Tracking 3-D vascular tree structures in the brain for analysis of tortuosity, diameter, and branching patterns

Visualization and Image Analysis Laboratory

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Background

- Analyzing MRI images provides crucial information in the diagnosis and treatment of numerous diseases of the brain. In particular, we are interested in the contribution of vascular pathology to some of these diseases. Various vascular parameters can be derived from MRI images, but present techniques require significant manual processing and are limited by their inability to operate truly in three dimensions, or to reveal variation in the higher-order structure of the vascular trees.

Purpose of Study

- The Visualization and Image Analysis Laboratory in the Department of Bioengineering is working with the Geriatric Psychiatry Neuroimaging Laboratory to develop automated algorithms to facilitate analysis of three-dimensional vascular tree structures in MRI images of the brain. These algorithms aim to reduce the extensive labor and inter-user variability of manual segmentation, while operating truly in 3D rather than on 2D projections of the underlying 3D data.

Methods

- The underlying principle is to find paths of maximum connectivity given a locus of starting and ending locations, allowing paths to combine given the expected direction of branching in the vascular structures. The algorithms provide local measures of vessel diameter, tortuosity, and branching pattern over an entire region of a vascular tree in a single automated pass. We believe these measures may represent early pre-clinical markers of brain pathology across a variety of mental health disorders.

- Specific algorithms have been developed for two applications:
  - (1) **BrainVein**: Segmenting small veins lateral to the lateral ventricles in susceptibility weighted images magnetic resonance (MR) images from an ultra-high field (7T) scanner, assuming that these veins branch outward from the lateral ventricles into the surrounding white matter;
  - (2) **TreeTrack**: Segmenting arterial structures from time-of-flight MR images from the 7T scanner branching out from the Circle of Willis along the middle cerebral arterial tree. Since the direction of this branching is less uniform, the algorithm has been adapted to allow for vessels to curve back upon themselves, by first producing a height-map down which branching patterns are found by following the steepest slope, analogous to water flowing down to connect the tributaries of a river.

- Both algorithms require minimal manual initialization and are computationally efficient (< 10 minutes).

Results

- We have demonstrated both algorithms on sample data sets. **Fig. A**: BrainVein applied to small veins in the white matter lateral to the lateral ventricles. **Fig. B**: TreeTrack applied to the Circle of Willis.

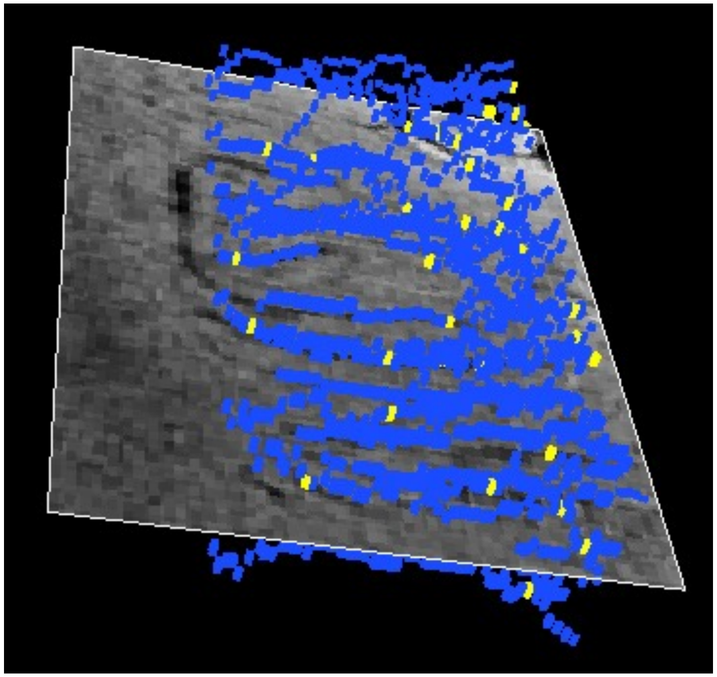

Fig. A

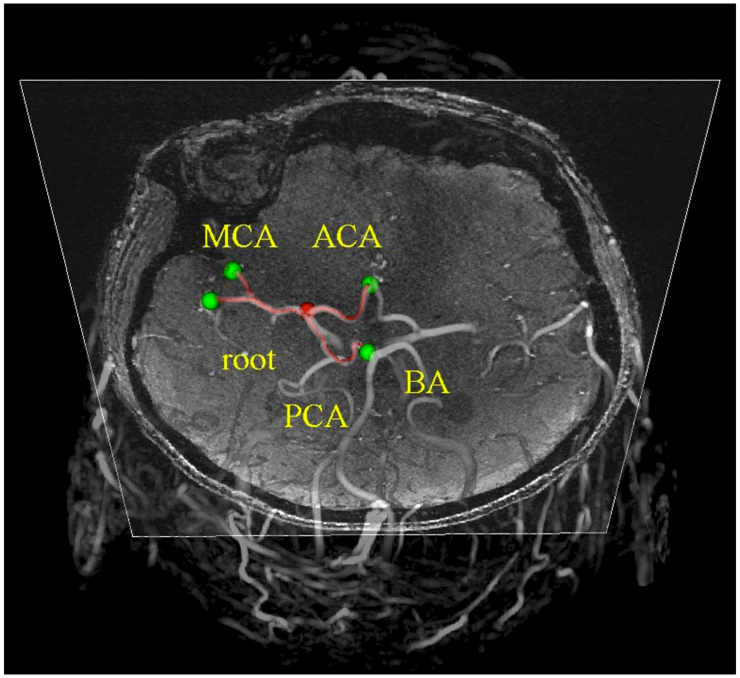

Fig. B

Future work

- We are presently refining the newer of the two algorithms and plan testing it on a collection of clinical images.