School of Computing

UNIVERSITY OF LEEDS

COMP5200M Scoping and Planning Document

Student Name: Aayush Verma

Programme of Study: MSc. High Performance Graphics and Games Engineering

Provisional Title of Project: High Performance Volume Rendering

Name of External Company (if any)**:**

Supervisor Name: Dr. Hamish Carr

Type of Project: Exploratory Project

NOTE to student*: ensure you have discussed the content with the supervisor before submitting this document to Minerva. Submit an* ***electronic version*** *of this report in pdf via the appropriate link in Minerva; with filename of the format <surname><year>-SP (e.g. SMITH15-SP.pdf).*

Signature of Student: Aayush Verma	**Date: 26 March 2021**

Contents

1. Background Research for the project

1.1 Context

Rendering an image or a model on the screen from a 2D or a 3D model data is the cornerstone of computer graphics. The renders that we usually see in a game or an animation movie are generally achieved by surface rendering. In surface rendering, only the interaction of light with the material at the surface is computed. Features such as reflection, texture and translucency are focused upon rather than what information it holds in 3D space, thus missing out on the level of detail that is important in scientific and engineering visualization.

Volume Rendering is a set of techniques by which a 3D model dataset can be viewed on a screen, i.e. a 2D projection [1]. The 3D dataset for volume rendering may be acquired from medical imaging devices like MRI and CT scan so that the collected data is precise and informative. The visualization of these 3D datasets are made of voxels (volume-pixels), and each voxel contains data that is important for research and analysis.

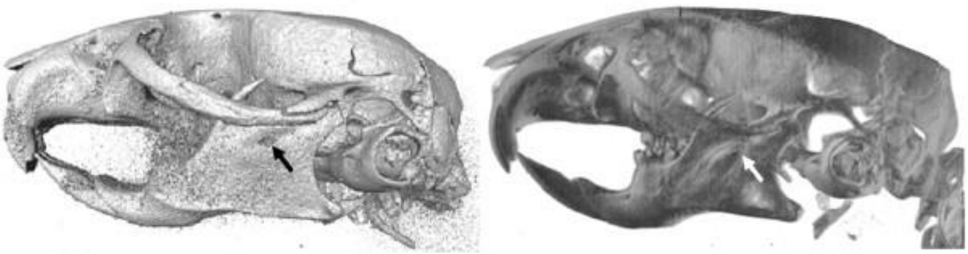


Fig.1: Surface Render of skull (left) versus Volume Render of skull (right) [2]

The arrow points to the lower jaw which is visible on the right image.

1.2 Problem statement

Volume rendering lets us visualize 3D datasets. These datasets are either a structured mesh (ordered by indices) or an unstructured mesh (unordered, associated with neighbouring nodes). Also, these datasets can be substantial in size. Rendering a large, unstructured mesh dataset is computationally very expensive, which directly affects the frame rate of the render. Therefore, achieving interactive frame rates for rendering these meshes is a significant challenge.

1.3 Possible solution

Performance of volume rendering is our main concern in the scope of this project. We shall achieve this by using a combination of optimisation techniques, namely, Space Skipping [3, 4] and Adaptive Sampling [3, 5], also with the utilisation of the GPU to accelerate the ray-tracing process [6].

1.4 How to demonstrate the quality of the solution

The rendered images, before and after the optimizations, should look the same and there should be an increase in the number of frames per second (fps) for the unstructured volumes.

2. Scope for this project

2.1 Aim

To increase efficiency and reduce the computational cost of rendering unstructured 3D models by using combinations of optimization rendering techniques and leveraging the GPU's ray-tracing capabilities.

2.2 Objectives

- Study direct volume rendering in unstructured mesh grids.
- Explore various visualization and optimization techniques to render unstructured meshes. Focus on: Space Skipping and Adaptive Sampling
- Take advantage of GPU's ray-tracing capabilities to increase performance.
- Work out a combination of optimization techniques and hardware acceleration to improve frame rates.

2.3 Deliverables

- Project Report
- Code for the implementation with a Readme file for installation instructions.

3. Project schedule

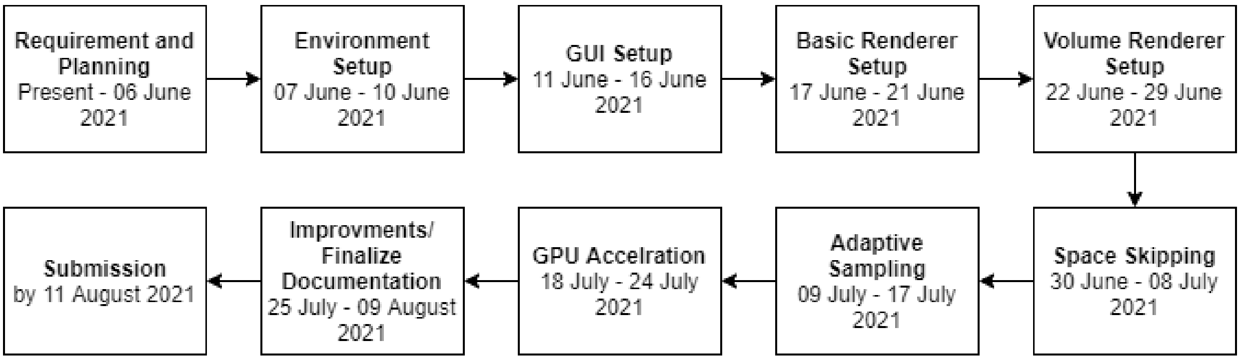
3.1 Methodology

Software Development Lifecycle: Iterative Model.

The steps involved in the methodology will be:

1. Get the renderer up and running.
2. Collect an appropriate dataset.
3. Efficient Space Skipping: Transparent voxels in the mesh are ignored for computation, thus decreasing the cost of computation.
4. Adaptive Sampling: It takes fewer samples of areas in the model where there is not much of a variation.
5. Take advantage of GPU's raycasting capabilities.
6. Document and testing and research.

3.2 Tasks, milestones and timeline



References

[1] NVIDIA Developer. Chapter 39. Volume Rendering Techniques [Online] Available from: https://developer.nvidia.com/gpugems/gpugems/part-vi-beyond-triangles/chapter-39-volume-rendering-techniques

[2] Schunke, Anja & Bromiley, Paul & Tautz, Diethard & Thacker, Neil. (2012). TINA manual landmarking tool: Software for the precise digitization of 3D landmarks. Frontiers in zoology. 9. 6. 10.1186/1742-9994-9-6. Available from: https://www.researchgate.net/figure/Differences-of-surface-rendering-and-volume-rendering-Two-different-representations-of_fig1_223961728

[3] N. Morrical, W. Usher, I. Wald and V. Pascucci, "Efficient Space Skipping and Adaptive Sampling of Unstructured Volumes Using Hardware Accelerated Ray Tracing," *2019 IEEE Visualization Conference (VIS)*, Vancouver, BC, Canada, 2019, pp. 256-260, doi: 10.1109/VISUAL.2019.8933539.

[4] Hadwiger, M, Al-Awami, AK, Beyer, J, Agus, M & Pfister, H 2017, 'SparseLeap: Efficient Empty Space Skipping for Large-Scale Volume Rendering', *IEEE Transactions on Visualization and Computer Graphics*, vol. 24, no. 1, pp. 974-983. https://doi.org/10.1109/tvcg.2017.2744238

[5] S. P. Callahan. Adaptive visualization of dynamic unstructured meshes, 2008.Available form: https://core.ac.uk/download/pdf/23798985.pdf

[6] S. Parker, M. Parker, Y. Livnat, P. -. Sloan, C. Hansen and P. Shirley, "Interactive ray tracing for volume visualization," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 5, no. 3, pp. 238-250, July-Sept. 1999, doi: 10.1109/2945.795215.

Appendix A. How ethical issues are addressed

This is a University requirement. See Resources on 'Ethics relevant to computing projects' for guidance and discuss it with your supervisor. If no ethical issue is involved, a sentence to that effect will suffice.

“No ethical issue is involved.”