A Fully Digitally Integrated Workflow for Brain MRI Point Cloud Generation and Augmented Reality 3D Model Visualization

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INTRODUCTION

This study aims to refine an automated workflow for neuroimages that generates three-dimensional (3D) point clouds in the Polygon File Format (.ply) to be deployed into augmented reality (AR) head mount displays (HMD). Our current work involves enhancing and refining core features, along with improving the point-cloud application to optimize the brain MRI intake. Our brain image segmentation algorithm and web-based point cloud generator show promise for clinical workflows, where high-quality point-cloud AR models can be generated from patient MRIs.

We hope to spearhead future development of features for visualizing, manipulating, and annotating medical scans in AR environments. The automated workflow can be implemented with MRI containing color differentiated neuroimaging segments, which can further increase physicians' abilities to visualize and interpret MRI brain scans. Our brain image segmentation algorithm and web-based point cloud generator show promise for eventual use in clinical workflows, where high-quality point-cloud AR models can be generated from patient MRIs. By expanding the functions of an integrated AR workflow, we hope to spearhead future development of features for visualizing, manipulating, and annotating medical scans in AR environments.

Step 1: Initial segmentation algorithm preprocesses MRI by selecting regions of interest

Step 2: Point Cloud Generation creates 3D models of processed brain MRIs

Step 3: The resulting 3D model is integrated into the Microsoft Hololens headset for clinical operations

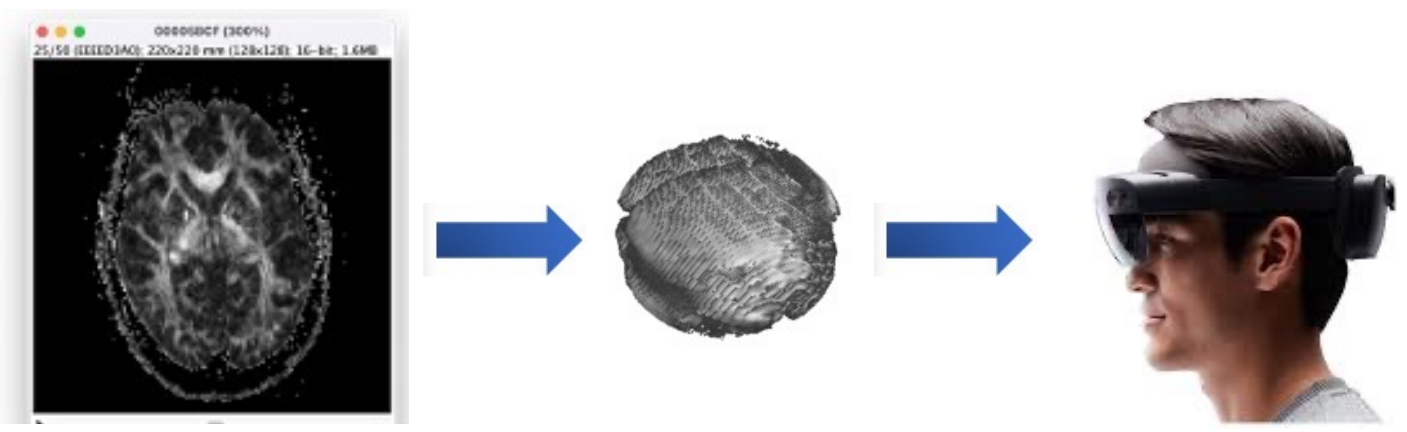


Figure: The existing workflow integrates all necessary steps to generate a viable 3D model in an augmented reality environment.

PURPOSE

We have previously developed a proof-of-concept workflow prototype with segmentation, point cloud and AR HMD integration features; the prototype primarily utilized spine and ankle orthopedic CT scans and MRIs. We want to see if we can apply such workflow towards other anatomical areas, such as the brain. Our current work addresses specific challenges in existing surgical augmented reality workflows and its applications in brain imaging. We would like to highlight such challenges:

1. Despite MRIs being a prevalent brain imaging modality, 2D brain MR images can only **convey a limited amount of 3D spatial information** for preoperative and intraoperative purposes.

2. Compared to soft tissue and bone, brain MRIs are relatively more difficult to visualize due to their **highly specialized and intricate anatomical structures.** Neuroimage visualization requires multiple contrast and intensity adjustments, where accurate post-processing must be performed on a case-by-case basis to generate 3D AR models.

3. Complex procedures that require precise imaging tools such as brain surgery would benefit most from accurate 3D anatomic visualization which can address both the **potential inaccuracies and time-intensive nature of the brain operations**.

MATERIALS AND METHODS

The workflow consists of 3 stages: segmentation, point removal and headset model integration.

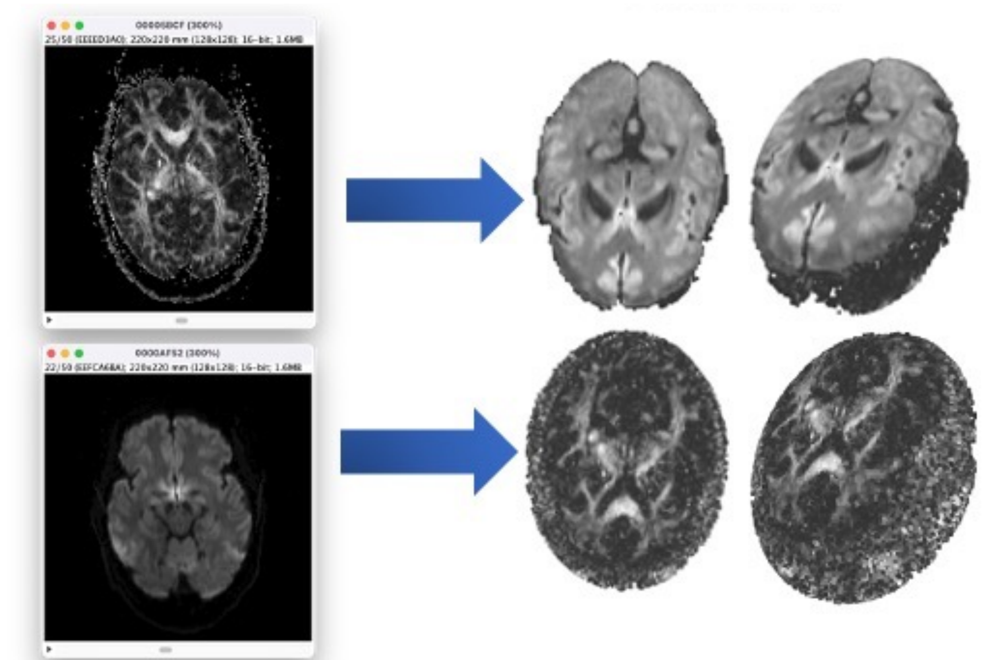
1. Segmentation: Segmentation starts with image segmentation to output processed 2D MRIs by isolating the image area of interest. The user can isolate certain regions of the uploaded DICOM sequence using intensity thresholding to differentiate between soft and hard tissues. Removal of undesired image data will expedite the 3D model generation process.

2. Point Cloud Generation: The resulting point cloud model is run through another application which removes excess regions of point clouds to reveal desired anatomical features within the segmentation boundaries. The point removal algorithm identifies the centroid point of the cerebrum and cerebellum, eliminating excess points about 2.5 standard deviation lengths away from the centroid point.

3. Headset Model Integration: The processed point cloud model will then be streamed into the Microsoft Hololens headset using the Unreal 3D augmented graphic generation engine. However, we have discovered even more technical software compatibility requirements must be addressed, which will persist given augmented reality software's infancy.

RESULTS

1. High-Quality and Fully Visualized 3D Point Cloud Models



2. Efficient Time and Resource Utilization

	Brain MRI #1	Brain MRI #2
Original Number of Slices	85	85
Original Slice Resolution	128 x 128	128 x 128
Interpolation Factor	2	2
Number of Slices Post Interpolation	170	170
Vertex Count	460858	556656
Time for Generation (s)	14.73	15.15
File Size (Mb)	13.3	8.9

3. Functional Features for New Anatomical Regions and Image Modalities

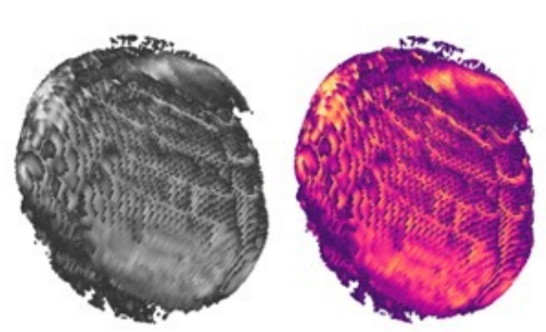


Figure: The color visualizer colorizes surface anatomy to improve contrast and brain anatomical details.

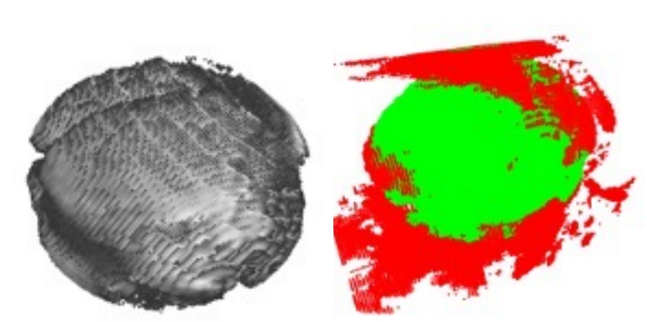


Figure: The outlier removal feature removes excess point clouds regions to reveal desired anatomical features of interest

CONCLUSIONS

Due to the brain's highly specialized and intricate regions, neuroimages are significantly more difficult to visualize than soft muscle and bone tissue. From our initial group of 7 brain MR image sets, only 2 image sets were viably generated into a complete point cloud model. The point cloud generation software was unable to generate the remaining models due to dimension and mathematical operation limitations. We are looking to better understand the limitations of underlying packages in a variety of initial images; this ensures the application is sufficiently versatile to process neuroimages of varying levels of image quality and in generating a complete point cloud model.

Our initial iteration of the point cloud generation software was building an integrated workflow that incorporated image segmentation, point cloud generation, and model visualization on head mount devices. More recent developments have focused on testing the robustness of the application on neuroimaging data, due to the brain's unique anatomical structure and relatively modest research attention to 3D visualization. We have developed several tools to improve the visualization of the 3D brain models: an outlier point removal which isolates the anatomy of interest and a model colorizer that increases contrast visualization. Further HMD brain visualization research advances will require a solid foundation of image segmentation techniques, point cloud generation, and HMD anatomic representation.

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