NIVR: Neuro Imaging in Virtual Reality

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ABSTRACT

Visualization is a critical component of neuroimaging, and how to best view data that is naturally three dimensional is a long standing question in neuroscience. Many approaches, programs, and techniques have been developed specifically for neuroimaging. However, exploration of 3D information through a 2D screen is inherently limited. Many neuroscientific researchers hope that with the recent commercialization and popularization of VR, it can offer the next-step in data visualization and exploration.

Neuro Imaging in Virtual Reality (NIVR), is a visualization suite that employs various immersive visualizations to represent neuroimaging information in VR. Some established techniques, such as raymarching volume visualization, are paired with newer techniques, such as near-field rendering, to provide a broad basis of how we can leverage VR to improve visualization and navigation of neuroimaging data. Several of the neuroscientific visualization approaches presented are, to our knowledge, the first of their kind.

NIVR offers not only an exploration of neuroscientific data visualization, but also a tool to expose and educate the public regarding recent advancements in the field of neuroimaging. By providing an engaging experience to explore new techniques and discoveries in neuroimaging, we hope to spark scientific interest through a broad audience.

Furthermore, neuroimaging offers deep and expansive datasets; a single scan can involve several gigabytes of information. Visualization and exploration of this type of information can be challenging, and real-time exploration of this information in VR even more so. NIVR explores pathways which make this possible, and offers preliminary stereo visualizations of these types of massive data.

Keywords: MRI, Virtual Reality, Medical Imaging

Index Terms: J.3 [Computer Applications]: Life and Medical Sciences—Medical Information Systems; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, Augmented, and Virtual Realities

1 OVERVIEW

NIVR is a Unity application, designed for the HTC Vive as a room-scale experience. NIVR works with a variety of neuroimaging data formats, pre-processed and restructured to render inside Unity. While some renderings are done wholly inside the NIVR-Unity framework, others also involve pre-rendering frames offline via Autodesk 3DS Max.

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All renderings, regardless of specific pipeline, are direct representations of neurological datasets collected by the Laboratory of Neuro Imaging (LONI) at USC.

1.1 NIVR Environment

NIVR users experience a short introduction and mock MRI scan. Afterwards, the user is presented with a 'Data-Cube' representation of their MRI file(s). The Data-Cube can be manipulated through the Vive controller, and can be placed into one of four 'sockets.' Each socket is labeled, and corresponds to one of the four visualization types later detailed. Once the Data-Cube is placed in a socket, the corresponding neurovisualization modality becomes active. The user can remove the data cube from any socket, and place it into another at any time to visualize the MRI data through another modality.

1.2 Visualization 1 - Volumetric MRI

The volumetric visualization provides natural 3D navigation of MRI scans. The rendering is done entirely inside the NIVR Unity application, and utilizes custom raymarching shaders applied to a volumetric texture constructed from an MRI scan from either an individual subject, or an atlas created by combining many scans. The user can 'slice' the volume with the Vive controller in any direction to better navigate the neural structure. The user is also able to approach the volume, offering an intuitive 'zoom' function. Additionally the user can enter the volume to view it from the inside, as well as adjust the scale, rotation, and opacity of the data. In this manner NIVR offers a natural environment to view structural MRI scans, enabling efficient exploration of the large scale structures to the fine details.

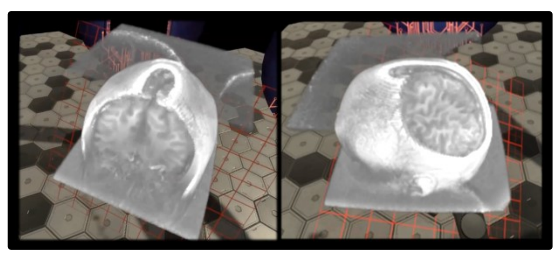

Figure 1: Volumetric MRI visualization in NIVR

1.3 Visualization 2 – Slice-Based Tractography

Recently, progress in the MRI field has enabled us to not only scan neural tissue, as typically done with neuroimaging, but also measure water diffusion. As diffusion is directionally biased in the brain due to the presence of axons or 'wires,' we can physically measure these biases and use them to construct estimates of the brain's many connections, a technique termed tractography.

NIVR enables users to experience tractography data from inside the brain. The information is scaled to room-size, and the user can walk across the anterior-posterior and left-right axes. Vive controllers allow 'elevator-like' navigation of the inferior-posterior axis. Three room-sized planes can be manipulated by the user, each corresponding to a given axis. As each plane transverses an axis, it updates its texture information to portray the appropriate structural tractography information.

This NIVR visualization enables a highly detailed, and physically navigable exploration of tractography data.

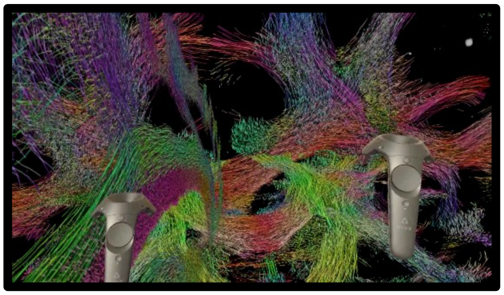

Figure 2: Slice-Based tractography in NIVR

1.4 Visualization 3 – Segmented Neurological Surfaces

Segmentation of a whole-brain scan into neurological components is an ever-evolving practice. The current state of the art enables automatic segmentation of individual scans into 80+ sub-structures through neuroimaging programs such as Freesurfer [2]. We extensively processed and segmented an individual's brain scan and computed surfaces meshes for each segment.

NIVR provides an interactive viewing environment for the segmented surface meshes. Users can interact with the visualization by manipulating/moving any segmented region. As a segment is 'grabbed' via the Vive controller, its neurological label appears in order to inform and guide the user. A menu system enables scaling and detailed options for specific exploration. For example, all cortical areas can be expanded outwards while leaving subcortical areas in place, enabling specific viewing of subcortical structure. Segments are individually colored so users can easily distinguish between them.

The combination of the immersive environment, stereo vision, and interactive brain segments offers a compelling neuroanatomical experience, or 'digital dissection' of an actual brain.

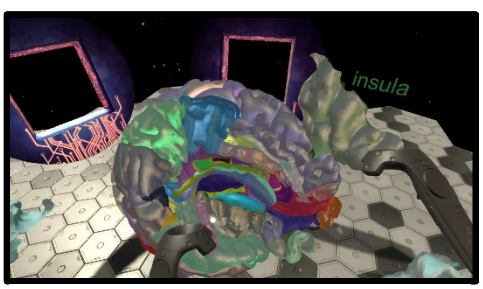

Figure 3: Segmented surfaces in NIVR

1.5 Visualization 4 – Near Field Renderings

While some types of neuroimaging data can be readily rendered in real-time, other neuroimaging scans can involve multiple gigabytes of information. This scale of data can take on the order of an hour per frame to render, and poses extremely challenging to navigate interactively.

In order to represent these massive neuroimaging structures, we've turned to pre-rendering the data structures. Once pre-rendering is complete, we are able to provide interactive data exploration via near-field rendering. The near-field rendering pipeline [1], developed at the USC Institute for Creative Technologies, allows us to stereoscopically view the pre-rendered data structures similar to a live rendering. Users can step towards, away from, and around the data structure, as well as rotate it with the Vive controller.

The application of near-field rendering enables us to surpass many of the boundaries of typical VR applications. For example, we can explore extremely fine details of super-high resolution MRI scans without the boundary of how many vertices, or points, we can render in real-time. This experience offers a striking vantage of some of the scale, detail, and information modern MRI scans can now detect.

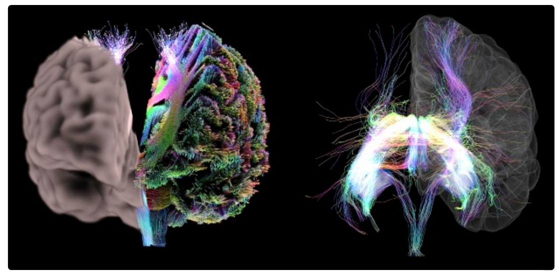

Figure 4: Near Field renderings in NIVR

2 Summary

Neuroscientific data is one of the most challenging and intriguing subjects in data visualization. NIVR is a virtual reality prototype environment to view various forms of neuroimaging data. Our proof of concept dramatically illustrates the superior navigation and conceptual advantages of viewing this complex information in an immersive, stereoscopic context.

While there are novel aspects of each of our visualizations, our immersive tractography experience as well as our neuroscientific near-field experience are particularly noteworthy, as to our knowledge they are the first of their kind. Additionally, NIVR represents the first attempt to encompass several types of neurological data and visualizations inside a single VR viewing program.

We are excited for future development and direction for NIVR, and anticipate completing a public release next year. The public release will include a standard experience encompassing the above visualizations. Additionally, we hope to create a later version inclusive of all neurological data pre-processing to enable users to view their own scan(s) with NIVR. We are also continually developing new visualization types and styles to accommodate the rapidly evolving field of neuroimaging, and plan to update and expand the program accordingly.

Acknowledgements

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