BrainVR: the virtual reality brain connectivity navigator

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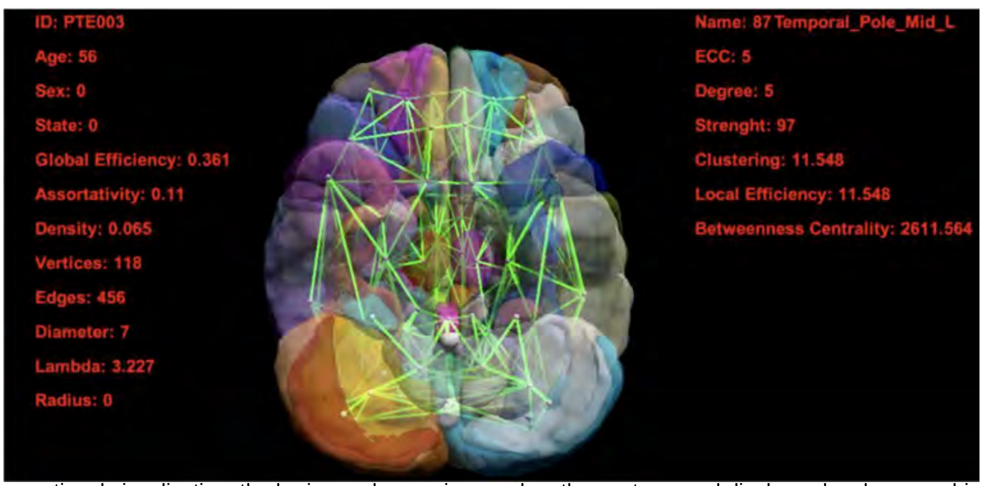
Target audience: Researchers interested in brain connectivity and medical imaging visualization.

Purpose: The visualization of complex medical data, in particular imaging data, in an intuitive, simple and comprehensive way is a challenge. This is especially true when considering the amount of data that is available and generated in brain connectivity studies, which are often whole-brain and increasingly multimodal [1, 2]. Typically, brain connectivity information is translated into network theory metrics, adjacency matrices, brain graphs and connectograms in order to get a better understanding of data [3-5]. In spite of this, the full comprehension of data and its anatomical relationships may be hard to achieve. In this regard we developed BrainVR, a virtual reality (VR) application with gesture recognition (GR), that enables the user to navigate in a brain graph that preserves anatomical relations and displays various whole-brain and region-specific imaging and brain connectivity metrics.

Methods: The application was developed in Unity3D framework [6] and integrated Oculus Rift as the VR head-mounted display (HMD) platform [7] and Leap Motion as the GR interface [8]. The application contains two main visualization interfaces: anatomical and connectivity, which are further described below. The anatomical visualization interface can display already available 3D brain models or import subject-specific data. Brain anatomical data can be derived from Freesurfer parcellation of volumetric T1-weighted images, which makes use of the Destrieux or Desikan-Killiany-Tourville atlases [9]. Alternatively, parcellations can be derived from the Harvard-Oxford, Talairach, Automated Anatomical Labeling (AAL) or even user-defined atlases. In case of Freesurfer image processing, each cortical and subcortical region-of-interest (ROI) is obtained along with corresponding metrics such as cortical thickness, surface area and volume, as applicable. For any atlas-based parcellation, ROI image data is converted to Wavefront objects in order to be more manageable for rendering in Unity3D [10]. The anatomical visualization interface is designed to enable the user to view single or multiple ROIs, to choose ROI color palette, to display imaging metrics (selected from a corresponding text file) and to choose conventional (non-VR) or VR visualization. The connectivity visualization interface imports adjacency matrices (in text format) that can be obtained from different imaging modalities and/or software packages [2]. It also enables the user to select which atlas was used in computing the adjacency matrices or imports (in text format) the matrices' ROI labels. Furthermore, it imports (in text format), both global connectivity metrics, such as characteristic path length, global efficiency and small-worldness, and local (node-specific) connectivity metrics such as node degree and strength, clustering coefficient and betweeness centrality [3]. From an adjacency matrix the application computes a brain graph and superimposes it on the anatomical rendering described above. Here, the user has the possibility to choose which ROIs to display and their levels of transparency. As before, the user can choose either conventional or VR visualization. Finally, visualization navigation can be controlled either using the keyboard, mouse or the Leap Motion GR interface by making use of the firmware's gesture library.



Results and Discussion: The figure shows an illustrative example of the application output. Here, volumetric T1-weighted and Diffusion Tensor Imaging (DTI) data were acquired for a healthy volunteer to obtain brain parcellations and a DTI-derived structural connectivity matrix based on the AAL atlas (details in [11]). The figure shows, in conventional visualization, the brain graph superimposed on the anatomy and displays also demographic and global and local connectivity metrics. When in VR visualization, one image is displayed for each eye to create the sense of depth in the VR environment. The user is able to navigate both inside and outside of the brain/brain graph and to visualize imaging and connectivity metrics while navigating.

Conclusion: An application based on VR and GR was developed for visualizing brain connectivity and bring novel insights on how connectivity information can be comprehended. We expect that this application could be useful for neuroscientists, educators and also clinicians regarding brain surgery planning.

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