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A Novel Approach to Brain Vessel Segmentation Using MRI for Alzheimer's Disease Research

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Abstract:

Alzheimer's disease is increasingly recognized as having a vascular component, with studies suggesting that impaired blood flow and vessel abnormalities contribute to cognitive decline. Consequently, methods to study the morphology of brain vessels are warranted. Current techniques allow for viewing 3D MRI brain scans to examine a patient's vessels, but automated methods to segment these vessels and obtain quantifiable metrics lack reliability and accuracy. We present a novel image analysis algorithm designed to accurately segment brain vessels from 3D MRI images, enabling more detailed analysis.

Our algorithm begins by preprocessing the image into 'variance wells' (vWells), a type of 'superpixel' derived from the variance in the image's intensity. VWells are small, irregular, and relatively homogeneous clusters of adjacent pixels, which can be connected to segment objects in an image while preserving sharp boundaries. The computed vWells are arranged into a graph structure where vWells serve as nodes, and edges connect adjacent vWells. The algorithm takes two manually placed points along a vessel, then uses the graph structure to connect and complete the corresponding section of a vessel by leveraging the statistical relationships between adjacent vWells. Detailed visualization tools allow users to superimpose the segmentation as a semitransparent surface over the original MRI data, facilitating visual confirmation of segmentation accuracy. By combining these automated techniques with human supervision based on detailed visualization, our approach provides a robust and reliable method for brain vessel segmentation.

Preliminary application of our method to segment the Circle of Willis arteries, a vital network for maintaining cerebral blood flow, in 27 time-of-flight MRI scans demonstrates its ability to consistently provide precise, quantifiable metrics (such as diameter, length, and curvature of vessel structures) across diverse 3D MRI datasets. This capability supports large-scale studies of vascular abnormalities linked to cognitive decline and advances Alzheimer's disease research.