Visualizing and Interpreting Volumetric Datasets Using Volume Haptics

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Abstract— **Volume Haptics is used for enhanced visualization and interaction of volumetric data. In this paper, evaluation of VHTK is presented which implements direct volume haptics with proxy based approach. The techniques are tested on medical and geophysical data. Different haptic modes are used that are controlled with transfer functions as parameters representing material properties.**
Keywords: **Volume visualization, Volume haptics**

I. INTRODUCTION

The collection, generation, and interpretation of volumetric datasets are gaining popularities in many applications. Volumetric data contains no explicit surface information which is used widely in the fields of geophysics, medical imaging, geology, and botany etc. However, volumetric data is somewhat difficult to interpret as it represents complex structure or arrangements of attributes that vary in various subtle ways. The current interpretation of 3D datasets is done by extracting and rendering of surfaces that represent singular intervals and contour values. This method is not able to fully visualize different features, properties, and trends in the data.

The term "haptic" comes from Greek which means to touch or tangible. It offers the opportunity to "feel" and add the sense of touch to the computer generated 3D data. Volume haptics provides haptic interaction with volumetric data to find and follow different shapes, features, or directions that are contained within the data [1].

The project investigates how volume haptics is applicable to provide improved interpretation of scientific and research datasets. Testing and opinions by researchers in related area are gathered to give recommendation on ways for using the equipment and relevant software for enhanced scientific visualization and interaction. Medical (MRI and CT scan) and geophysics (Seismic) data are used for the evaluation.

II. SYSTEM SET-UP

A. Volume Haptics Toolkit

The Volume Haptics Toolkit (VHTK) is aimed at providing haptics for volume data exploration interfaces and understanding processes [1]. The implementation is based on using H3D API from SenseGraphics which is an open source and cross platform scene graph system for 3D graphics, haptics, and sound multimodal applications. The structure of the system is based on X3D, an XML based scene graph and virtual reality world definition file format, which is also used as a standard for loading and exporting scenes [2].

VHTK extends H3D by adding nodes that provide haptics functionality for interaction with volumetric data. These different nodes are haptics nodes, visualization nodes, data container, and processing nodes that are developed in C++ language. These low level programming nodes are to be used with X3D and Python to handle its different behavior in the scenes. It allows a programmer to extend the toolkit further by using the combination of the languages used. Moreover, X3D comes with an event handling system which allows VHTK to bring run time updates due to the changes in the scene graphs [2].

B. Processing Pipeline

Volume data is read and interpolated at the local position of the haptic probe. It is then processed to extract a local feature such as gradient vector or vector curl. Transfer functions are used to generate different material properties. For example surface friction and strength. Both the local feature and material properties are used to control haptic primitives that are mapped to calculate the final force feedback. Finally, the force feedback signal is sent to the haptic device typically at a rate of 1 KHz [3].

III. METHODOLOGY

A. Direct Volume Haptics

There is a challenge to generate volumetric data's haptic feedback that is commonly generated by using surface data. Volumetric data does not have explicit surface information thus certain processes are required in order to give the required haptic feedback. The traditional approach to solve this problem is to extract surface data using thresholding in a pre-processing step or to extract an intermediate local surface in real time. However, this limits the haptic feedback to be generated only by a predefined subset [3].

Direct volume haptics is a method that renders a continuous haptic information field through out the entire volume [3]. It aims to allow free exploration by not allowing occlusion from distinct surfaces in the data and provide haptic representation

of the data at any position in the volume [2]. There are two approaches to implementing direct volume haptics. These are force function-based and proxy-based.

The force function-based approach calculates the force feedback between the haptic probe and the active point of the haptic device as a vector valued function [3].

The proxy-based approach has a scheme that uses two representations of the probe. The probe is the haptic device that is directly affected by force feedback while the internal proxy is controlled by the algorithm within the code. For each time-frame of the haptic loop the force feedback is calculated by collecting data at the local position being probed, using the data to specify proxy movements and calculating force feedback from proxy displacement relative to the probe [3].

B. Haptics primitives

The implementation of haptic primitives improves the method of proxy-based volume haptics. It forms a comprehensive layer of interaction schemes and gives an effective feedback calculation. The method uses one, two, and three degrees of freedom that are represented as plane, line, and point as the constraints. There is also directed force primitive which contains active forces or any other forces functions. Force feedback is then calculated by using superposition of these four primitives. The advantage of this method is that it avoids the requirement of orthogonal constraints which is a shortcoming of the proxy-based approach [3].

C. Haptics modes

Haptic modes are the entities of haptic interaction schemes that are based on the use of haptic primitives. By selecting which haptic primitives are used and controlling the parameters, different modes of haptic interaction can be achieved. It also implies that different haptic modes can be used together since the use of different haptic primitives is allowed inside a haptic mode [3]. The available haptic modes that come with VHTK are: viscosity mode, gradient force mode, simple force mode, vector follow mode, vortex tube mode, and surface and friction mode. The relevant haptic modes that are used with the data in this project are Surface and Friction mode, and Vector Follow mode.

The vector follow mode guides the user via haptic instruments in the direction of the vector field by providing resistance that is oriented orthogonal to the vector field. It implements the haptic line primitive where the normalized vector value is used as direction and transfer function is applied to define the strength [3].

Surface and friction mode makes use of plane primitive to provide surfaces which are directed by the normalized gradient vector. Primitive lines are used as the implementation to calculate the strength and friction which is managed by transfer functions. Thus, it gives consistent haptic feedback

simulation of surface and its frictions [3].

IV. IMPLEMENTATION

A. Graphic rendering

Seismic data typically comes in the form of 32 bit of floating data. The color scheme is commonly arranged so that the negative values appear in red color, the positive values have blue color, and the whites represent zero values.

As suggested in [4], datasets need to be classified in order to give better quality of both graphic and haptic rendering. Karlu stated that data container in VHTK is divided into samples and field in which sampled data is required by the volume renderer [5].

The scalar local features of seismic data is extracted using transfer function that maps negative and positive voxel values into 0 and 1. This need to be done in order to follow the mapping of RGB color functions in VHTK.
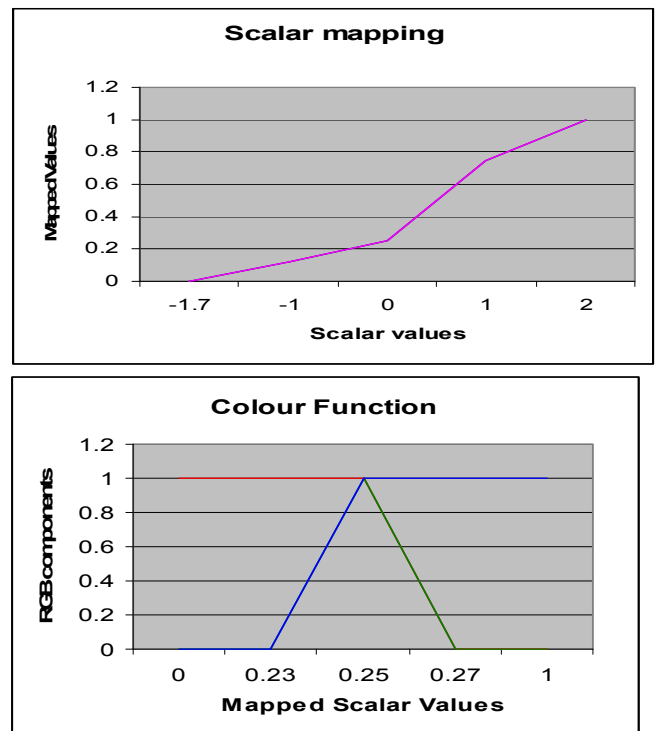

Fig. 1 Scalar and color mapping for seismic data

On the other hand, medical data generally contains 16 bits of integer data per voxel. The data is not restricted in a certain color scheme. The applied color scheme to the heart data is similar with cortex color template that comes from MRICro. Gold color template that is also taken from MRICro is used with the human body data. The opacity is tuned to delete the black volumes which are typically the dominating color inside MRI or CT scan data.

Plotting dot points is enabled by using the main button of

the haptic device. This additional feature is added into the scene graph visualization to allow track recording while exploring the data.

B. Haptic rendering

The haptic modes applied with MRI and CT scan data are Surface-and-Friction mode and Vector-Follow mode. The parameter that defines the material properties of strength, friction, and distinctness are mapped using tuned piecewise and window transfer function. In spite of using pre-defined vector data that represents different feature of the data, the vector-follow mode is used with vector data that are extracted from the scalar data using one of the built-in VHTK function. Padding image option is turned off since it raises haptic device failure rate while it is supposed to give better haptic representation by removing holes in the data. In addition, toggle mode option is enabled as additional feature which allows changing different haptic modes.
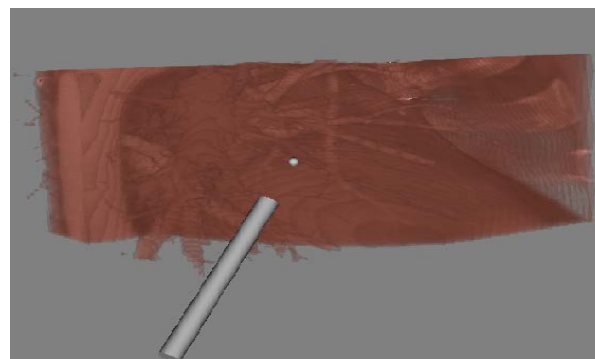
The seismic data is applied with the same haptic modes of Scalar Surface and Friction and Vector Follow mode as in medical data. The difference is that constant function is used rather than piecewise or window functions as the transfer mapping method to define material properties of strength, friction, and distinctness. Seismic data should not present different densities between its layers. The constant value gives consistent and gentler feedback on each surface represented within the data.

V. RESULTS AND DISCUSSION

The haptic feedback generated from surface friction mode provides different force feedback between different tissues inside medical data. It also differentiates materials properties. Objects with higher pixel values such as bones or skin generate more force feedback compared with other thin layer objects. On the other hand, the Surface and Friction mode allows user to palpate through different surfaces within the seismic data. As constant function is used for each material property, every object produces the same force feedback. In addition, placing dot point features also enable user to give record on data exploration as shown in Figure 3.

Vector Follow mode somehow does not guide the haptic device in the right direction. It is believed that the vector is not converted as having the intended direction or field represented as in the visualized image. The hidden vector generated can be seen by applying stream ribbon functions which generates ribbons that represent the surrounding vector fields within the data.

(a) CT Scan of human heart using cortex color scheme

(b) MRI data of human body focused on kidney using gold color scheme

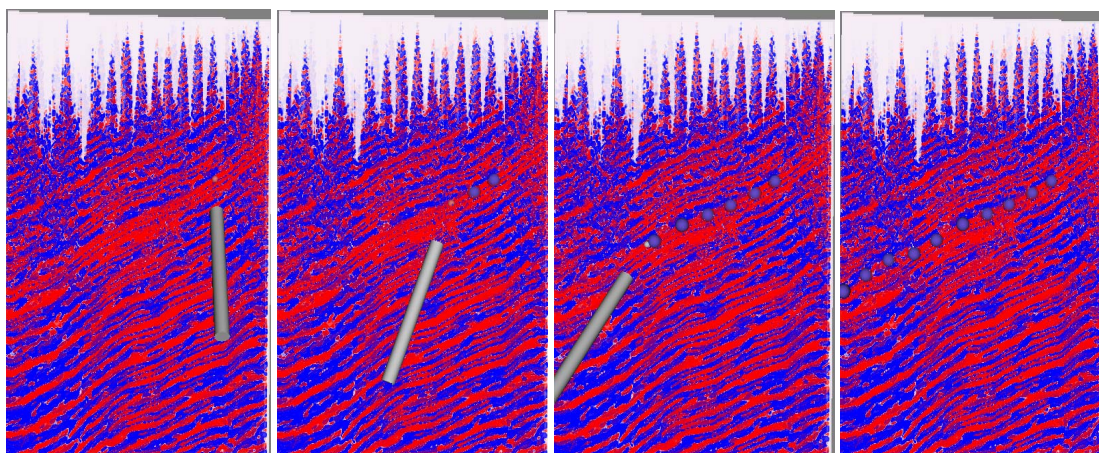Fig. 2 Rendering and haptic interaction of medical data set

Fig. 3 Placing dot points to track record in seismic data

VI. CONCLUSION

The usage of direct volume haptic enhances data visualization and exploration in volumetric data. Using VHTK as the implementation tool, the medical and seismic data are rendered as required, providing recognizable interpretations of typical data that are used within the corresponding field of study. Surface and Friction mode and Vector follow mode provide sufficient haptic feedback to help understanding the data. Although Vector Follow mode does not seem to guide user in the correct manner, it somehow helps user to palpate through different objects when it is used with Surface and Friction mode. Moreover, the Surface and Friction mode is able to generate feeling of different tissues within medical data that improves visual interaction of the volumetric data.

VII. FUTURE WORK

There are still many issues to be addressed in the usage of Direct Volume Haptics. VHTK provides many tools for handling vector data that provide range of different haptic modes. It also allows the generation of animations that would enhance data interaction. In seismic data, the ability of placing dot points can be the start of generating a specific surface which is a typical method of analyzing this type of data.

As stated in previous sections VHTK is based on H3D which provides flexibility to extend its features. For example, it would be helpful to design a generic user interface which enables selection of images, haptic modes, and specifically different tuning of transfer function.

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