Investigations on Techniques for Rapid Extraction of Topology Information for the Circle of Willis

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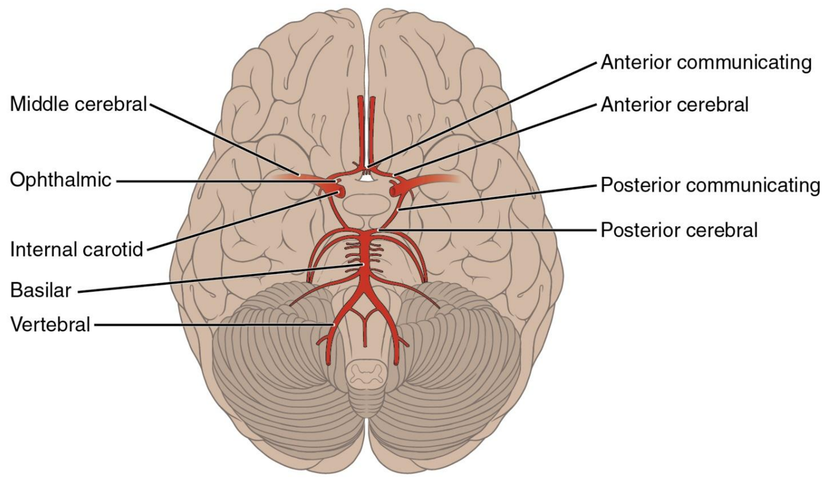
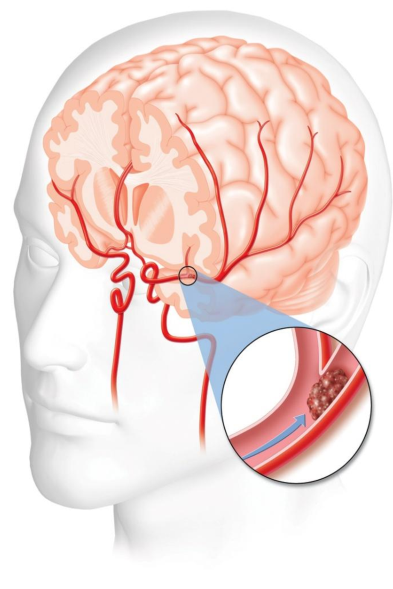
Abstract

The Circle of Willis[1]



The Circle of Willis is a network of the major cerebral arteries in the brain, playing a key role in cerebral circulation. Considerable anatomical variations exist in its topology, with the complete network being observed in only about one-third of human population. Such topology variations are likely to influence cerebral hemodynamics and distribution of embolic particles that cause ischemic stroke. The correlation between these aspects has not been clearly established. Extraction of topology from medical image data is essential for such an effort. The objective here is to develop tools to enable rapid extraction of topology of the Circle of Willis vasculature from medical image data.

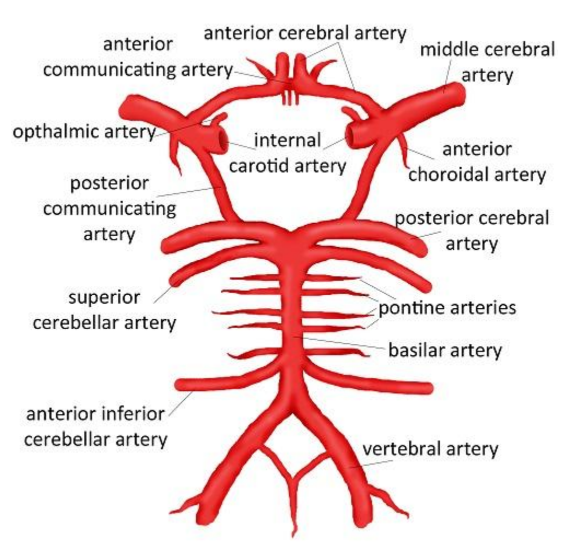


Embolic Stroke[2]

Overview

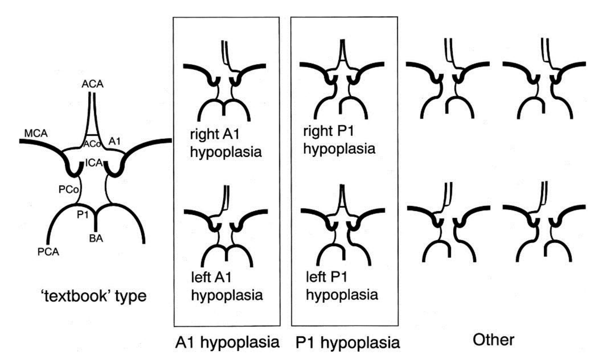
- 85% of strokes are ischemic, and 35-40% of these are embolic[3]
- Little has been done to describe the impact of topology of the Circle of Willis oo embolic stroke risk, location, or severity.

Complete anatomy of the Circle of Willis[4]



- A complete Circle of Willis is present in most individuals; however, a well-developed communication between each of its parts is only seen in about 34.5% of the population[3].

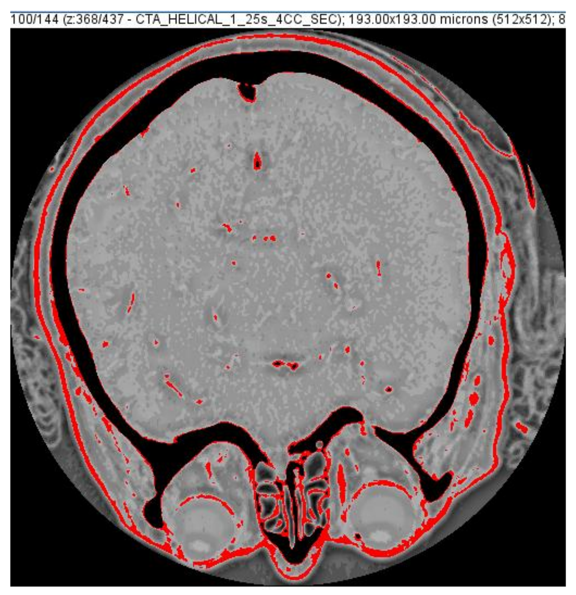
Variations of the Circle of Willis[5]



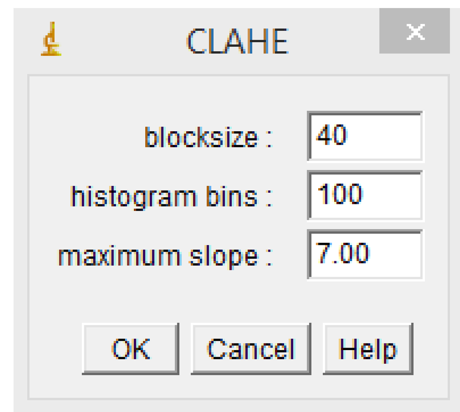
- Such variation in arterial topology is likely to influence the distribution of embolic particles, although the correlation has not been clearly established.
- Computed tomography (CT) scan data are processed by rapid extraction and its topology information is further analyzed for hypoplastic or missing parts in the Circle of Willis.

Methods

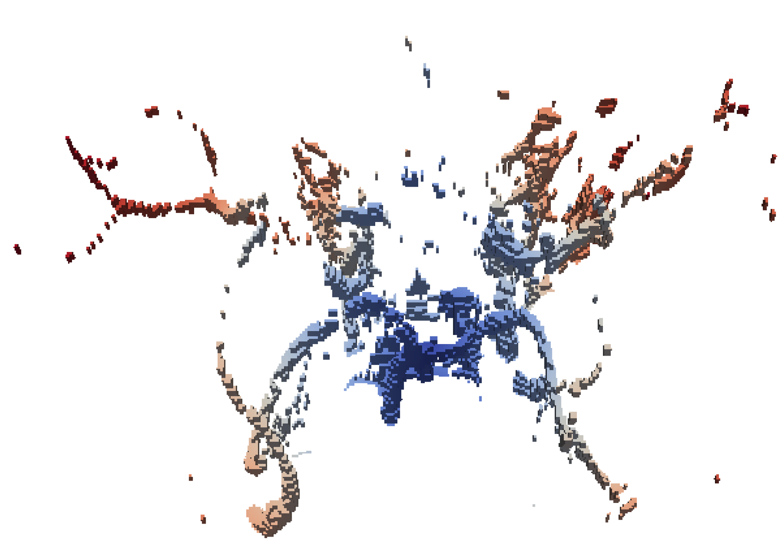
CT scan data →



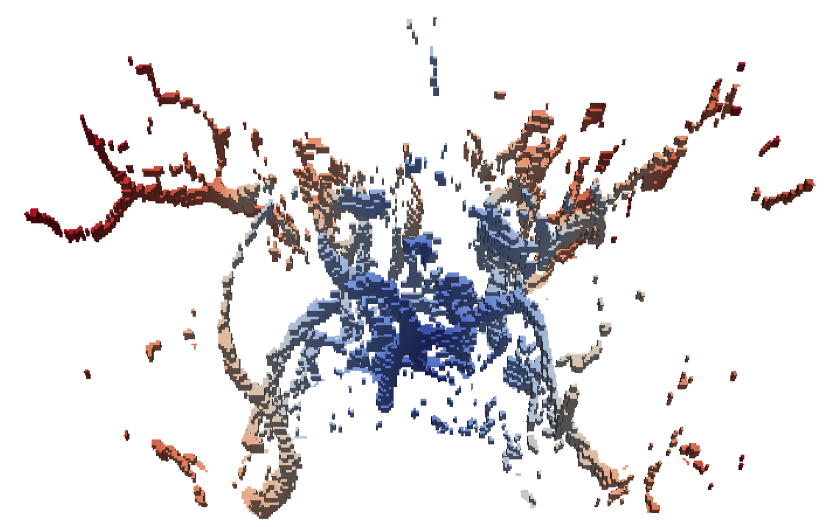
CLAHE contrast adjustment →



Processed in VTK →



Composition →



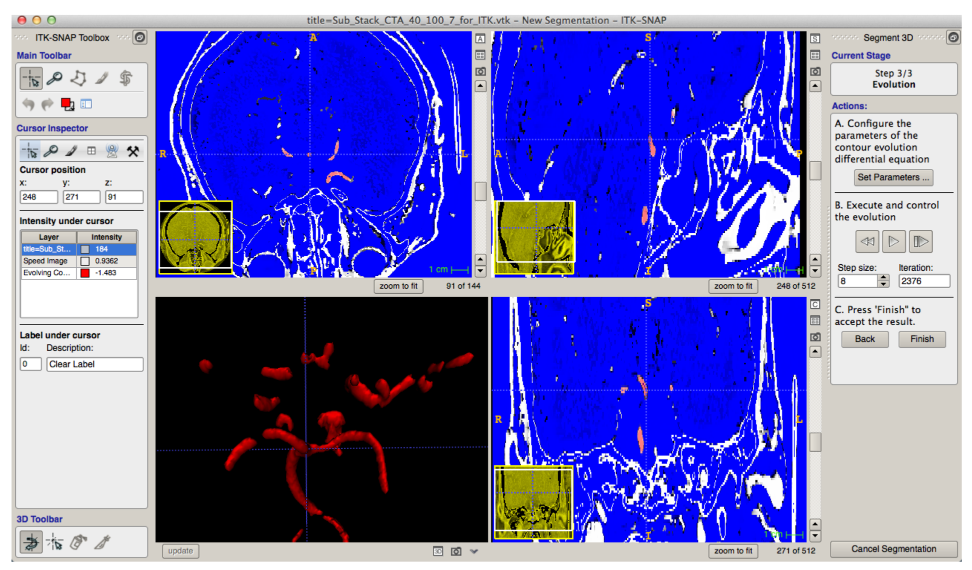
Analyze anatomy

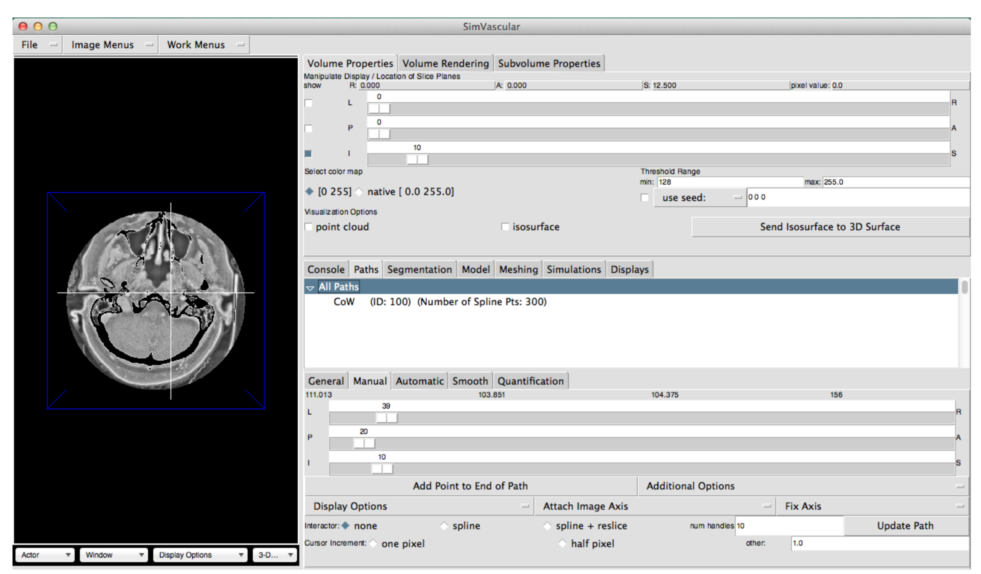
- Is topology clearly displayed?
- How effective were the parameter inputs used?
- Are any parts of the Circle of Willis hypoplastic and/or missing compared to the ideal model?

Results

Evaluation of Existing Tools

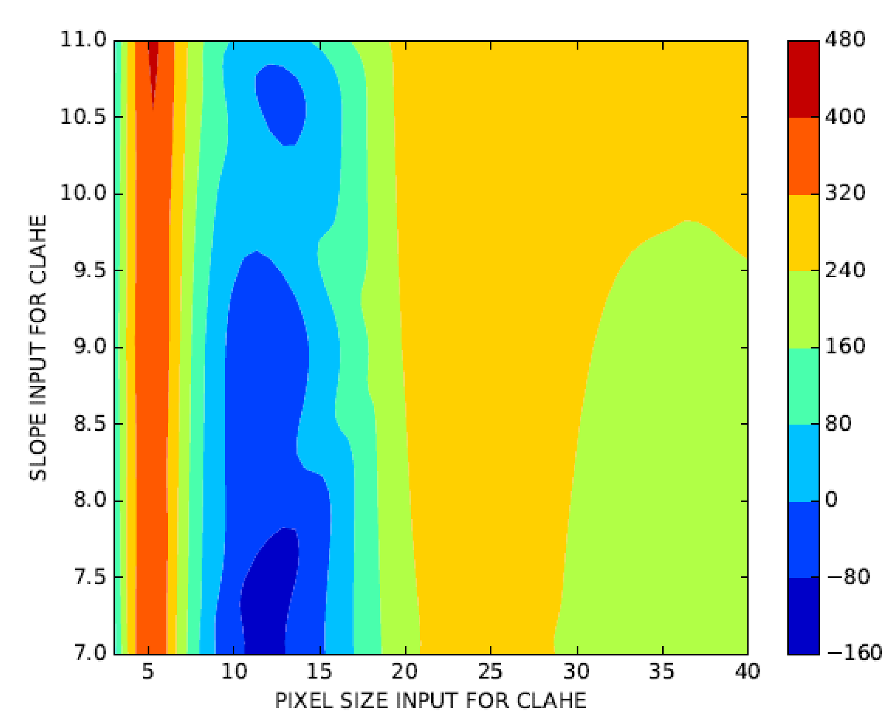
- Automated 3D Segmentation: ITK-Snap
  - Simple process, but difficult to capture a vessel's entirety
  - Process takes approximately 2 hours
  - Enhanced contrast makes identification easier; however, image resolution is limited
- 2D Manual Segmentation: SimVascular
  - Moderately difficult
  - Control allows room for smoothness of model
  - Process takes approximately 3 hours
  - Enhanced contrast with CLAHE allows segmentation without any discontinuity



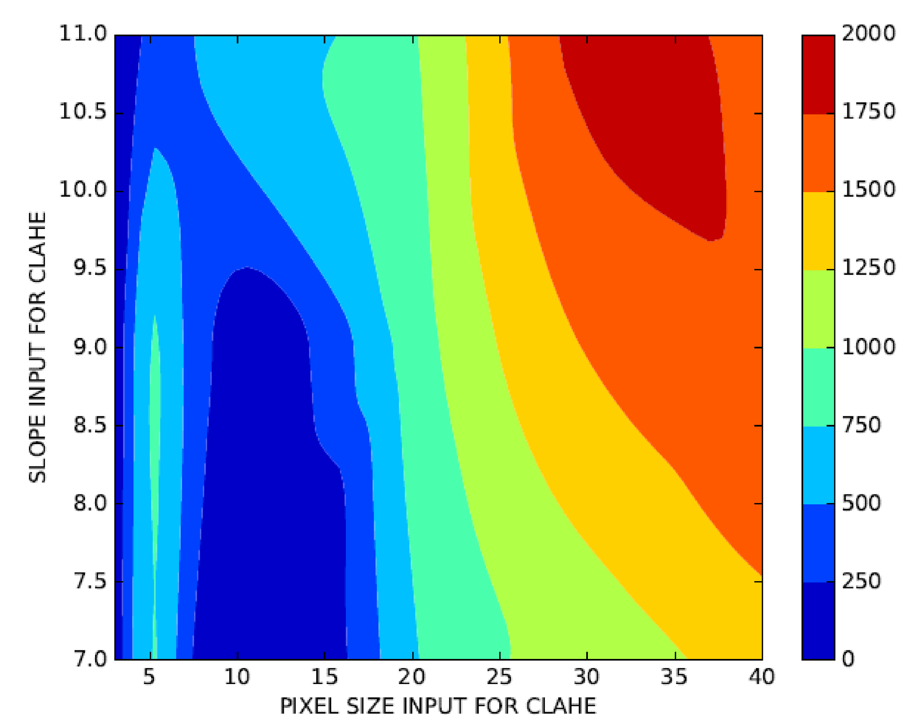


Summary of CLAHE Contrast Enhancement

Region ID Assessment



Volume Assessment



Composition of Small to Large Vessel Extractions

- 18 datasets were processed using different parameters in CLAHE, assessed by post-processing in the VTK library, and composed together to create one image
- Geometry is more connected, but heavier noise
- Cleaning up operations (clip and threshold) used to decrease noise

Questions

- How well do the existing tools perform in generating topology information?
- How do the various parameters of the CLAHE algorithm affect the image data set?
- Does the composition of small to large vessel extractions aid the process of analyzing topology?

Conclusion

- The automated 3D segmentation and 2D manual segmentation methods were more difficult to use than expected, but improvements can be made upon pre-processing contrast enhancements and software development.
- This research took exploratory steps in a longer project that looks at the problem of anatomical information extraction from image-data rapidly.
- With the results and analysis, people in the lab will be able to implement the methods and tools utilized and build on this research in the future.

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References

[1] http://cnx.org/resources/ad81523d6f8187d6df2fd981afa686087d9bb76e/2123_Arteries_of_the_Brain.jpg
[2] http://keck.usc.edu/en/Education/Academic_Department_and_Divisions/Department_of_Neurology/Clinical_Activities/Stroke_and_Cerebrovascular_Center/Patient_Education/About_Stroke.aspx
[3] A. Arboix and J. Alio. Cardioembolic stroke: clinical features, specific cardiac disorders and prognosis. *Current cardiology reviews*, 6(3):150-61, August 2010.
[4] http://www.chw.org/~/media/Images/MedicalCare/birthmarksandvascularanomalies/circle%20of%20willis.jpg
[5] http://www.ajnr.org/content/27/8/1770/F2.large.jpg

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Support Information
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