Medical Visualization Final Assignment 2019
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Improving the visualisation by combination of surface rendering, volume rendering and non-photo-realistic pipelines for medical education and surgical planning

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Abstract

This work aims at improving the quality of the rendering of medical images by combining multiple existing visualisation pipelines and utilising the benefits of each pipeline. This scheme was developed using segmented medical volume data. Along with the combination of the different pipelines, information about the anatomical axes was also added to the visualisation to help the medical professional understand the bearings of the object of interest with a better clarity. Another feature which was added to the visualisation was the interactive colour picker and isosurface extractor which made the visualisation more appealing and flexible with the choice of object of interest. This was achieved and developed in MeVisLab by developing a macro which was capable of performing all the aforementioned tasks.

1. Introduction

Volume rendering and surface rendering are the two most widely used visualization techniques that is used for medical applications. Rendering of CT and MRI medical images are very popular and are used extensively for diagnostic and medical training purposes. Recently there has been a trend to use non-photorealistic rendering techniques as it makes some of the features more prominent and helps in better emphasizing of the selected structures.

Direct Volume Rendering presents a very good representation about the true nature of the anatomical structure but it has an inherent shortcoming that with DVR techniques it is very difficult to visualise a part of the volume with high level of details without making the visualisation pipeline very complex. Surface rendering or indirect volume rendering address this issue very well by rendering of the subject of interest with great details by converting the volume data into representational polygon data-points from which a surface is rendered very accurately. But the surface rendering is also not free from its shortcomings. The surface rendering while on one hand results in quite impressive visualisation of a selected structure it is usually pretty difficult to get anatomical context to the visualisation without making multiple surface visualisation thereby increasing the computational load significantly. It is a general rule of the thumb that if a fast visualisation is required without performing much action on the dataset at hand volume rendering is preferred and if a detailed visualisation of a certain part of the medical data is to be seen surface rendering is preferred. The combination of the two type of the visualisation pipeline provides anatomical context as well as detailed rendering of the dataset. One problem generally arises when the combination of the two visualisation techniques is employed to render data. The transparency of the volume visualisation causes visual cluttering and the loss of the details to some extent in the final visualisation. To fix this problem, the authors present a pipeline which addresses this.

The proposed visualisation pipeline for this work is a combination of 3 techniques, which are direct Volume Rendering, Indirect Rendering and Non Photorealistic Rendering. The non-photorealistic rendering is done with the help of the generation of silhouettes. The generation of the silhouettes help us in overcoming the problem of the visual clutter which leads to loss of information in the rendering. In this work, the direct volume rendering is generated using the maximum intensity projection method and the surface rendering has been performed with marching cubes algorithm. In order to enhance the information content of the visualisation, anatomical planes have been added to the final visualisation which helps the medical professional to locate better the anatomical axis of the subject of interest. In order to make the rendering more appealing, an interactive colour picker has been added which provides the end users to change the colour of the visualisation according to individual preference. Along with that an iso-surface selection field has also been provided wherein the users can put their choice of ISO-values to visualise different structures. This was done in MeVisLab by developing a user defined MACRO wherein all these functionalities were added.

2. Related Work

In our literature survey we found out many hybrid visualisation techniques which were trying to address the shortcomings of individual visualisation pipeline. Tietjen et al [TIP05] proposed a method to combine volume rendering, indirect volume rendering pipeline and line based non photorealistic rendering pipeline which inspired our work. This proposed method came up with a clear final rendering with the help of the non-photorealism which helped in avoiding visual clutter that results in direct volume rendering. Bruckner et al [Bru08] in his work came up with a solution to utilise the simple pipeline of direct volume rendering and improved the visual information content by creating an interactive illustration from the direct volume rendering. Hadwiger et al [HBH03] developed an adaptive extraction and visualisation technique from volumetric data. In this method the authors try to come up with a visualisation which has the right mix of aestheticism using NPR techniques and realism using DVR technique. Initially a tri-variate B spline function is used to represent the volume data from which a subdivision system is implemented to generate a non-photorealistic illustration. Csebfalvi et al [CM01] came up with a fast method to generate illustration from volumetric data. This method avoids the time consuming method of transfer functions and implements illustrative rendering by tuning of very few parameter. Zolt et al [ZSW02] in their work came up with a solution to generate a line rendering to augment the traditional volume rendering results. They use MIP based volume rendering to generate the initial rendering and then utilise the gradient information from the viewing angles to generate the non-photorealistic boundaries.

3. Proposed Method/Visualisation Design

The visualisations generated in this project was the result of the combination of 3 visualisation techniques. Through the combination of the different visualisation pipelines the author generated a visual representation of the volume data with anatomical context and without information being lost to visual clutter. The pipeline consists of a marching cube based surface rendering technique which is use to highlight the detailed information of a particular surface. Anatomical context was retained by the generating a volume visualisation using the maximum intensity projection technique and the information about the surface inside the volume rendering was preserved with details through silhouette based non-photorealistic technique.

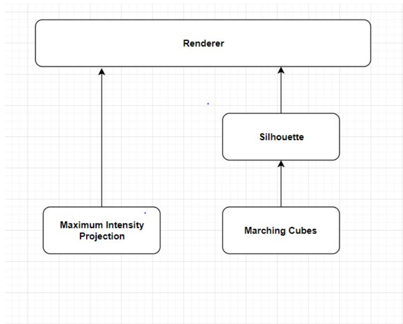

Figure 1: *The proposed visualisation pipeline*

3.1. Marching Cubes based Indirect Volume Rendering

Marching cube algorithm is a famous algorithm which is widely used to render surfaces using the 15 unique surfaces utilising the symmetric nature of the cube. The connection of the unique surfaces inside two adjacent cubes is determined on the basis of coherence, i.e, whether the closed structure which is formed by joining the 2 surfaces form a free flowing structure and doesn't lead to any very abrupt changes in the surface configurations. To generate a surface from a volume data the data-points are mapped to polydata points which is used to render the surface structure.

3.2. Maximum Intensity Projection based Direct Volume Rendering

The volume rendering was done using ray casting and the composting of the data was done with Maximum Intensity Projection algorithm which collects the maximum value along a unique raycast and the volume information is generated using all the maximum intensities collected from all the rays traversing the volume segment.

3.3. Silhouette based Non-Photorealistic Rendering

This non-photorealistic technique uses the gradient information and the surface normal to generate silhouette lines. Silhouette like other non-photorealistic techniques increases the aesthetic value of the final rendering. Here in this project, silhouettes are used to perform another very important function which is to counter the effect of rendering a surface inside the volume rendering. If the rendering is done without the silhouettes due to the transparent nature of the volume rendering the object inside the volume rendering gets obscured and the silhouettes are used to highlight these features.

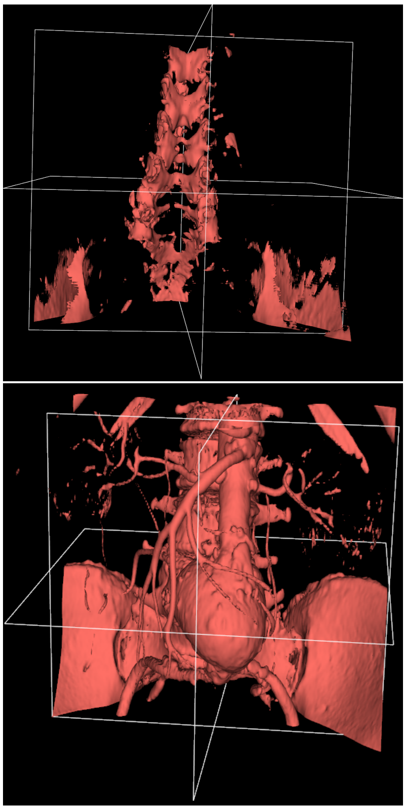

Figure 2: *Indirect Volume Rendering of the object of Interest with ISO value of 900 (Top) and 200(Bottom)*

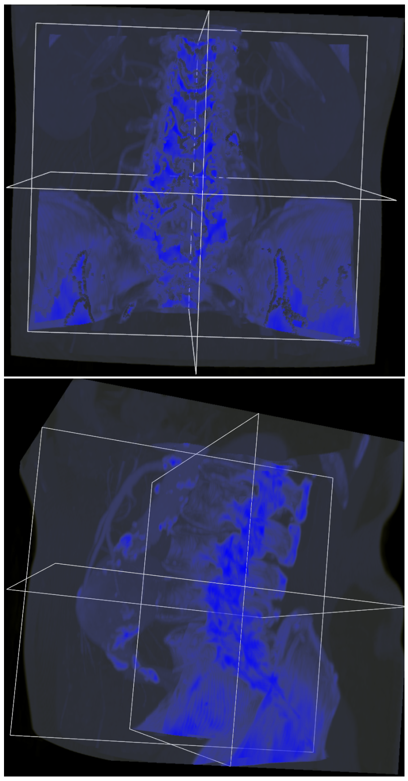

Figure 3: *Direct Volume Rendering of the abdominal region along with the anatomical structures and aneurysm*

4. Implementation

The implementation has been carried out on MeVisLab which is a hybrid graphical/text based programming environment. The development of the three pipelines is done using the python scripting feature of the Integrated Development Environment (IDE). The generation of each of the pipelines involves the combination of the numerous classes, objects and functions which are derived and utilized from Visualization Tool Kit (VTK) system which are subsequently combined to form a macro that performs the operations of all the pipelines. The medical data used to test the effectiveness of the proposed technique is the CT scan of a patient suffering from Aortic aneurysm in the abdominal region. 3D rendering of the abdominal aortic aneurysm along with the lumbar spine is performed using the inbuilt VTK renderer module which is an interactive Graphical User Interface.

The IVR of the medical image used for the generation and visualization of the surface of the object of interest is developed using Marching Cubes algorithm, geometry filter, mapper, actor and renderer as shown in Figure 2. The choice of the selection of the object of interest is based on isosurface value. The DVR of the chosen medical data involves the use of Mapper, Actor, Renderer, MIP Ray Cast function and transfer functions namely opacity, gradient and color as shown in Figure 3. One of the aforementioned parameters are varied to determine the suitable values that result in the most efficient and aesthetically appealing volume visualization. To render the scene using silhouette, active camera oriented in specific direction that depicts the object of interest is included as shown in Figure 4. An interactive isosurface extractor has been developed to enable the user to dynamically vary the iso value which results in the development of a desired object of interest. To enhance visualization of the extracted object, an interactive color picker is incorporated as shown in Figure 5 and its output is as shown in Figure 6. Additionally, the anatomical axes information is included through the development of the plane widgets which are mutually orthogonal.

5. Results

The final renderer works effectively portraying the three visualizations as shown in Figure 7. The interactive GUI successfully enables the user to dynamically alter the color and iso value for better visualization. It was observed that bright colors which are in contrast with that of the illustrative vol-

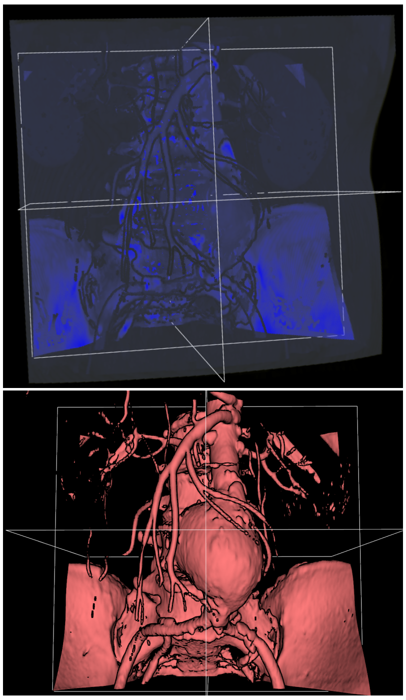

Figure 4: *Silhouette based Non-Photorealistic Rendering*

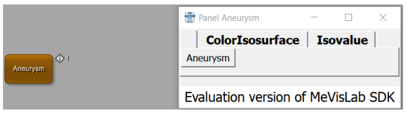

Figure 5: *Aneurysm Macro module (left) and the corresponding Aneurysm panel with ISO value extractor and color picker tabs*

ume of the anatomical image were needed to be used to be able to effectively differentiate the object of interest from the background. The lumbar spine is clearly visible for relatively higher iso values and the aortic aneurysm can be clearly seen with lower iso values. The anatomical planes have been a very an important feature to distinguish each of the regions. NPR using silhouette successfully suppresses the visual clutter.

6. Conclusion and Future Work

As mentioned in the introduction, the objective of this project was to improve the quality of the rendering of medical images by combining and utilising the benefits of surface, volume and non-photorealistic rendering pipelines. A portion of the lumbar spine along with the hip bones can be clearly visualized and so are the rest of the anatomical structures through direct volume rendering. Silhouette and anatomical planes enhance the visibility and information of the object of Interest. The dynamic color picker and ISO value extractor features also work effectively. At the end, we can conclude that our visualization occurs to be very promising with respect to intuitiveness and clarity for students, teaching professionals and doctors. Although, the goal of the project has been achieved, there is a great deal of work needs to be done in the future to overcome some of the limitations and improve the quality of the visualization through inclusion of multiple other features. In this project only one object is developed through surface rendering. In the future multiple ISO surface extractors can be developed to select multiple objects as per the user's liking and so with the choice of color for each of the objects. The tri-pipeline technique can be tested on multiple other medical datasets to examine its performance and effectiveness with the change of image format. Glyphs which result in surface normal projections can be incorporated to represent direction and magnitude of the vector field in case of blood flow or to depict the vector attributes such as temperature, pressure or density.

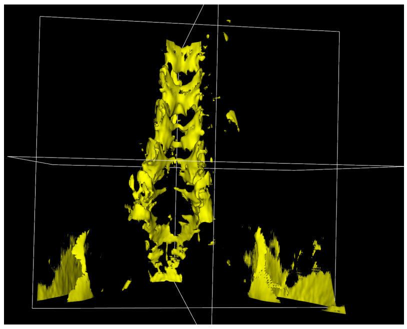

Figure 6: *Object extraction and visualization through color and ISO value selection*

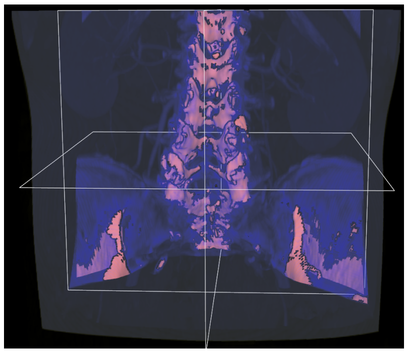

Figure 7: *Final Visualization*

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