy-and-paste without citation, quotation, or reference, is considered plagiarism. Procedure requires that plagiarism is reported to the examinations committee.

1.2.2 Course-specific guidelines

- Provide details about techniques/methods that you use. Do not just write "We have implemented the marching cubes algorithm". Describe the method too, in your own words. Even if it is well described in a book, you should still explain the method yourself; this is part of the exercise. Also, the reader may not know the method, nor can the reader be bothered to find the document that you are referring to.
- Discuss interesting implementation aspects, but do not include code fragments in the text. Pseudo code is allowed, but mathematical formulas are preferred.
- For the D3-based assignments, you are free to use any example code that is available on the web. However, you should refer to where you obtained it from, and in your report explain why you chose this particular method. If you adapted the code in a non-trivial way, explain this in the way described in the previous point.
- Describe parameters of methods and explain which settings you used and why.
- Provide evidence that the method you have implemented actually works as intended.
- Explain how you designed a color map, a transfer function, or even your whole visualization approach.

Part I

Set 1 – Deadline December 7

Chapter 2

Information visualization

2.1 D3

The JavaScript library *D3.js* (http://d3js.org) provides a wealth of visualization techniques that can be run directly in your web browser. The website has many examples and code snippets, all of which you are free to use in this assignment. There are also many other good resources on D3, so it should not be hard to get started.

Useful resources:

- The D3 website itself has lots and lots of resources: http://d3js.org.
- A huge number of examples is available here too: http://christopheviau.com/d3list/.
- Scott Murray's book on Interactive Data Visualization for the Web, can be read online for free at http://chimera.labs.oreilly.com/books/1230000000345/index.html. The book also has an introduction in JavaScript, CSS, and HTML.
- For a quick intro, browse the D3 workshops slides: http://bost.ocks.org/mike/d3/workshop/.

2.2 Dataset

The dataset originates from http://www.opencbs.nl (in Dutch), and it consists of shape information of Dutch municipalities in GEOJson format (`cities-geometry.json`), and a tab-separated file containing many statistics of these municipalities (`cities-data.txt`). The following statistics are provided:

GM_CODE [string]
This code provides a numerical identity to a municipality.

GM_NAAM [string]
The official name of the municipality.

WATER []
Has no relevance here.

OAD [number]
Average number of addresses per square kilometer.

STED [number]
Describes the urban character using the following classification:

1	very strongly urban ≥ 2500 addresses per km^2
2	strongly urban $1500 - 2500$ addresses per km^2
3	moderately urban $1000 - 1500$ addresses per km^2
4	slightly urban $500 - 1000$ addresses per km^2
5	not urban < 500 addresses per km^2

AANT_INW [number]
Number of inhabitants.

AANT_MAN [number]
Number of men.

AANT_VROUW [number]
Number of women.

P_00_14_JR [percentage]
Percentage of inhibations aged 0 to 15 years.

P_15_24_JR [percentage]
Percentage of inhibations aged 15 to 25 years.

P_25_44_JR [percentage]
Percentage of inhibations aged 25 to 45 years.

P_45_64_JR [percentage]
Percentage of inhibations aged 45 to 65 years.

P_65_EO_JR [percentage]
Percentage of inhibations aged 65 years and older.

P_ONGEHUWD [percentage]
Percentage of unmarried people.

P_GEHUWD [percentage]
Percentage of married people.

P_GESCHEID [percentage]
Percentage of divorced people.

P_VERWEDUW [percentage]
Percentage of widows and widowers.

BEV_DICHTH [number]
Number of inhabitants per km^2.

AANTAL_HH [number]
Number of households.

P_EENP_HH [percentage]
Percentage of single households.

P_HH_Z_K [percentage]
Percentage of households without children.

P_HH_M_K [percentage]
Percentage of households with children.

GEM_HH_GR [number]
Average number of people in all households.

P_WEST_AL [percentage]
Percentage of foreigners from Europe, North-America, Oceania, Indonesia, and Japan.

P_N_W_AL [percentage]
Percentage of foreigners not from Europe, North-America, Oceania, Indonesia, and Japan.

P_MAROKKO [percentage]
Percentage of foreigners from Morocco, Ifni, Spanish Sahara, and Western Sahara.

P_ANT_ARU [percentage]
Percentage of foreigners from the Dutch Antilles and Aruba.

P_SURINAM [percentage]
Percentage of foreigners from Surinam.

P_TURKIJE [percentage]
Percentage of foreigners from Turkey.

P_OVER_NW [percentage]
Percentage of foreigners from other countries than mentioned in the above 4 attributes.

AUTO_TOT [number]
Number of cars.

AUTO_HH [number]
Number of cars per household.

AUTO_LAND [number]
Number of cars per km^2.

BEDR_AUTO [number]
Number of company cars (minivans, trucks, etc.).

MOTOR_2W [number]
Number of motorcycles, including scooters.

OPP_TOT [number]
Total land and water area in hectares.

OPP_LAND [number]
Land area in hectares.

OPP_WATER [number]
Water area in hectares.

P_00_04_JR [percentage]
Percentage of inhibations aged 0 to 5 years.

P_05_09_JR [percentage]
Percentage of inhibations aged 5 to 10 years.

P_10_14_JR [percentage]
Percentage of inhibations aged 10 to 15 years.

P_15_19_JR [percentage]
Percentage of inhibations aged 15 to 20 years.

P_20_24_JR [percentage]
Percentage of inhibations aged 20 to 25 years.

P_25_29_JR [percentage]
Percentage of inhibations aged 25 to 30 years.

P_30_34_JR [percentage]
Percentage of inhibations aged 30 to 35 years.

P_35_39_JR [percentage]
Percentage of inhibations aged 35 to 40 years.

P_40_44_JR [percentage]
Percentage of inhibations aged 40 to 45 years.

P_45_49_JR [percentage]
Percentage of inhibations aged 45 to 50 years.

P_50_54_JR [percentage]
Percentage of inhibations aged 50 to 55 years.

P_55_59_JR [percentage]
Percentage of inhibations aged 55 to 60 years.

P_60_65_JR [percentage]
Percentage of inhibations aged 60 to 65 years.

P_65_69_JR [percentage]
Percentage of inhibations aged 65 to 70 years.

P_70_74_JR [percentage]
Percentage of inhibations aged 70 to 75 years.

P_75_79_JR [percentage]
Percentage of inhibations aged 75 to 80 years.

P_80_84_JR [percentage]
Percentage of inhibations aged 80 to 85 years.

P_85_89_JR [percentage]
Percentage of inhibations aged 85 to 90 years.

P_90_94_JR [percentage]
Percentage of inhibations aged 90 to 95 years.

P_95_EO_JR [percentage]
Percentage of inhibations aged 95 years and older.

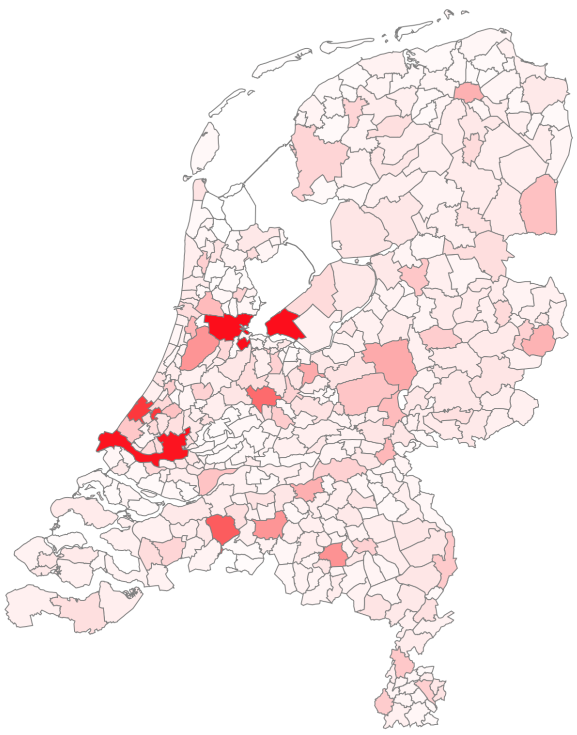

Figure 2.1: *Visualization of the number of cars in each municipality. The colors range linearly from white (0) to red (maximum value).*

2.3 Example visualization

The file `map.html` contains an example D3 script to show the number of cars per municipality as color-coded regions on a map of the Netherlands, see Fig. 2.1. The visualization is very simple: a linear color map ranging from white (0) to red (maximum value) is used, and the only interaction is mousing over a region to reveal a tooltip that displays the municipality name and the number of cars in it.

This example should only be seen as a starting point to understand how the data can be read into D3. Feel free to make use of any of the more involved examples provided on the D3 website or elsewhere on the Internet (do not forget, however, to cite the source in your report).

2.4 Assignment

- Read the description of the dataset carefully and look at its raw textual form. Next, derive and document aspects of the data that could be of interest to an analyst. Formulate a set of tasks that an analyst might want to perform with the data, and some specific questions.
- Consider various (interactive) visualization techniques that support these tasks, and that are suitable to analyze this data. Discuss pros and cons, and also consider the combination of multiple techniques.

- Build an interactive application in D3 to visualize the data with the techniques chosen. You should have at least three different techniques in your approach. Each technique may be used in a separate view, and they need not be linked interactively. Do also not forget about basic elements such as color legends, labels, tick marks, etc.
- Use your application to make interesting observations about the data. Document how you came to these observations and how the application design was beneficial (or not) to your discoveries.

Part II

Set 2 – Deadline January 11

Chapter 3

Volume rendering

In this assignment, you will develop a volume renderer based on a raycasting approach. The skeleton code provides a set-up of the whole graphics pipeline, a reader for volumetric data, and a slice-based renderer. The main task is to extend this to a full-fledged raycaster.

3.1 Getting the skeleton code running

We provide skeleton code to help you get started on the assignments. The code is in Java, and provided as Netbeans projects. It should be possible to run the project out-of-the-box on Mac OS X, Linux, and Windows systems. For OpenGL graphics, the code relies on the JOGL libraries, which are included in the archive.

3.2 Skeleton code

The skeleton has the familiar set-up of a main application (`VolVisApplication`), which holds the visualization and user interface. The helper classes `Volume` and `VolumeIO` represent volumetric data and a data reader (AVS field files having extension `.fld`), respectively. Furthermore, the class `VectorMath` offers a number of static methods for vector computations. Finally, `TrackballInteractor` provides a virtual trackball to perform 3-D rotations.

The class `RaycastRenderer` provides a simple renderer that visualizes a view-plane aligned slice through the center of the volume data. The renderer also draws a bounding box to give visual feedback of the orientation of the data set.

3.3 Assignments

3.3.1 MIP (40 points)

Study the method `slicer()` in the class `RaycastRenderer`, and use this as a basis to develop a raycaster that performs Maximum Intensity Projection (see Fig. 3.1(a) for a reference result image for the orange dataset). The coordinate system of the view matrix is explained in the code. Implement the following functionalities:

1. Tri-linear interpolation of samples along the viewing ray.

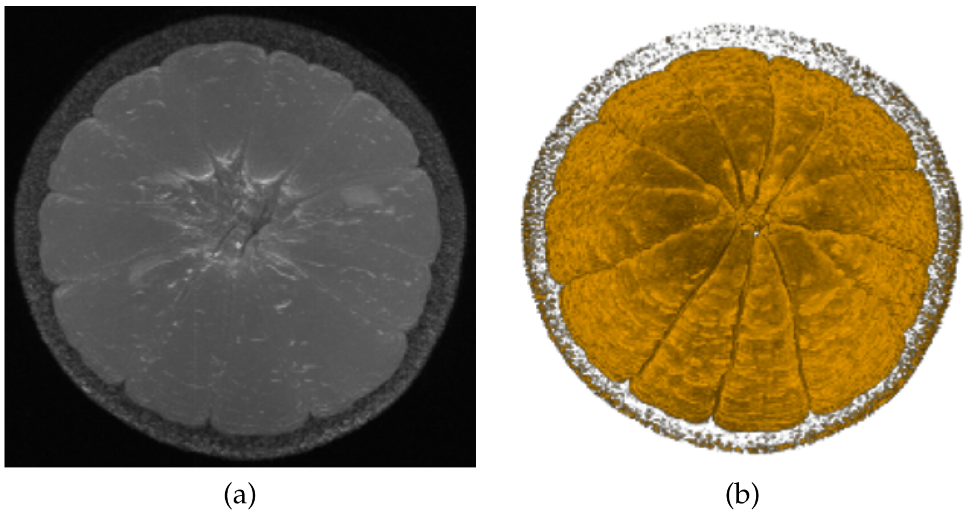

Figure 3.1: *(a) MIP of the orange dataset. (b) Result of the compositing ray function on the orange dataset with the default settings in the transfer function editor.*

2. As you may notice, a software raycaster is quite slow. Make the application more responsive during user interaction. A straightforward way to do this is to compute the image at a lower resolution.

Experiment with various data sets. When is MIP useful and when not?

3.3.2 Compositing (30 points)

Extend your basic raycaster so that it performs *compositing* of colors and opacities of all voxels along the view ray (see Fig. 3.1(b) for a reference result image for the orange dataset). The code already provides a transfer function editor, so you only need to concentrate on the compositing aspect.

Take the same datasets, and try to make more sophisticated visualizations of them. Compare and discuss the results to those obtained with MIP.

3.3.3 Opacity weighting (30 points)

Implement gradient-based opacity weighting in your raycaster, as described in Levoy's paper [1] in the section entitled "Region boundary surfaces", eq. (4). Ensure that the user can control all of the parameters in an intuitive way.

Experiment with various data sets and compare the results with those obtained by the approach in the previous exercise.

Part III

Set 3 – Deadline February 1

3.4 Available soon

Bibliography

[1] M. Levoy. Display of surfaces from volume data. *IEEE Computer Graphics and Applications*, 8(3):29–37, 1988.