Collaborative Web-Based Merged Volumetric and Mesh Rendering Framework

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Abstract. In this paper, we present a novel web-based collaborative data visualization approach combining the output of multiple rendering methods into a final seamless merged visualization. We have extended an existing web-based visualization framework Med3D with support for additional visualization plugins and an option for merging the outputs into a seamless final visualization. Such an approach allows users to place the anchors of 3D pinned annotations into volumetric data by ray casting mouse position to selected mesh geometry. The presented web-based collaborative volumetric data visualization framework is to the best of our knowledge the first of it's kind using state-of-the-art volumetric rendering system.

Keywords: Collaborative rendering · Volumetric rendering · WebGL 2.0 · Web-based rendering

1 Introduction

With the development of new technology, visualizations are becoming crucial in real-life decision-making activities. Most of us are making decisions based on different data visualizations displayed on our hand-held devices (e.g. checking the precipitation forecast, using navigation etc.). Moreover, we are also often discussing our decisions based on such visualizations with our friends, coworkers, and others through chat, video call or other means of communications. While many joint decisions are important for us, in some cases they are particularly important (e.g. the second opinion of a doctors decision). To make such decisions possible the collaborating party has to have a good insight into the discussed data and also the ability to share each others' view of the data as well.

Such scenarios are common in many areas; from the medical field to constructions, architecture, smart city infrastructure, military etc. An example from medical field are Multidisciplinary team meetings, which are a standard of care in modern hospital-based clinical practice for safe, effective patient management [2]. An information sharing framework for medical team meetings is presented in [4].

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While most of such solutions offer to share of files containing documents, images or radiological data. Participants can also communicate via audio and/or video connection. Even though the discussion of the content of documents and images works well with the presented solution, it might be hard to show to other participants what exactly to look for in the imaging data. This is even more true in case of 3D radiological data (such as computed tomography- CT [1,3], magnetic resonance imaging - MRI [13], ultrasound - US [5] or positron emission tomography - PET [12]).

Some solutions already offer the use of web technologies for visualizing 3D medical data in the browser during the sessions, which can be achieved using A* Medical Imaging (AMI) Toolkit [11]. One of the downsides is that the visualization of the data does not use state-of-the-art volumetric rendering capabilities as are available in offline tools such as Exposure Render [6] or in online tools such as Volumetric Path Tracer [9]. Another downside is that individual users do not share the same view of the data. Also, in some cases, such a solution requires high network throughput due to the use of video streaming functionalities to display the individual's view to other participants. This was addressed in [7] with sharing the view with other participants in the session without streaming, and additionally with support for 3D annotations pinned to specific places in 3D models and in [8] with view-aligned annotations overlaid over the visualization of 3D models, the presented solutions are limited to the visualization of mesh geometry 3D models only.

In following sections of this paper, we present an extension of web-based real-time visualization framework with state-of-the-art volumetric rendering capabilities presented in [9] and is intended for sharing 3D visualizations with other collaborators via web-browser as presented in [7,8] allowing the users to add 3D pinned and view-aligned annotations to the direct volume rendering of radiological data. The rest of the paper consists of the presentation of used and developed methods in Sect. 2, the presentation of implementation results in Sect. 3, and the final conclusions and pointers for future work are presented in Sect. 4.

2 Methods

To achieve the presented goals, we make use of the already existing frameworks Med3D [7] and VPT [9], shortly presented in the following subsection. Next, we present the integration and extension of both frameworks: (1) system design outline, (2) data sharing, (3) view and rendering parameters sharing, and (4) merging the rendering outputs.

2.1 Med3D and VPT

Med3D is a web-based visualization framework with customizable rendering pipeline, where individual steps in the pipeline can be individually defined (e.g. mesh rendering, annotation rendering, 2D overlay etc.). As such it is a great base for developing a visualization system where we want to combine different visualization techniques for final image output. The framework supports loading mesh models (in OBJ format) and volumetric data (in MHD/RAW format) as well as conversion from volumetric to mesh data using Marching cubes [10]. The framework also allows the users to add two kinds of annotations to the scene: (a) 3D pinned annotations anchored to a specific point on 3D mesh model and (b) view-aligned annotations drawn by the user over the displayed data visualization displayed in Fig. 1.

Fig. 1. Examples of 3D pinned (left) and view-aligned (right) annotations in Med3D.

VPT is a web-based framework for direct volumetric rendering using state-of-the-art volumetric path-tracing methods. The framework allows users to define their own transfer functions for visualizing data from different domains and acquired using different scanning techniques (e.g. CT, MRI, US, PET). The framework supports the use of different visualization methods displayed in Fig. 2: (a) maximum intensity projection (MIP), (b) ISO surface rendering (ISO), (3) Emission-absorption model (EAM), and (4) Monte-Carlo single scattering path-tracing model (MCS).

For our purposes we used the functionalities of both frameworks and implemented our own extensions for achieving the desired goals.

2.2 System Design

The overall system is designed around Med3D, which was extended to support arbitrary rendering plugins. The output of rendering plugins can be used in one of the steps in the Med3D rendering pipeline. For plugins to create images for final merged visualization the plugins such as VPT need appropriate inputs. In case of VPT, the plugin needs camera parameters so that the view of the data is aligned with the view in Med3D, and the access to the desired data in different modality. The resulting output image from VPT plugin is then merged with internal Med3D rendering. Integration of VPT into Med3D framework is presented in Fig. 3.

2.3 Data Sharing

For collaborative visualization of the data, the data has to be shared with all the collaborating users. Med3D already covers the sharing of mesh-based data,

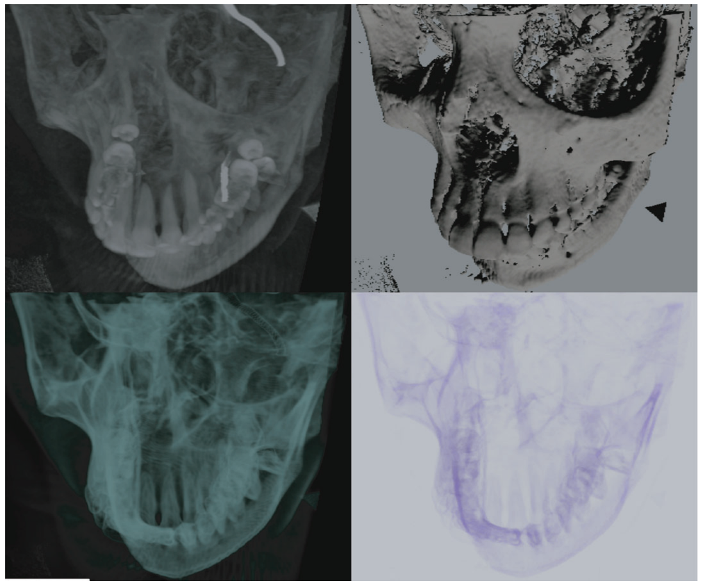

Fig. 2. Examples of different volumetric rendering techniques: (top-left) maximum intensity projection, (top-right) ISO surface, (bottom-left) Emission-absorption model, and (bottom-right) Monte-Carlo single scattering path-tracing model.

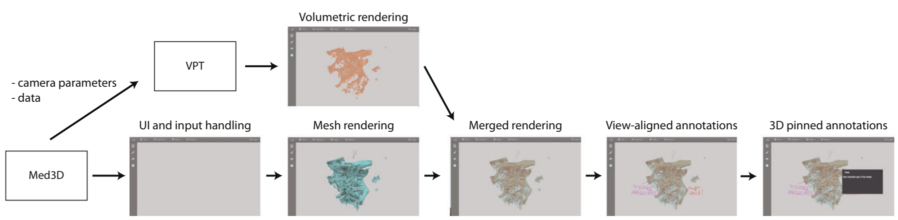

Fig. 3. The figure shows how data is shared between the frameworks and how the outputs are merged and displayed.

it's position and material properties. For collaborative visualization of volumetric data, we had to extend the sharing capabilities with support for binary volumetric data and it's descriptor meta-data. The data was encoded into an appropriate string (depending on the type of data) to include it into JSON description of the shared scene.

2.4 View and Rendering Parameters Sharing

While shared session already enabled view sharing (position and orientation of the camera) we extended the support for sharing visualization parameters as well. Med3D only offered mesh visualization option with predefined visualization properties (lighting, materials, etc.). The additional parameter set includes the selection of volumetric rendering methods (MIP, ISO, EAM and MCS) and their rendering properties. This allows users to share not only data and view properties but also visualization parameters.

2.5 Merging the Rendering Outputs

To achieve the desired goal of merging mesh geometry visualization with volumetric data visualization, we had to extend the existing pipeline with support for merging multiple types of rendering outputs. In this additional step of the pipeline, we take the output of internal mesh visualization and merge it with the output of the VPT plugin. The resulting image is alpha blended visualization where the weight of individual rendering is defined by the user.

3 Results

The first result of the developed framework is an option of merging mesh visualization with volumetric visualization as presented in Fig. 4.

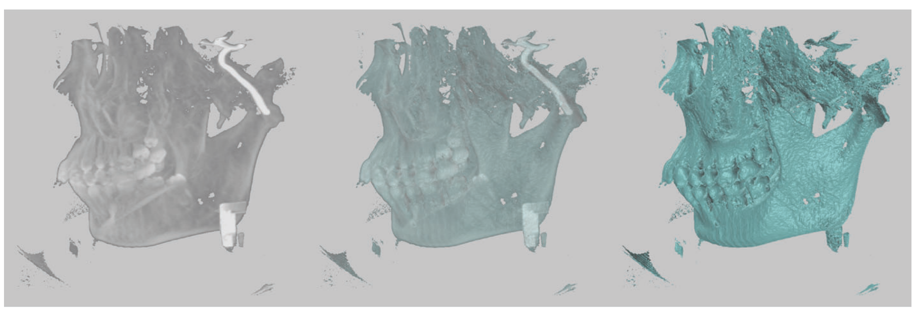

Fig. 4. The result of merging mesh and volumetric rendering with use of different alpha blending option: 100% volumetric rendering - MIP (left), 67% MIP 33% mesh rendering (center) and 100% mesh rendering (right).

The second result is an option of overlaying volumetric rendering output over different mesh geometry. This is presented in Fig. 5 for mesh geometry extracted from volumetric data using Marching Cubes with a different thresholds. This allows users to add 3D pinned annotations on the geometry surface and thus effectively labeling features in the volumetric data.

The third result is an extension of the existing Med3D framework with support for direct volumetric rendering using different techniques and merging it with mesh geometry visualization. Example of such merged visualizations are presented in Fig. 6 where EAM output is merged with mesh geometry visualization.

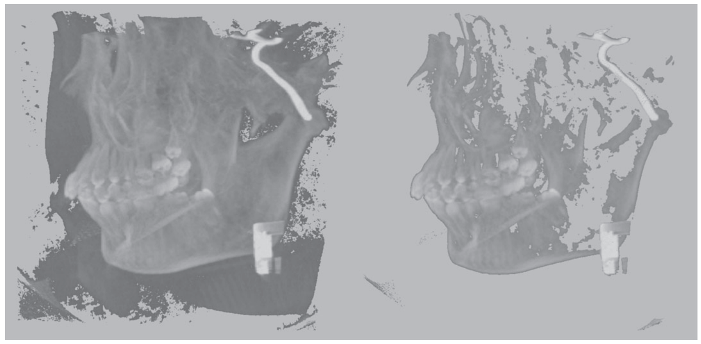

Fig. 5. The result of overlaying volumetric rendering over different geometry: geometry created with lover threshold (right) and geometry created with higher threshold (left).

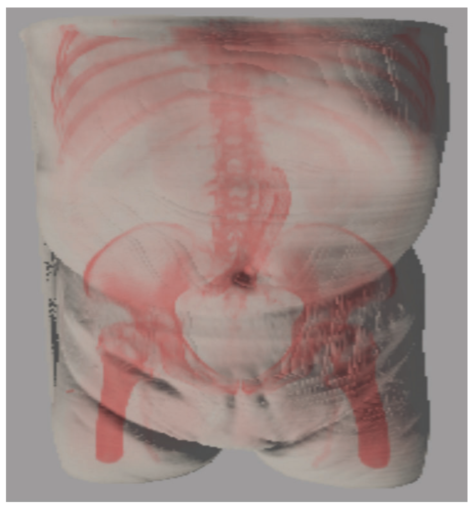

Fig. 6. Emission absorption model rendering overlaid on top of mesh geometry rendering, expressing the bones in the body.

4 Conclusion

In this work, we presented a novel web-based collaborative visualization framework with support for state-of-the-art volumetric rendering methods. The framework also allows users to easily insert 3D pinned annotations directly into volumetric data and share them with other users. An individual user in a collaboration session can individually change the view on the data and/or change parameters of visualization.

In the future, we are planning to further improve collaboration options by integrating voice and video chat into the platform. We also plan to integrate the options for volumetric data segmentation and support for remote rendering capabilities with the use of the state-of-the-art volumetric rendering techniques.

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