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Scientific Visualisation and Virtual Reality:
Pierre, the virtual frog

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Abstract

This paper explores a multitude of ways to study the anatomy of a frog. Specifically in a virtual setting, making real hands-on frog practicals obsolete. In this paper data processing for virtual uses is discussed. As well as the augmented and virtual reality visualisations that makes use of this processed data. Furthermore the visualisation is put online to reach a broad audience [1].

1 Introduction

Over the last decade an increasing amount of scepticism has developed around the hands-on approach of science education. This approach entails the dissection of animals. The general thought behind dissecting animals is that it reinforces learning behaviour and increases motivation of students for creating an understanding in morphology and anatomy (Akpan and Andre, 1999). A survey held nationwide in America has stated that 68% of teachers report to have used the dissection of frogs during their classes, while 78% of the students in this survey report having dissected a frog (Osenkowski et al., 2015). In this same survey is was stated that for 67% of the teachers the main reason for using dissection methods in their curriculum was that the students wanted this. Other reasons were that 42% of the teachers said that alternatives to animal dissection were inadequate, and 41% said to experience concerns about performance of students using these alternatives. This gives rise to the notion that if alternatives were to get more advanced and easy to use, these numbers would decrease and less and less animals would be used for educational uses. Subsequently this gives rise to the goal of this paper, creating a virtual frog and analysing it's functionalities and faults.

Creating a virtual environment wherein it is possible to dissect a frog has been done before by Robertson et al. (1995) with the "Whole Frog Project". This project was conducted in 1993-1995 by the Lawrence Berkeley National Laboratory and shows a 3D visualisation of a frog that is to be used as a curriculum tool. However, this project, while ahead of its time, has now become outdated. As such, this paper will make an effort to bring the Whole Frog Project to a next level. This will be done by using the data provided by Robertson et al. (1995) and creating an interactive 3D representation of the frog that can be studied from all angles. This interactivity and the possibility to examine the frog from all directions will be accomplished using an augmented reality framework. The application will also allow the user to selectively visualize and prioritise all different tissue types by changing their

[1] https://baschatel.socsci.uva.nl/aframe/aframe.html/index.html

opacity and HSL (Hue, Saturation, Lighting) values. As an extra the frog will also be available in a virtual reality setting, although this setting will cover less interactivity as tissue types cannot be selected.

For accessibility, like Robertson et al. (1995), the application will be put online so that a broad audience can be reached. By putting the application online without the need of an external device, besides a smartphone or laptop with a camera, accessibility is assured. An average 87% of adults worldwide use the internet and 68% of adults worldwide report to owning a smartphone (Poushter, 2016). Furthermore, our virtual frog dissection toolkit will, for accessibility reasons, be given a fun name to appeal to children. Therefore, the project will be called "Pierre" named after a frog in sesame street.

2 Methods

2.1 Used Software

For our application we have used several different pieces of software. To process the frog data and create an image, ParaView was used (which under the hood uses VTK). Then to create a virtual environment, Three.js and A-frame were used, which supports augmented reality and virtual reality in a very fluent and intuitive fashion. And finally D3.js was used for the added functionality of colour picking and the changing of opacity, as this library lends itself to easy visualisations and DOM manipulations.

2.2 Data

The data used in this project was provided by (Robertson et al., 1995), and consists of two parts. One part consists of photographs of consecutive slices through the frog in coronal orientation. The other part also consists of consecutive slices through the frog in the same order and orientation but a segmentation of the frog based on 15 types of tissues. Each different type of tissues has its own value that identifies it. Each part consists of 136 files that are 500 by 470 pixels. The spacing between the slices (the z-axis) is 1.5 times the size of a pixel.

2.3 Visualisation Pipeline

As described above, processing of the data was done in ParaView. This pipeline can be viewed in figure 1. The main goal of this pipeline was to create a polygonal mesh that had a resolution that was as high as possible while also having a vertex count that was as low as possible. This reduction is needed, because it will greatly improve loading times and reduce the amount of data that needs to be downloaded from the server.

To achieve this goal, two sub images where formed. Creating two images and then recombining them gives the smallest amount of noise and reduces the amount of holes/misalignments in the final mesh. The first image samples specific values from the complete dataset by applying a threshold. These values are then transformed into a polygonal mesh by using the contour filter. The second image was formed by applying a median filter to the z-axis of the

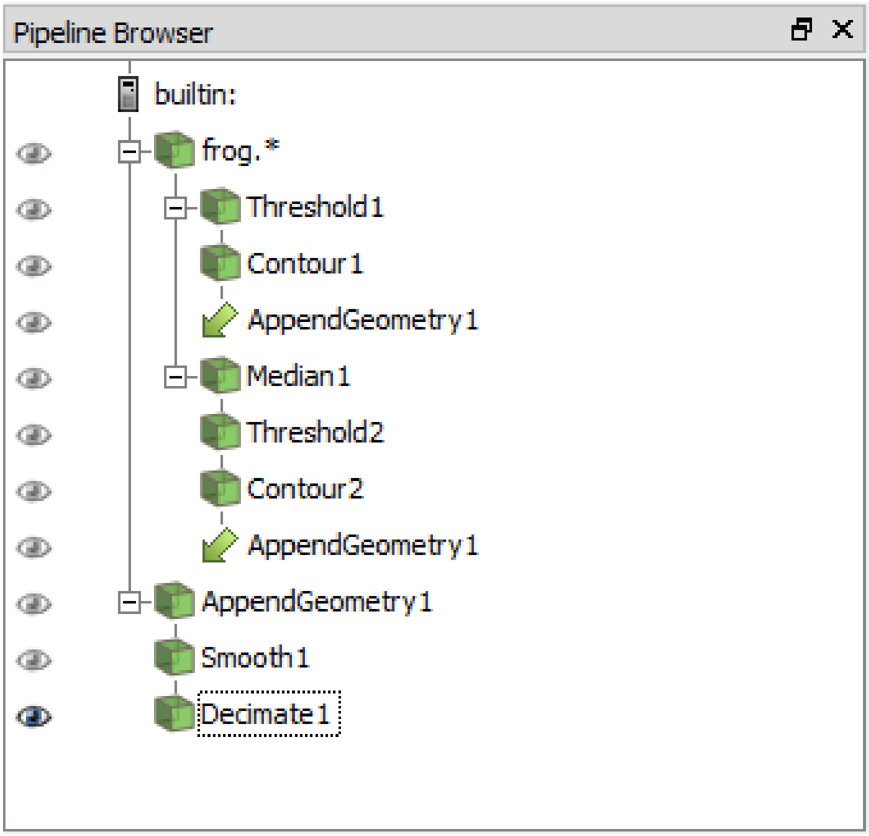

Figure 1: This visualisation pipeline depicts the processes that transform the data into a polygonal mesh. Threshold samples specific values from the dataset. The contour filter transforms these values into a mesh. The median filter calculates the median for the two neighbouring voxels along the z-axis. The data is then combined, the mesh is smoothed and a decimate filter is applied to reduce the amount of polygons.

data. This filter was applied because there is a lot of noise (missing values, misaligned values) and the distance between discrete datapoints is bigger along this axis (as described above). The median filter takes the median of the voxel itself, the voxel above, and the voxel below. The two images are then combined through the append geometry filter. This creates a mesh with a lot of artefacts and unnecessary polygons, thus the mesh is smoothed and a decimate filter is applied that attempts to reduce the amount of polygons. This decimate filter is told to try to reduce as much of the polygons as possible (maximum of 80% reduction), whilst preserving the topology of the mesh.

The result of this pipeline is a .vtk file that contains a polygonal mesh.

2.4 Online Environment

Figure 2: The marker required to attach the frog mesh to in augmented reality.

To load the VTK image object into an HTML5 Canvas, three.js was used. This library has a VTKLoader (which can read .vtk files) and is specialized in the rendering of 3D objects in the browser. Then, a scene was created using Three.js, which was then added to an A-frame web framework for building virtual reality experiences. A-frame, which has Three.js running under the hood, is specifically designed to make the programming of virtual and augmented reality visualisations as easy as possible. As such, our Three.js scene was easily added to the A-frame scene, creating an interactive virtual and augmented reality environment. This augmented reality environment needs a marker to attach a mesh to. This marker can be seen in figure 2. The D3.js library was used for the interactive components like sliders and an HSL color picker. D3.js is specialized in DOM manipulations and it was used to dynamically manipulate the colour and transparency attributes of the frog tissues.

3 Results

In this results section three different aspects will be discussed. The quality of the VTK image, the Augmented Reality visualisation and the option to use a Virtual Reality setting to examine the frogs anatomy.

3.1 VTK polygonal meshes

As described in section 2, a VTK pipeline was used to produce the number of polygons and to create an image of higher visual fidelity than just creating a contour of the dataset. The result of one of these pipelines applied to the data that corresponds to the skeleton is shown in figure 3.

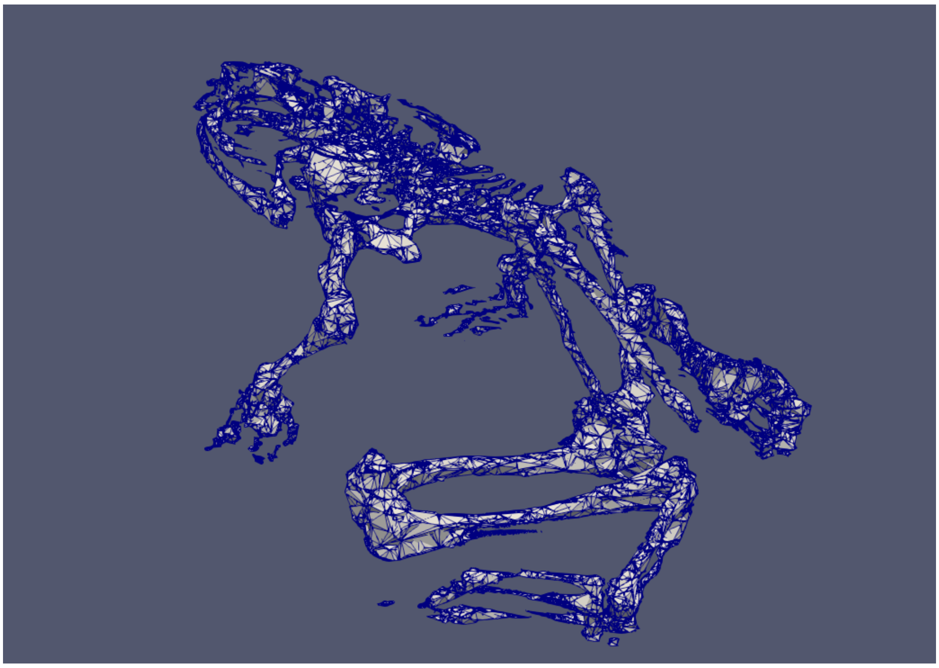

Figure 3: This figure shows the skeleton of the frog after applying the pipeline shown and discussed in section 2. This is one of the sixteen meshes that was created.

The final total number of vertexes (addition of all sixteen different types of tissues) is 2055396, the total number of faces is 685132, and the total file size is 27.5 mb. It takes (on average, $N = 10$) 496ms to load the polygonal meshes into the HTML 5 canvas using Three.js.

3.2 Visualisations

This section will describe the final visualisation that was produced in this paper. There are two final products. There is an Augmented Reality (AR) part of the visualisation (shown in figure 4), and a Virtual Reality (VR) part (shown in figure 6). All visualisations can be found on our website[2].

[2] https://baschatel.socsci.uva.nl/aframe/aframe.html/index.html

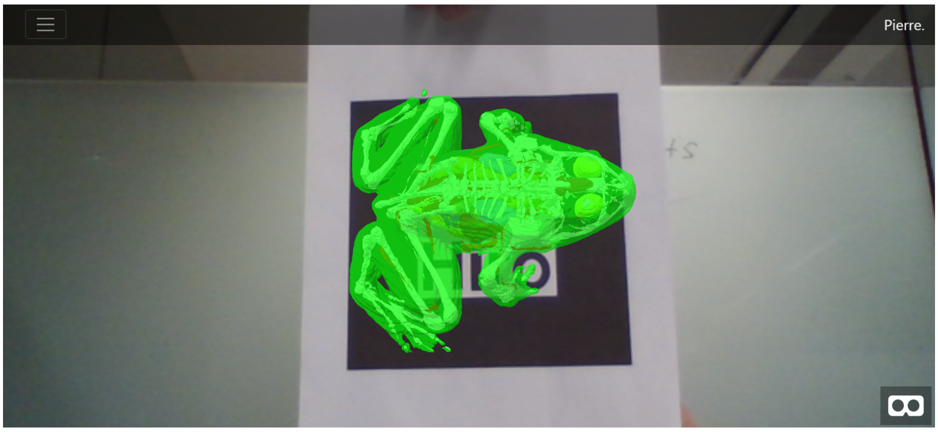

Figure 4: An example of how the Augmented Reality visualisation looks like. In the top leftmost corner it shows the menu (see figure 5), in the top rightmost corner there is a button to go back to the main page (a page with further information about the visualisation), and in the bottom leftmost corner a button is shown that will bring you to the Virtual Reality part of the visualisation (see figure 6).

3.2.1 Augmented reality

The Augmented reality part of the visualisation contains the most extra features as there can be interaction with the screen (this is not possible with simple touch gestures in VR). The flow of interaction start by pressing on the "BodyParts" tab, which will show a list of different tissues that can be selected. Upon selection a menu that makes it possible to alter the HSL values of specific tissues is shown as well as a slider that represents the opacity of the tissue. The resulting colour and opacity is shown in the 'apply'-button by applying the same colouring and opacity values to the button itself. There is also a button that resets the colour and opacity values to the defaults. Pressing the menu button again closes the menu. These interactions are shown in figure 5.

Figure 5: In the menu bar there are three options. Default which brings everything back to its default values. BodyParts (upper figure), which will give an overview of all of Pierre's body parts. If a body part is chosen by clicking on it, the third option will open up. Coloring (lower figure), where a color and opacity can be chosen for the selected body part. This is done via an HSL coloring method. The upper bar is Hue, middle is Saturation and the lowest bar is Lightness.

3.2.2 Virtual reality

When the button on the bottom right of the AR visualisation is pressed, the VR visualisation is opened. This visualisation is fairly simple; there is a black background on which the polygonal mesh of the frog is displayed twice. The two meshes that are shown are shown at a slightly different viewing angle, thereby creating the illusion of depth. It is important to note that this can only be viewed in a VR environment that also has support for a camera, as it still uses the marker to rotate the frog. For a full VR experience (controllable with the WASD keys), the main page of the website can be visited. Here, an example of the visualisation is shown. When the virtual goggles in the lower right button is clicked here, a pure VR version of the visualisation is opened.

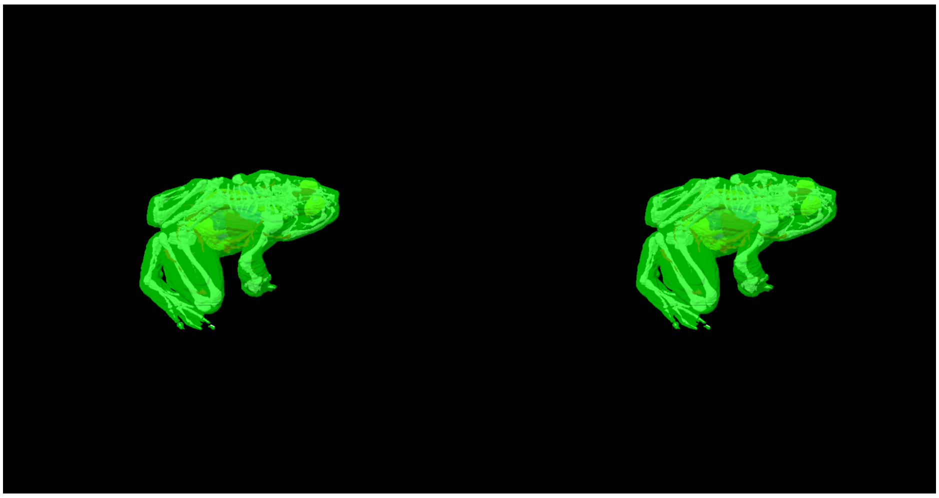

Figure 6: This figure shows how the visualisation looks like in Virtual Reality. It shows the frog twice; once for each eye at a slightly different viewing angle. This creates the illusion of depth.

4 Discussion

In this paper we set out to accomplish a multitude of design goals and functionalities to incorporate into Pierre and subsequently analyse the pro's and cons of this method/application.

First of all, the most obvious advantage of our application would be the saving of animal lives, as real frog subjects would become obsolete.

Furthermore, virtual dissection adds interactions that are not possible on a physical frog. In virtual dissection it is possible to undo any operation you have performed. Deleting the skin of the frog, for example, is not permanent while, for obvious reasons, removing a real frog's skin cannot be undone. In the visualisation discussed in this paper it is also possible to change the colour and the opacity of the separate tissues. This can help reinforce learning behaviour as the former makes it easier to identify the internal structures, and the latter makes it easier to differentiate between different types of tissue.

Another advantage is that this method of visualisation is very portable. Internet is widely available and can be used on many devices. Especially compared to the alternative, which is that you would need to bring a frozen frog and a dissection kit with you. With a visualisation that can be run from the cloud and a smartphone being available to more and more people every year (Poushter, 2016), which makes it possible to reach a larger audience. Using augmented reality also means that you just need an augmented reality capable device and a marker, which can be either printed or displayed on a different device creating near endless possibilities for teaching.

Using a virtual environment also helps reduce the cost of a dissection practical. Normally, a frozen frog and a dissection kit would have been required for every two or three students. With the virtual frog dissection, you can make use of devices that the students already have. There is also no need for additional hygiene regulations or a lab, and unlike the frogs it does not smell bad.

Although virtual dissection has its benefits, there are also some downsides. The physical interaction with the tissue of, for example, a frog could help understand its structure. Herein, the texture of the tissue (hardness, roughness, etc.) and weight might be important factors. These factors are excluded from the simulation. Furthermore, the visual aspects that belong to the tissues, like reflection and colour, are not present in the visualisation either. A solution to improper reflection would be to give the materials in the mesh of the visualisation the correct properties. These visual properties would have to be added to the dataset. For colour however, this is not necessary, as one key property of the visualisation is that it makes it easier to separate different types of tissues.

Another disadvantage of virtual dissection is the resolution and noise inherent to discrete data. The dataset used in this paper is fairly noisy and of low resolution. Although efforts where made to decrease this noise and enhance the perceived visual fidelity, it is quite evident that this visualisation is not equivalent to the experience you achieve when dissecting a physical frog. However, the data is not the only limiting factor. What also needs to be taken into consideration is the device that is used to display the data. This device not only needs sufficient computational power to display the 3D meshes, but it also needs to analyse the video it is making with its camera and recognise the position of the marker (as described in 2). These disadvantages may become smaller in the future when the resolution of data and performance of the devices used to display this data increases.

Moreover, the visualisation is only available in two ways; it can be visited on the internet, or be run locally. This means that either an internet connection is required or one needs to have sufficient knowledge of running a local web server. The former is of course preferred, as the latter may be too difficult for an end user.

4.1 Future works

There are several features that could be added to the visualisation to make it better. For example, should the need arise as internet accessibility is less then expected, the application could be provided as an executable. This would enhance accessibility without making the application too difficult to use.

Secondly, more interaction could be added to the visualisation. Especially interaction for touch enabled devices like pinching and rotating could be added to the controls. These would then zoom and rotate the meshes in the visualisation respectively. Interactivity through hand controllers could also be added to the VR part of the visualisation. Added intuitive interactions would greatly improve usability, increase educational value, and make the visualisation more fun to use.

Thirdly, tooltips could be added that display extra information on what each of the visualised components is and what it does. Currently, when a user wants to know what organ a specific part of the frog is, he or she has to make a guess and change the colour of organs to see which organ it is. The proposed tooltips would not only solve this problem, but also introduce a way of integrating more information into the visualisation.

Lastly, other tools like clipping/slicing planes could be added. This would make it possible obscure parts of the visualisation and view one layer of the frog more precisely. However, this would need a change in the pipeline described in section 2, as separating or sampling a mesh along a plane is currently very difficult to do dynamically.

4.2 Conclusion

This paper has explored possibilities to create a way for animal dissection to be replaced (see the website) by a visualisation. A new way of visualising educational data has been created, and its usability analysed. In this respect an interactive augmented reality frog was developed, usable across devices, and accessible throughout the world. The ease and possibilities arising from these methods bring a myriad of applications with it that could make it useful not only for the exploration of frog anatomy, but also for all anatomical purposes, or maybe even for purposes transcending the biological field spreading to chemistry or physics. But for now, at least, the frogs can rest assured.

References

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