Augmented Reality Visualization for Guidance in Neurovascular Surgery

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Introduction

- In mixed reality visualization (e.g. augmented reality), physical and virtual environments are merged to produce new visualizations where both real and virtual objects are displayed together.

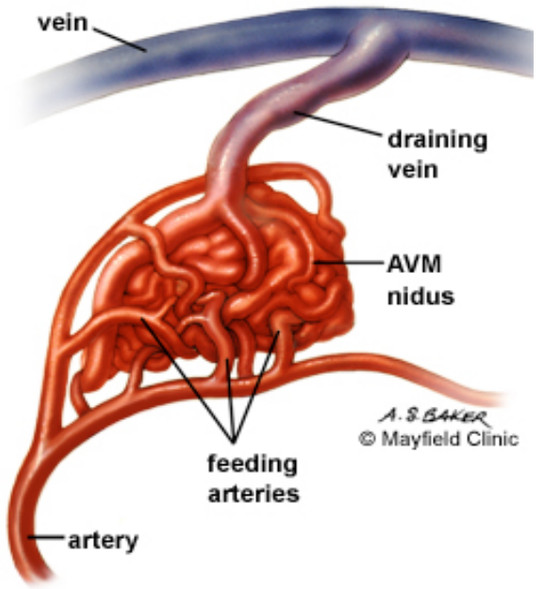
- Used in image guided surgery (IGS) to:
  - Overcome the surgeons’ limited field of view.
  - Aid mapping between pre-op images and patient.
  - Improve understanding of complex multimodal data.

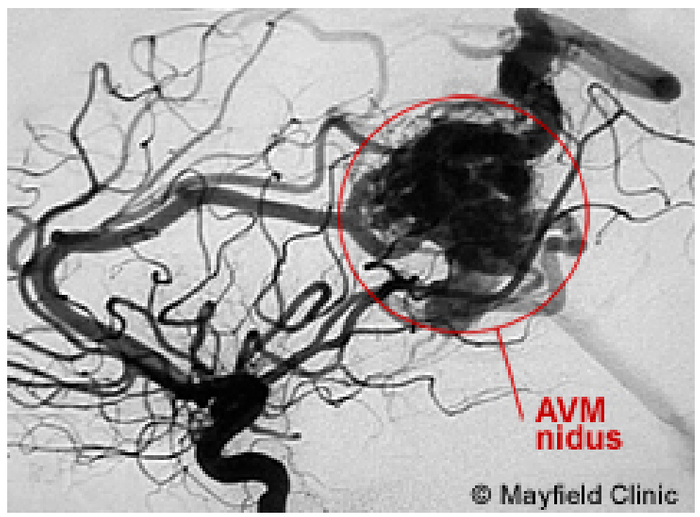
Arteriovenous Malformations (AVMs)

- AVMs are abnormal collections of blood vessels, fed by one or more feeding arteries (*feeders*) and drained by draining veins (*drainers*).

- Vessels may be unusually winding or large, and have weakened walls, which may result in intracranial hemorrhage

- Treatment is recommended to protect against bleeding, can be in the form of radiation, embolization, and/or surgery.





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Motivation

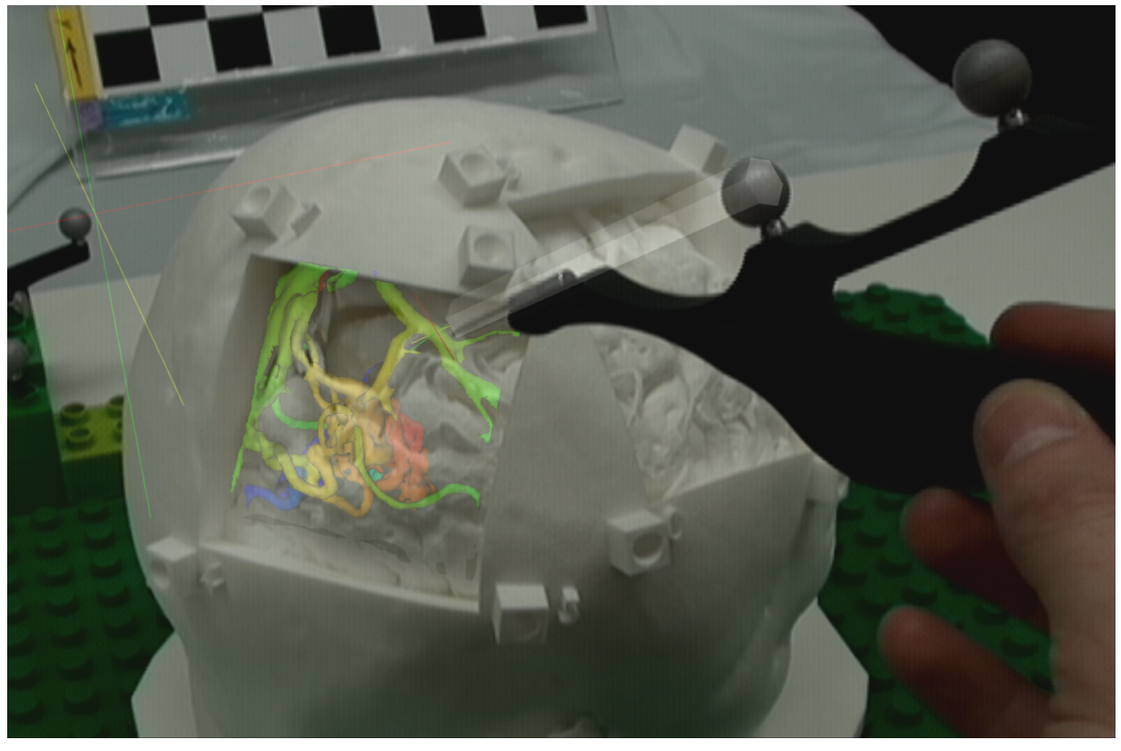
- In AVM surgery (and other type of neurovascular surgery), an operating microscope enables a magnified view of the surgical scene. However there is no:
  - Information as to the vessel anatomy below the surface.
  - Indication of the location of feeding and draining vessels
- The surgical task is made more difficult with the frequent repositioning of the microscope during the surgery.
- This often difficult mapping task may be facilitated by using mixed reality visualizations.

AR Visualization for AVM Surgery

- In our work: used our prototype AR system, IBIS, (Interactive Brain Imaging System) for simulated neurovascular surgery.

- Explored two colour mapping visualization techniques for image-guided AVM surgery.

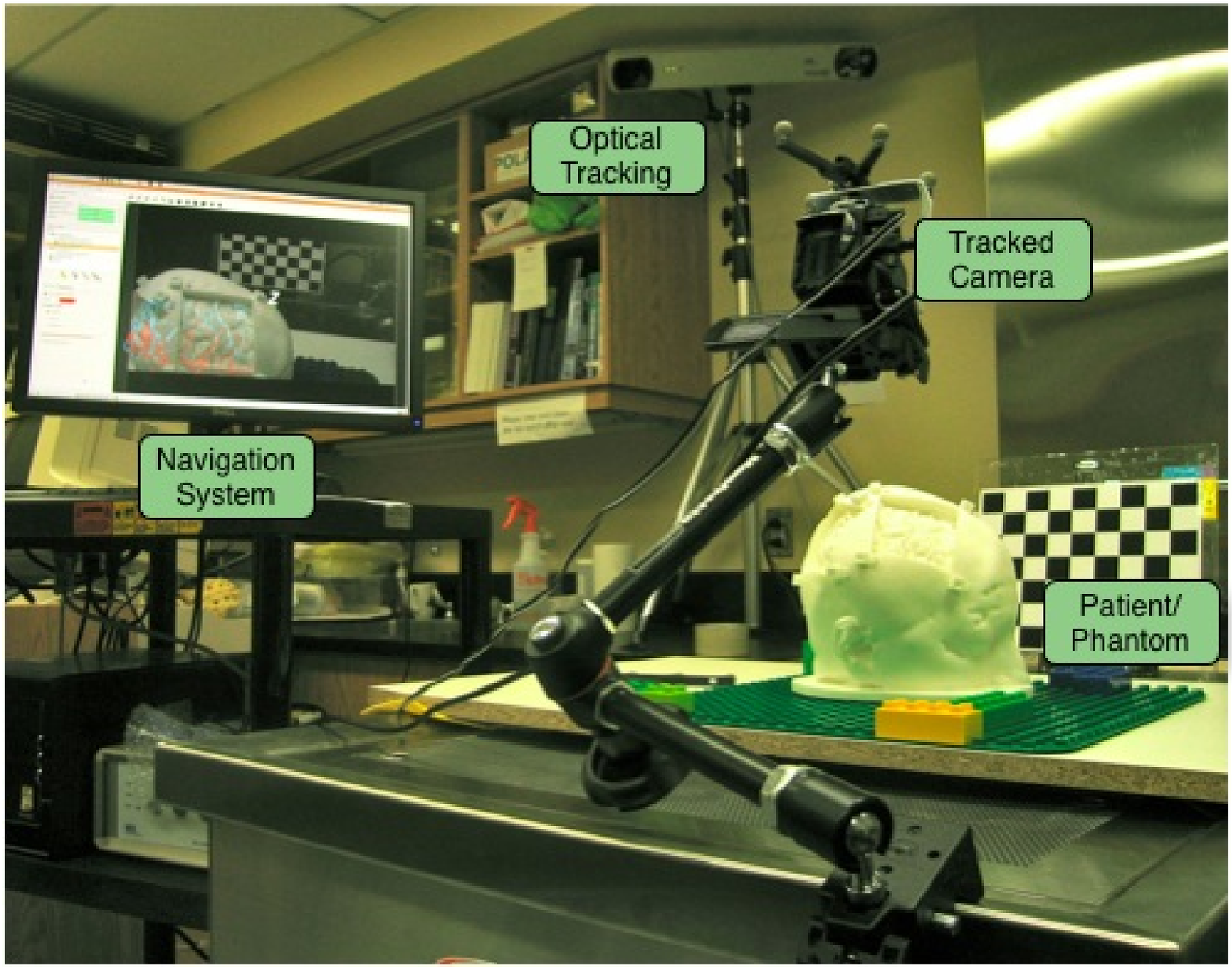
- Qualitatively evaluated by neurovascular surgeon.



Platform for AR in AVM Surgery

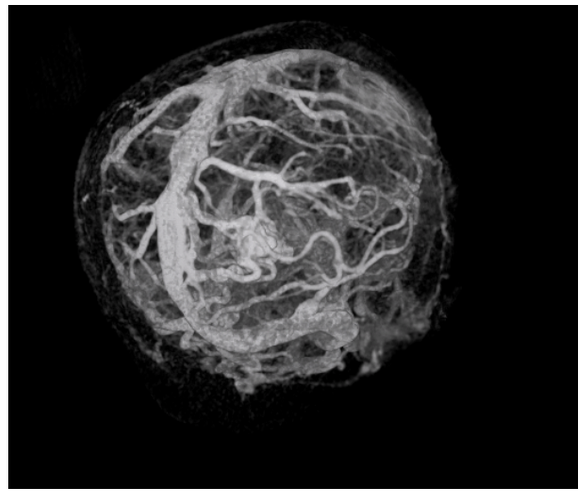
- We have created an AR evaluation platform for simulated neurovascular surgery.

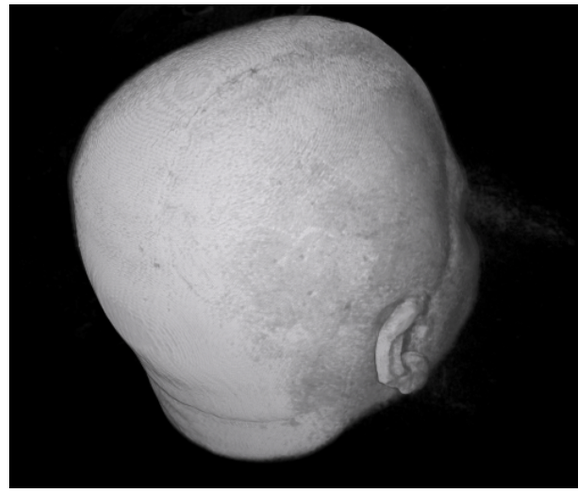
- A tracked camera and a 3D plastic phantom were used to substitute for the surgical microscope and patient, respectively.

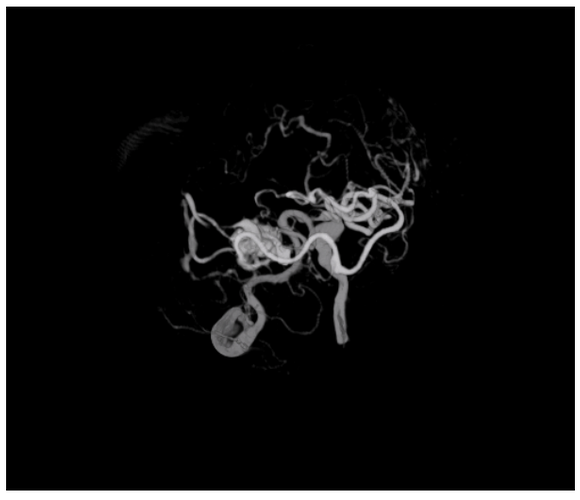


Materials

- Datasets used:
  - Computed tomography digital subtraction angiography (CT DSA),
  - Contrast enhanced magentic resonance angiography (CE-MRA).
  - X-ray angiography (3DXA).
- The surfaces of the vessel datasets were obtained by segmenting the CT DSA and 3DXA volumes using semi-automated region growing.

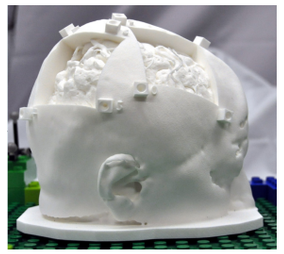


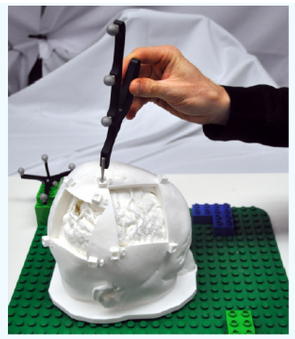




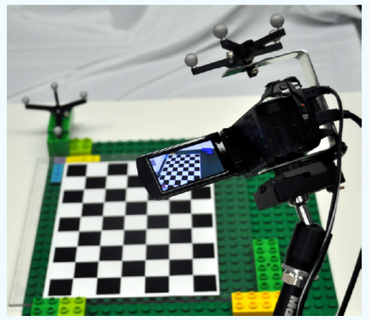
Materials & Methods

- Nylon phantom printed using meshes from the datasets.
- Calibration done using Camera Calibration Toolkit for Matlab.
- Registration using pointer (VTK Toolkit used).
- AR Visualization using neuronavigation software (IBIS).



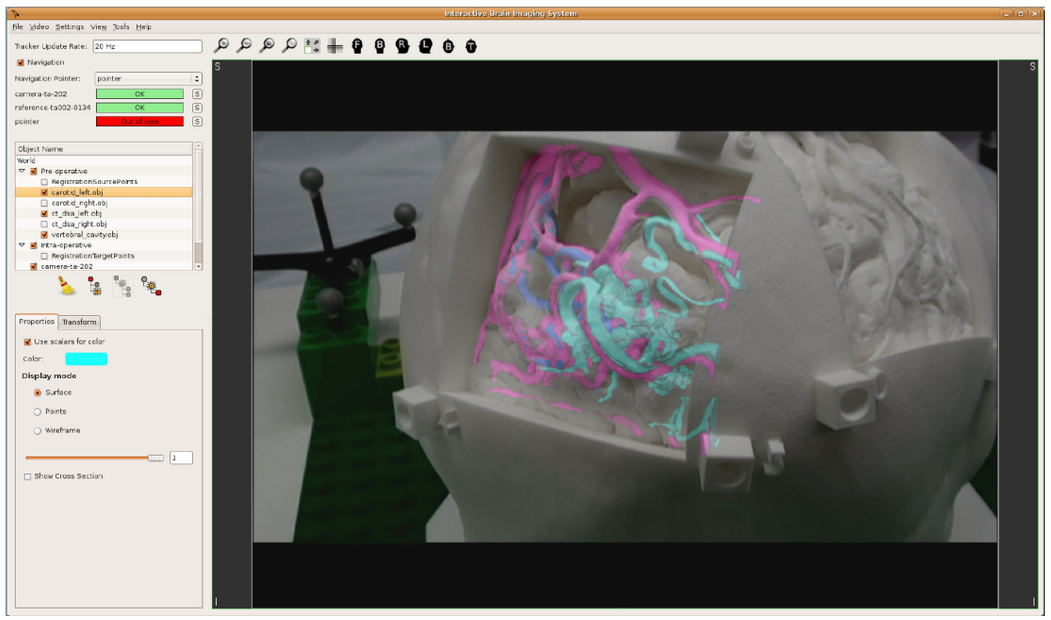


Phantom registration



Camera calibration

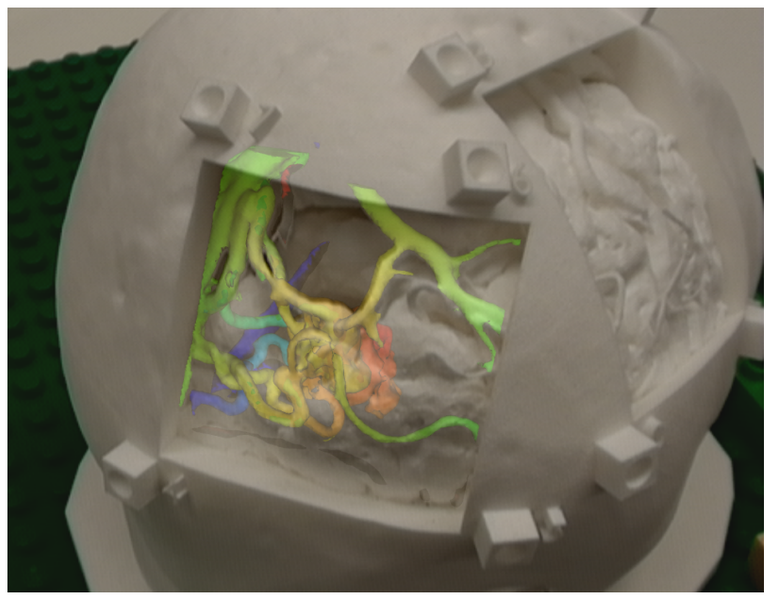
Grid registration

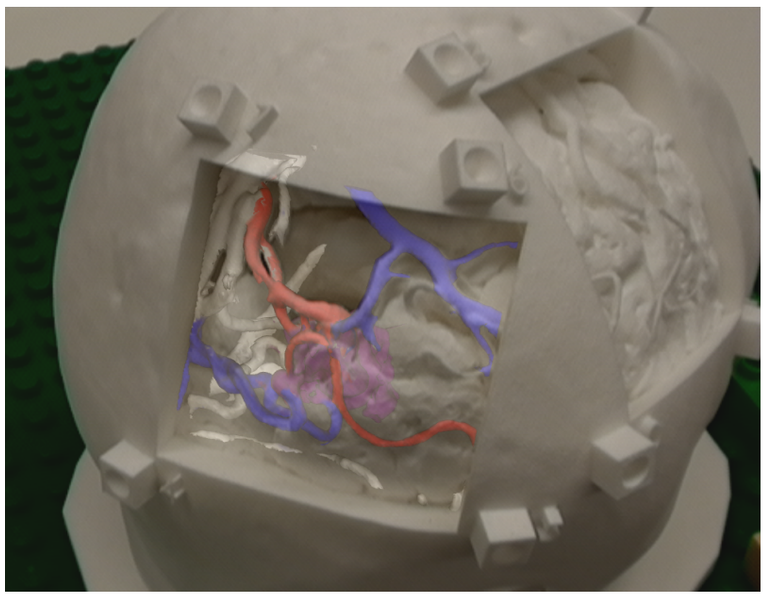


S. Drouin, M. Kersten-Oertel, S. J. S. Chen, and D. L. Collins. (2011) “A Realistic Test and Development Environment for Mixed Reality in Neurosurgery”, AI-CAI 2011, Toronto, ON,Canada

Colour Coding Visualization

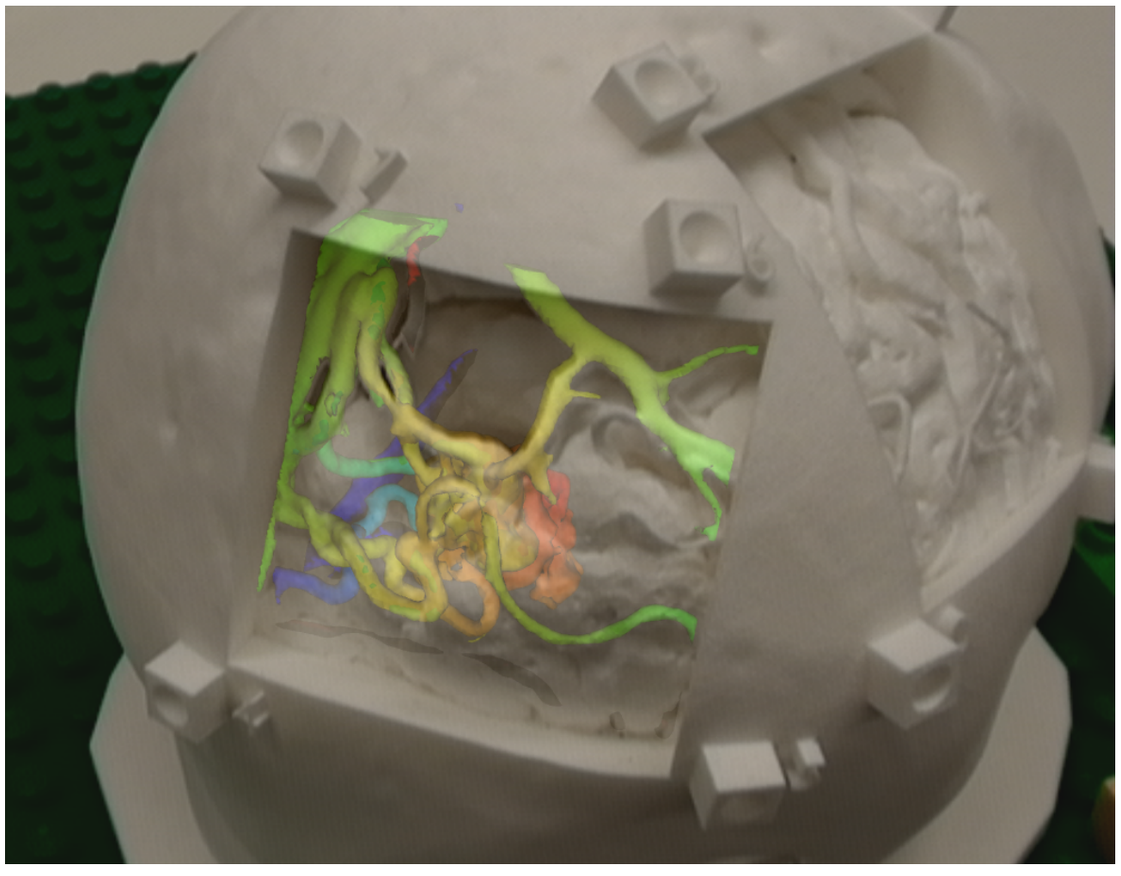
- Explore the use of two colour-coding visualization schemes:
  - Chromadepth: Distance mapped to colour
  - Vessel-type: Colour labeling based on feeding and draining vasculature



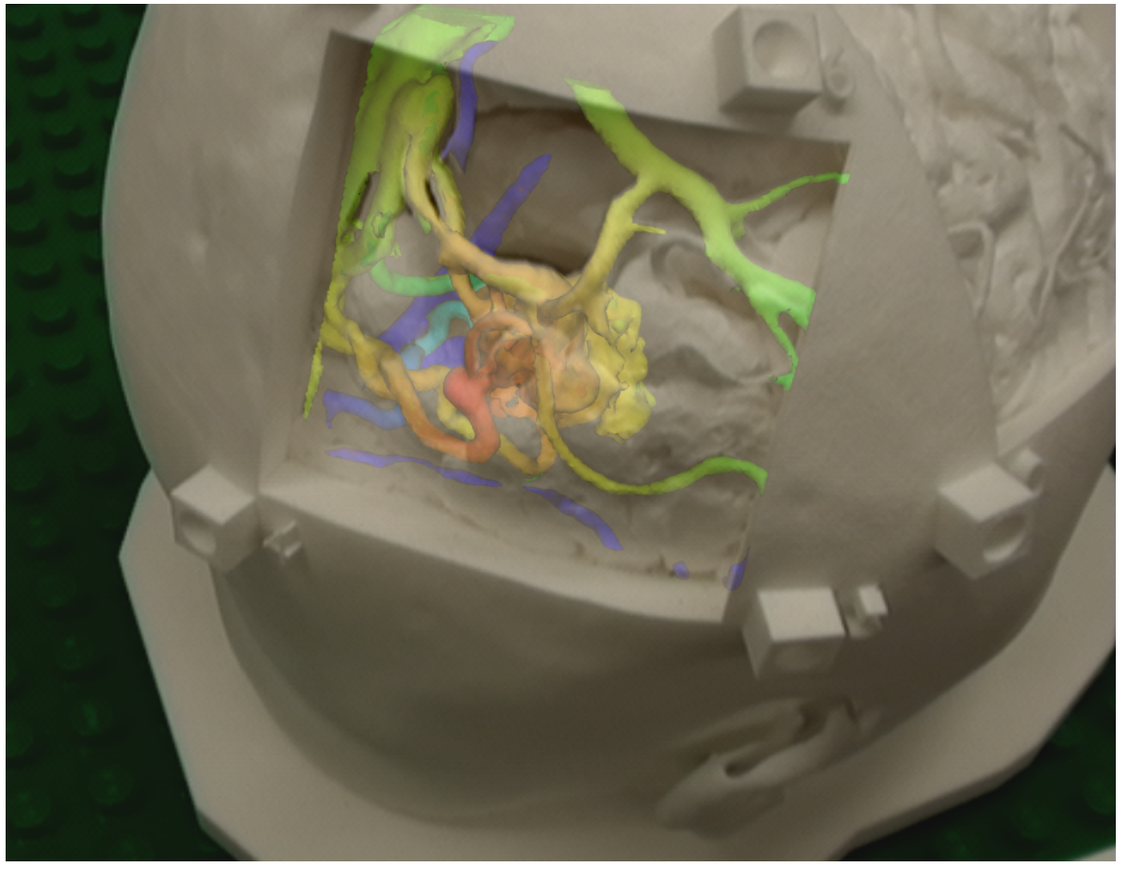


Chromadepth Visualization

- Tested two variations of chromadepth colour mapping:



AVM Euclidean distance: Colour coded distance from the center of the AVM nidus



Viewpoint distance: Colour coded distance from the viewpoint of the camera

Qualitative Evaluation

- The neurovascular surgeon found the AR system useful, particularly in terms of the ability to have the pre-operative images aligned with the intra-operative microscope view. This facilitated the localization of important vessels, especially the small deep feeder arteries to the AVM.

- In terms of the chromadepth rendering, although information about distance from the nidus and the viewpoint was given, the chromadepth rendering did not give a good perception of depth.

- In terms of the vessel colour labeling, the surgeons were able to clearly discern between feeding and draining vessels

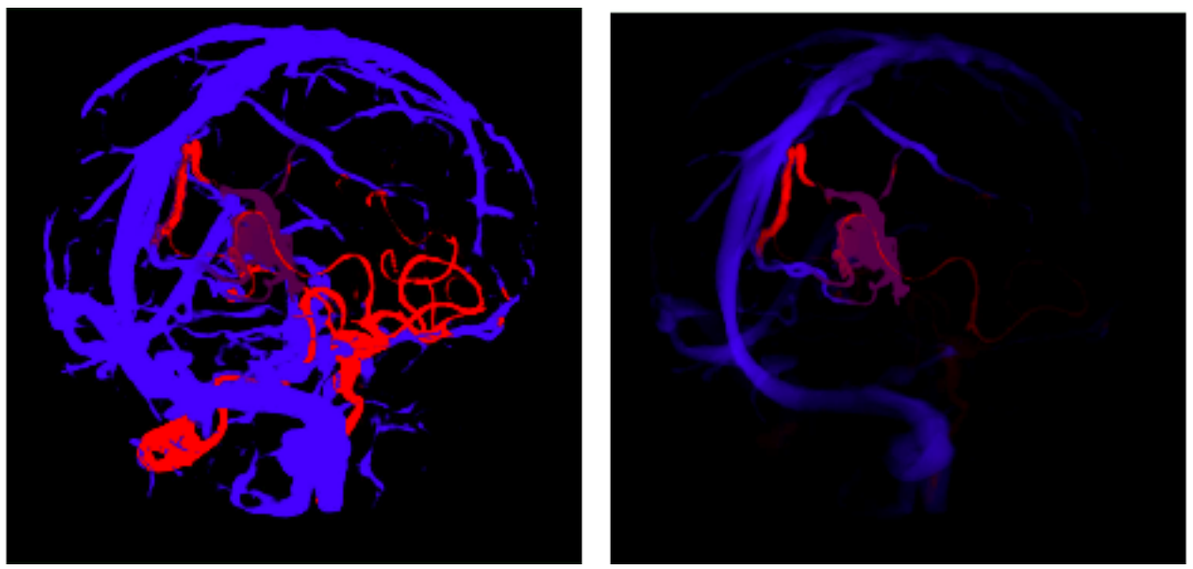
Conclusions

- Developed a prototype AR system and looked at two colour coding schemes to help distinguish the depth and type of vessels visible.

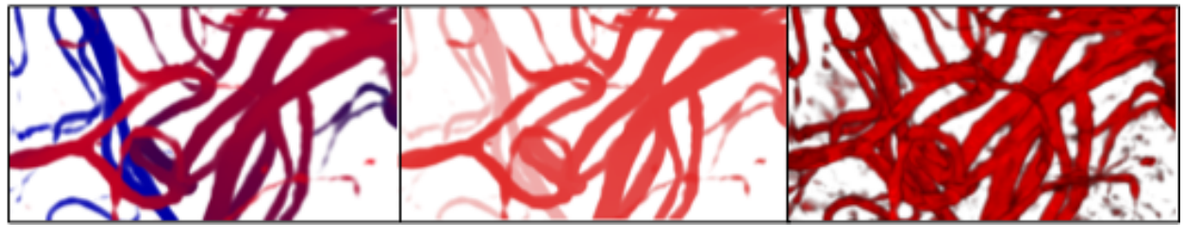
- By using AR:
  - Help the surgeon understand the location and type of vessels below the visible surface of the brain,
  - Reduce surgical time, increasing surgical precision
  - Enable a better intra-operative understanding of AVM topology.

Future Work

- We have developed visualization methods and will them integrate into our AR system:
  - Visualization methods based on topological distances to reduce clutter
  - Previously evaluated volume rendered depth cues
- Evaluate with expert subjects, to see which visualization methods provide best spatial and depth understanding of the vessels



S. J. S. Chen, M. Kersten-Oertel, S. Drouin, and D. L. Collins. Visualizing the path of blood flow for image guided surgery of cerebral arteriovenous malformations. SPIE Medical Imaging, San Diego, CA, Feb 4–9, 2012.



M. Kersten-Oertel, S. J. S. Chen, D. L. Collins. "Enhancing depth perception of volume-rendered angiography data". VIS 2011, Providence, RI, Oct. 23–38, 2011.

Questions?