The Virtual Frog

Project for the course “Scientific Visualization and Virtual Reality” of the University of Amsterdam.

Introduction

The “Whole Frog Project” was conducted in 1993-1995 by the Lawrence Berkeley National Laboratory to show how 3D visualization can be used as a curriculum tool [1]. The project’s website and in particular the Virtual Frog Dissection Kit show how 3D imaging and visualization techniques can be used to construct an interactive website to study the anatomy of a frog.

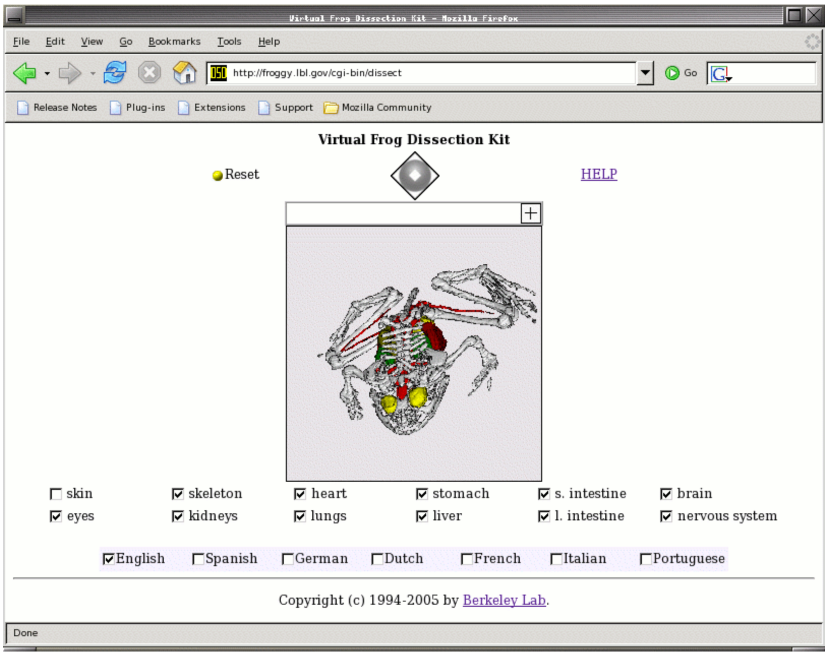

Figure 1. Website of the Virtual Frog Dissection Kit.

The project uses a dataset that consists of two parts (download the dataset from Blackboard):

1. the files that start with “frog” are photographs of consecutive slices through the frog, from back to belly (i.e. in “coronal” orientation);
2. the files that start with “frogTissue” are also consecutive slices through the frog, in the same order and orientation, but contain a segmentation of the frog based on 15 types of tissue:

Value	Tissue type
1	Blood
2	Brain
3	Duodenum
4	Eye retina
5	Eye white
6	Heart
7	Ileum
8	Kidney

Value	Tissue type
9	Large intestine
10	Liver
11	Lung
12	Nerve
13	Skeleton
14	Spleen
15	Stomach

> Think of these values as masks that identify the pixels in the first part of the dataset that belong to the same tissue type. The empty space around the frog is represented by the value 0. There are additional values present in the dataset, but you can ignore those.

Each part consists of 136 files that are each 500 by 470 pixels. Each pixel is represented by one unsigned byte. The spacing between slices is 1.5 times the width of a pixel (or height: pixels in a slice are isotropic).

Objective for this project

This day and age, especially with the techniques offered to you by this course, we should be able to do better than the crude images on this website. The objective of your project is to create a Virtual or Augmented Reality (VR or AR) application that provides a modern way to study the anatomy of this frog. The application must use the original data set and should support the following set of minimal requirements:

- The application should show an interactive 3D representation of the frog that can be studied from all angles.
- As with the website, the application should allow the user to selectively visualize the different tissue types; i.e.: the user should be able to turn the visualization of any tissue type on or off, in any combination.
- For a VR application we expect the 3D representation to be stereoscopic (using binocular disparity, as for example with CardboardVR) in the case of an AR application we want to be able to study the frog by moving the display around (e.g. through a marker, see images below).
- We want the application to be used by a broad audience. This rules out expensive VR/AR devices such as an Oculus Rift, HTC Vive or Microsoft Hololens. Since everyone nowadays owns either a smartphone or tablet (or both), the application should be accessible on that. Ideally, it should not matter whether the device is running Android, iOS or Windows.

	
Stereoscopic Virtual Reality using a smartphone and CardBoardVR.	Handheld Augmented Reality using a tablet and an image marker.

Bonus points for implementations that:

- add text labels that identify each tissue, or a key if tissues are coloured;
- provide an interactive "clipping plane" that allow part of the visualization to be obscured;
- provide an interactive "slicing plane" that shows the image content in the "frog" dataset sampled onto that plane;
- provide a combination of a clipping *and* slicing plane where the slicing plane shows the image content at the location and orientation of the clipping plane.

Hints

1. There are several IDEs[1] that support the authoring of VR/AR software for smartphones. The most popular are Unity and Unreal, which are extremely powerful and versatile but have a steep learning curve. Another interesting approach that appeared quite recently is one that is followed by, amongst others, PlayCanvas which provides an easy-to-use web-based IDE and generates applications that can be run on any WebVR-enabled browser.
2. Whichever IDE you use, you will not be able to run VTK visualization pipelines in a smartphone application. Instead, pre-process the dataset into 3D objects for each tissue type that can be incorporated as "assets" into your IDE.
3. It helps to get acquainted with the dataset using Paraview (which internally uses VTK). Because of how the data is stored, reading this data into Paraview requires a bit of wizardry that I will help you with:
   - Download the dataset from Blackboard and unpack the ZIP file into an empty directory.
   - Select File -> Open from the menu bar and browse to the location of the dataset.
   - You will notice that Paraview collapses the dataset into two parts; select either one of them and click "OK".
   - Open data with "Raw (binary) Files".
   - In the "Properties" panel on the lower left, the tricky bit is the specification of the "File Prefix" and "File Pattern":
     - Change "File Prefix" so that it ends with "frog." or "frogTissue." (depending on the set you choose to open – do not forget the period at the end!);
     - Change "File Pattern" to: "`%s%03d.raw`". Programmers will recognize this as a "printf" pattern: what this does is substitute "%s" for the value in "File Prefix", "%03d" for the file number (using 3 digits per number, prefixed with zeros) and then add ".raw" at the end. This allows Paraview to find all files in the dataset.
   - Set "Data Scalar Type" to "unsigned char".
   - Because the data values are represented by single bytes, the "Data Byte Order" does not matter.
   - Set "File Dimensionality" to 2.
   - Set "Data Spacing" to 1, 1, 1.5.
   - Set "Data Extent" to 0, 499, 0, 469, 1, 136.
   - Click "Apply". A wireframe box should appear. If not, recheck all settings carefully.
   - Set "Representation" (now new in the Properties panel) to "Volume". A volume rendered representation of the frog appears.

   By default, Paraview uses a predefined colour/opacity lookup table. Experiment with the "Color Map Editor" by clicking the "Edit" button under "Coloring" (in the Properties panel). For example, try this: modify the opacity mapping so that tissues 1..7 are visible but 8..15 are

[1] Integrated Development Environment: a software environment that helps in the construction of computer software.

not. Or: modify the opacity mapping so that only the skeleton is visible. Then change the colour mapping so that the skeleton is white. Now modify the tables so that only the skeleton and “Blood” (in red) are visible. Finally; see if you can create an opacity and colour mapping that allows you to clearly discern all 15 types of tissue.

Please note

1. Work in pairs.
2. As the solution for this project, you must submit (1) a PDF report that describes your solution and (2) the source code of your software.
3. In your report and source code, clearly state both your names and student numbers. This will serve as proof that this is *your* work and that you contributed *equally* to this project.
4. The report must be a proper scientific report, i.e.: it contains a title, author names + student numbers, abstract, introduction (with research question), methods, results, discussion and bibliography.
5. Submit one ZIP file per pair through Blackboard that contains everything I need to reproduce your work. Do not submit the dataset!

References

[1] Robertson, David, William Johnston, and Wing Nip. "Virtual frog dissection: interactive 3D graphics via the Web." *Computer networks and ISDN systems* 28.1 (1995): 155-160. https://doi.org/10.1016/0169-7552(95)00117-6