TOWARDS ROBUST AND FAST VESSEL EXTRACTION FROM MRA IMAGES

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Introduction: An increasing demand for sophisticated tools to characterize the integrity and functional state of vascular networks from different imaging modalities has emerged. Currently available tools are time-consuming and limited in their ability to assess the state of vascular architectures, hence there is a need for developing robust and fast computer-based techniques for extracting vessel trajectories as well as estimate their diameters. Towards this goal, we evaluate a novel technique based on the well-known Hough transform (HT) to dynamically estimate the trajectory and vessel diameter without resorting to time-consuming multiscale techniques[1]. Results are validated using synthetic datasets and applied on a magnetic resonance angiography (MRA) image of a human brain.

Material and Methods: Synthetic vessel images were constructed with a voxel size of 1mm^3 in order to mimic vessel trajectories with high curvature and branching patterns. Intensity values inside the vessels were drawn from a Gaussian distribution and were maximal at the vessel centerlines. An MRA of a human brain was acquired on a 3.0T scanner using a T1-FFE sequence with TR/TE=25/3.15ms, with voxel-size=0.78x0.78x1mm^3. The tracking method starts by the selection of a seed point within the vessel of interest (VOI) using orthogonal cross-sections of the MR volume. At the seed point, an image plane perpendicular to the vessel tangent is used to start the tracking process. Following plane selection, an anisotropic diffusion filter to reduce noise and enhance linear structures was applied to the extracted image plane. Next, morphological opening and subtraction operators are applied to highlight maximum intensities and the Canny filter is employed in order to extract edges. Once the edge image is obtained, the HT is computed to identify circle centers and their estimated diameters. If more than one vessel is found in the chosen plane of extraction, the best match is chosen. At this stage, both centerline and vessel radius are determined. Based on detected centerline and on the detected radius taken as a vessel scale, the eigenvalues and eigenvectors from a Hessian matrix are estimated at the centerline location and provide the local vessel coordinate system. The eigenvector corresponding to the eigenvalue closer to 0 (λ_1) indicates the vessel direction. This direction defines the normal to the next extraction plane in the 3D image. This process finishes when it is not possible to detect a significant difference between the eigenvalues.

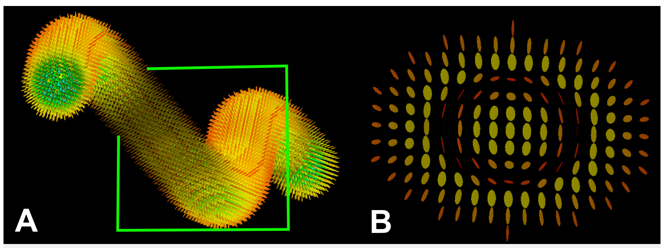

Figure 1. (A) Ellipsoidal field representing the Hessian information throughout a blood vessel segment. Green rectangle indicates the cross-section for depiction of image structure in blood vessel locations. (B) Vessel exterior, interior and boundary representation by Hessian-based ellipsoidal field.

Results: The proposed tracking method consists of successive executions of the above steps to extract a vessel trajectory. Figure 1A depicts tracking process scheme. Initially, only one vessel is detected for each 2D cross-section during tracking. The idea is detect all centerlines of a unique vessel branch and then go back to each branching point to continue the centerline detection. The methodology has shown to work well under significant amounts of noise using the synthetic dataset with high curvature trajectory (Fig. 2C, 2D and 2E) and with several branches (Fig. 2G, 2H, 2I). Fig. 2J displays the tracking result of a carotid artery segment.

Conclusion: In the present study, we have proposed a semi-automated method to detect and track vessel trajectories in MRA. The novelty of this study is the use of HT to define the seed point for tracking and detecting the vessel scale without resorting to multiscale analysis techniques, and in spite of presence of noise, a mean diameter can be established. While branching in the synthetic datasets was handled, it still remains to be thoroughly validated, given the complexity of real vessel bifurcations. The tracking algorithm yielded high reproducibility rates, robustness to different noise levels, associated with simplicity of execution. Future work will focus on automatic bifurcation handling using analysis of curvature of the vessel profile at the cross-section.

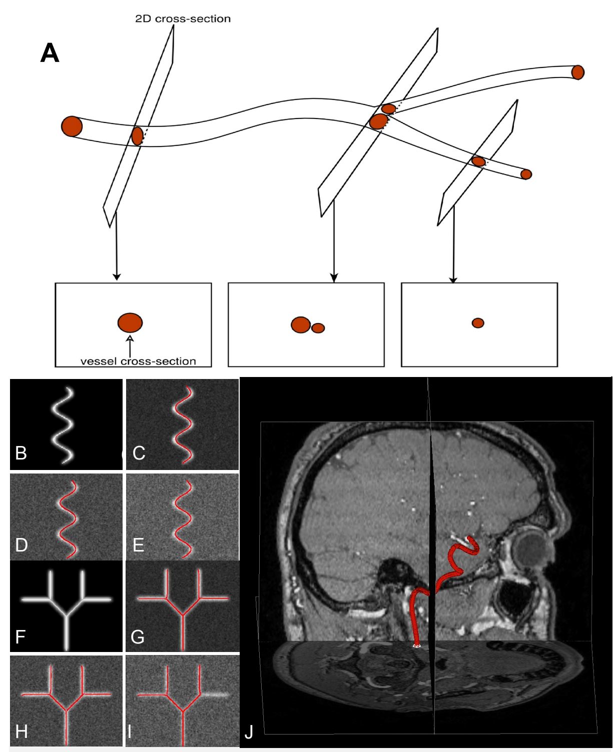

Figure 2. (A) Proposed tracking scheme. (B) Sinusoidal synthetic vessel image. (C-E) Synthetic image corrupted with 5%, 10% and 15% Gaussian noise, respectively and tracking results. (F) Synthetic bifurcation image. (G-I) Synthetic image in (F) corrupted with 5%, 10% and 15% Gaussian noise and tracking results. (J) Brain MRA dataset and results from tracking a segment of the carotid.

References
1. Lesage, D., Angelini, E. D., Bloch, I., Funka-Lea, G. A review of 3d vessel lumen segmentation techniques: Models, features and extraction scheme. Medical Image Analysis (2009).