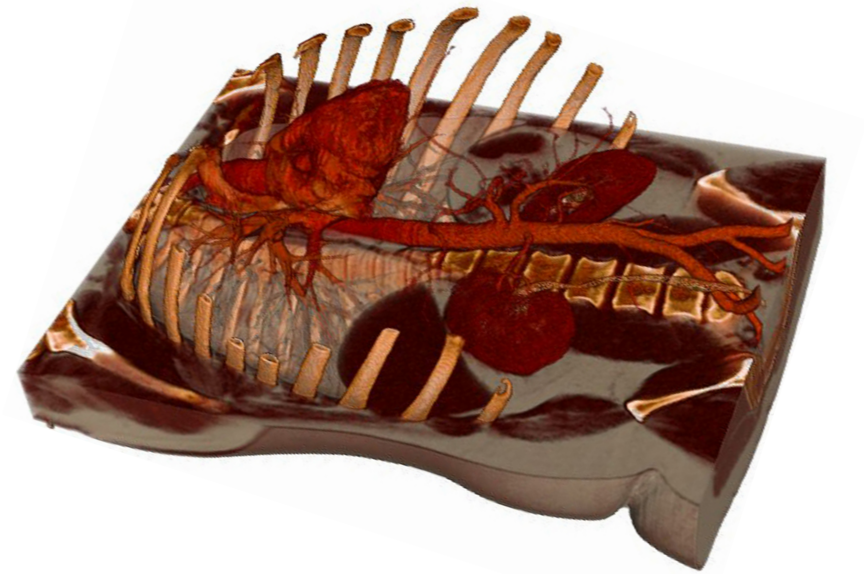
FACULTY OF ENGINEERING
AND ARCHITECTURE

E016712: Computer Graphics

Medical Visualization Part 2



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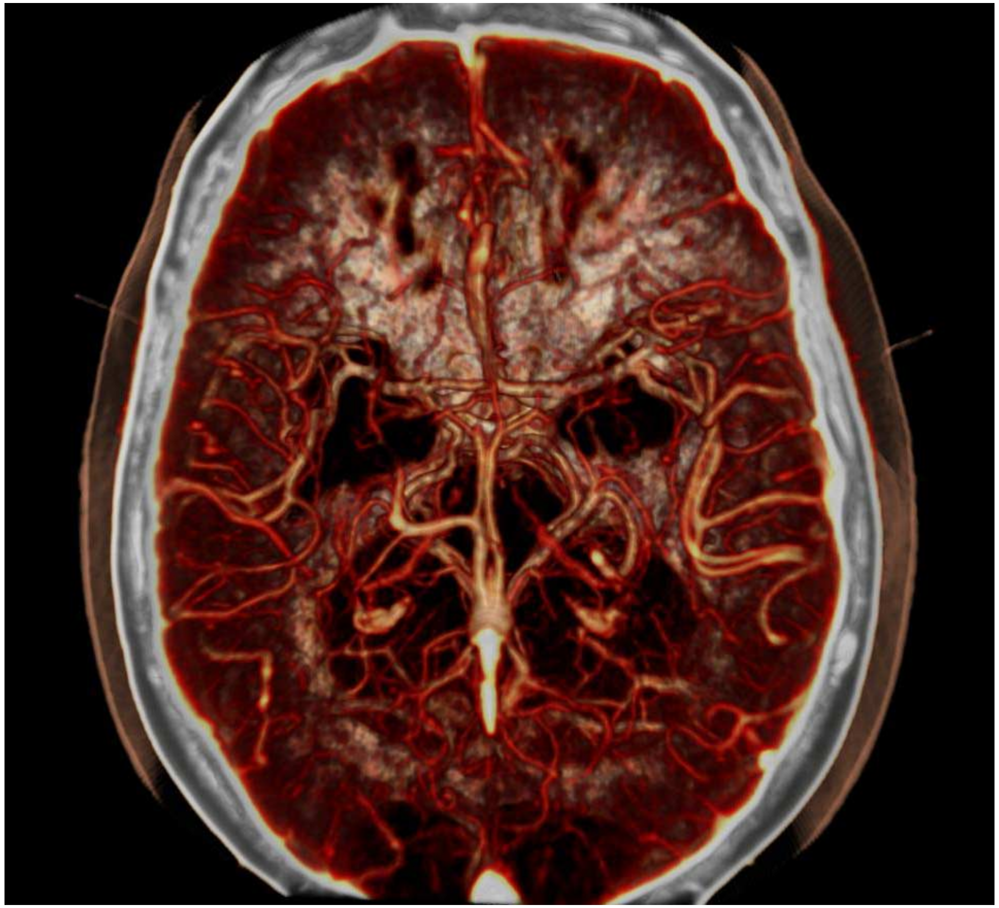
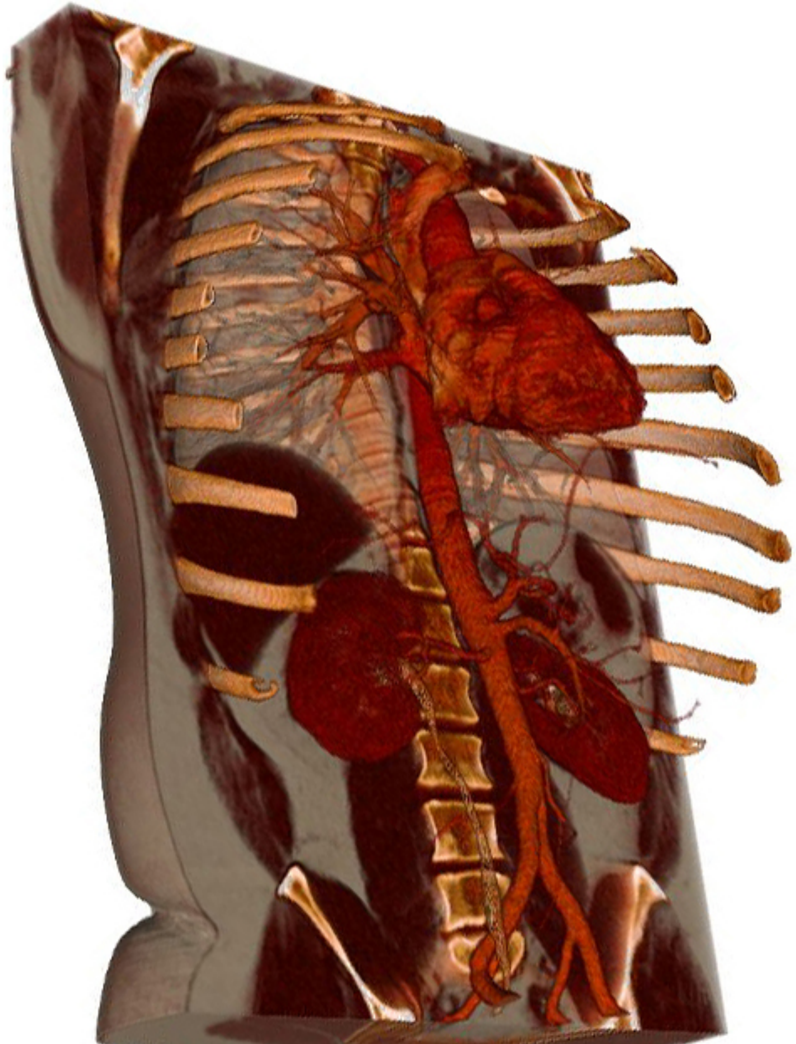
Outline

- Presentation outline:
  - Segmentation & skeletonization
  - Functional imaging & visualization
  - Use cases

Visualization vs quantification

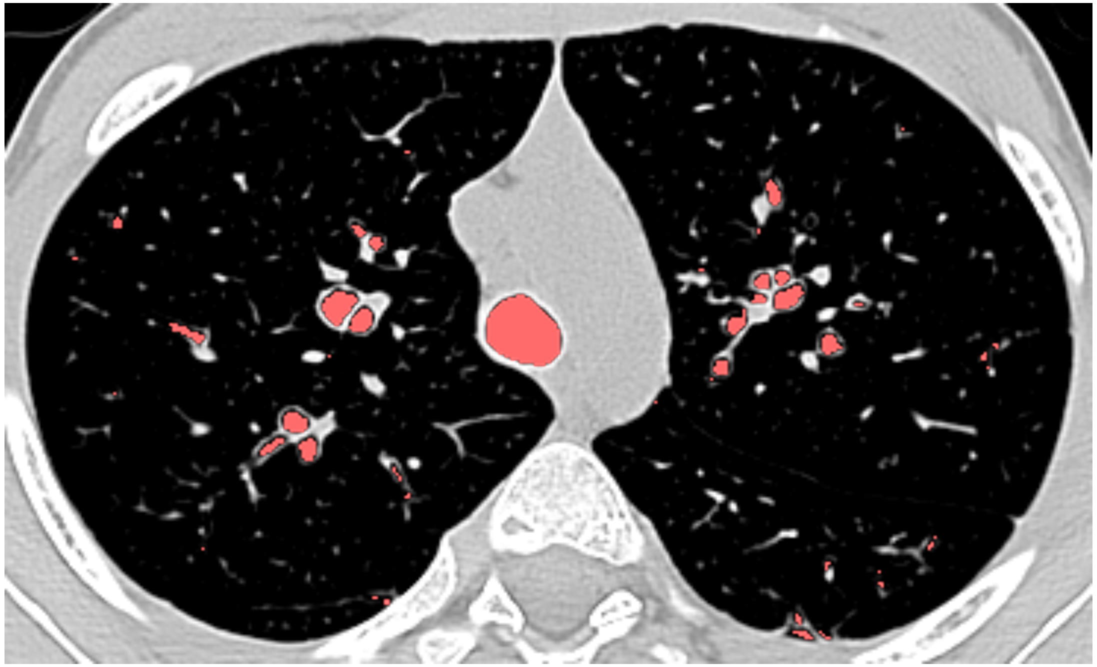
- Visualization: surface rendering, volume rendering…
- Not enough for diagnosis or treatment: we need measurements!



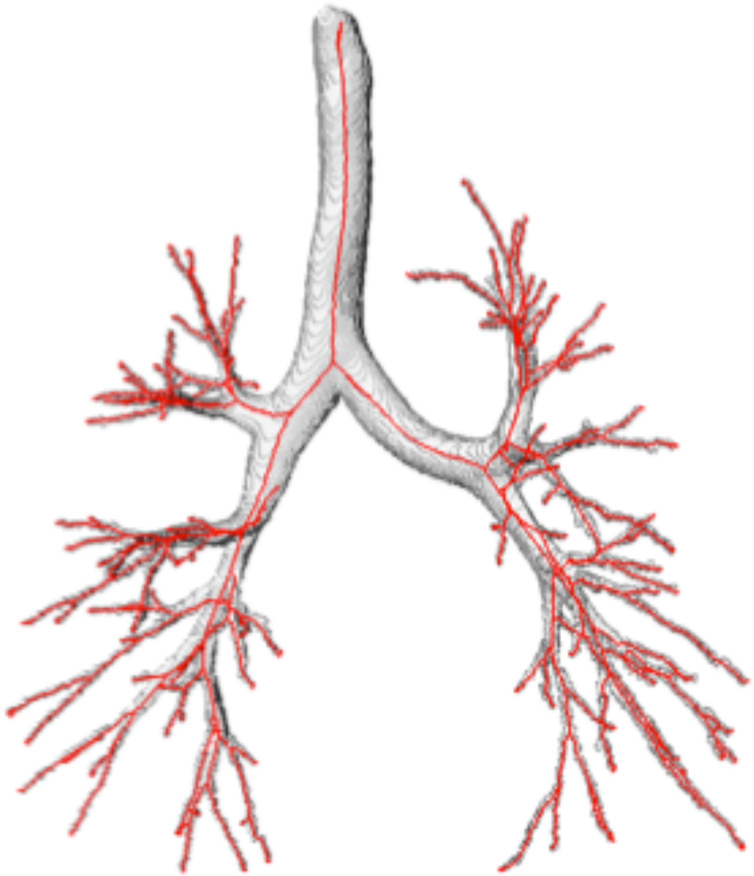


Medical image analysis

- Segmentation: determine which pixels belong to which organs/tissues
- Skeletonization: extracting centerlines
- With segmentation and skeletonization we can perform measurements!



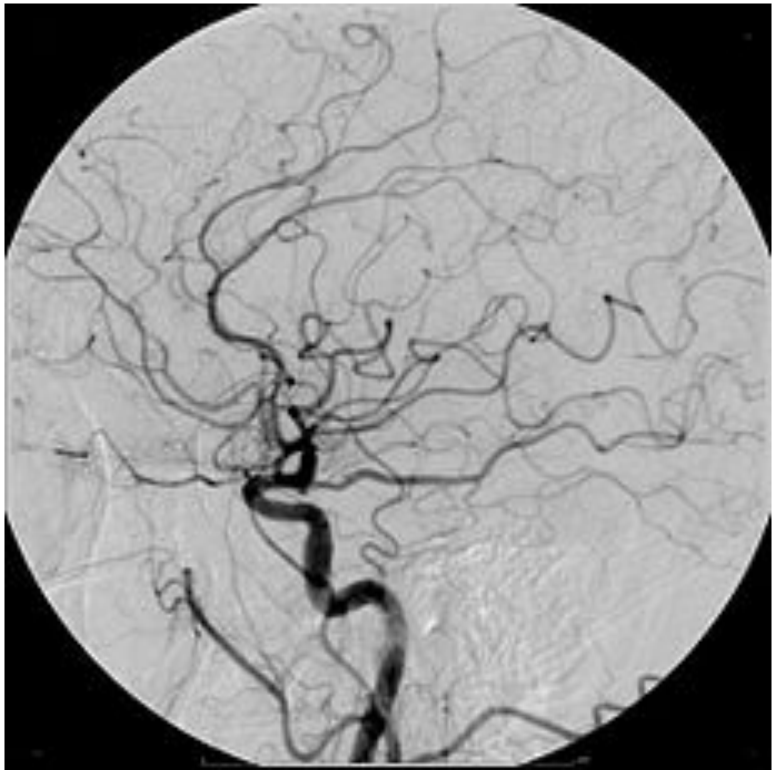
Lung cross-sectional slice



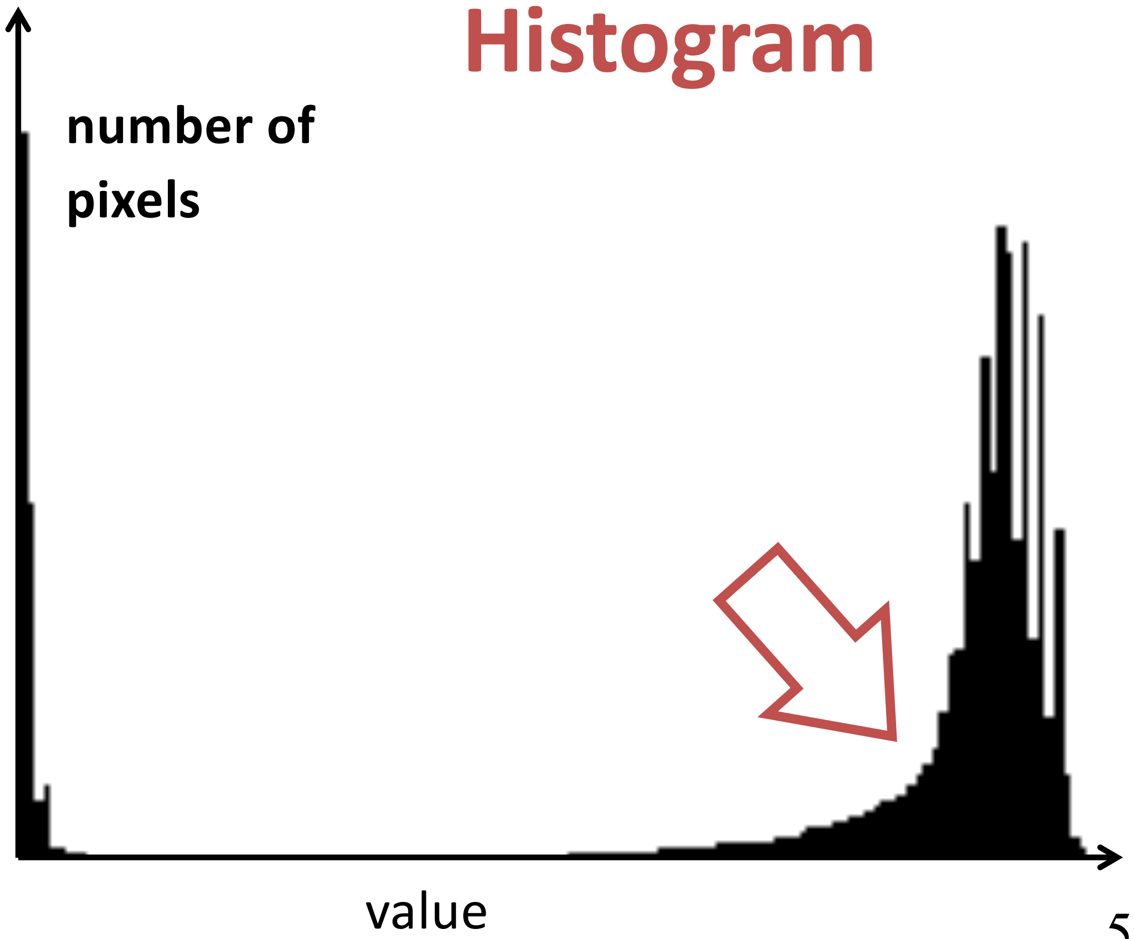
Segmentation methods: Thresholding

- Separate objects in image by their brightness (“color”)
- Automatic method: choose threshold at maximum histogram curvature

Image



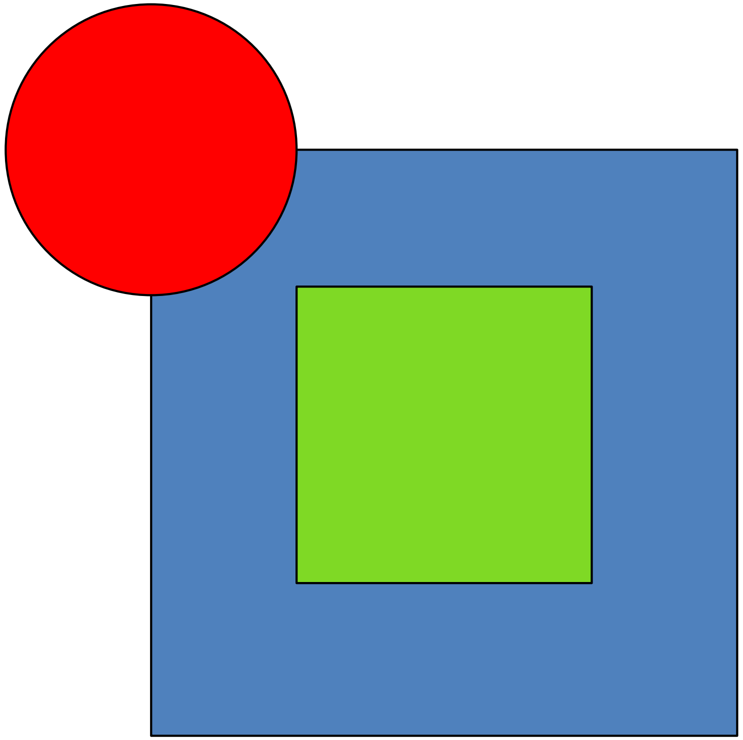
Histogram



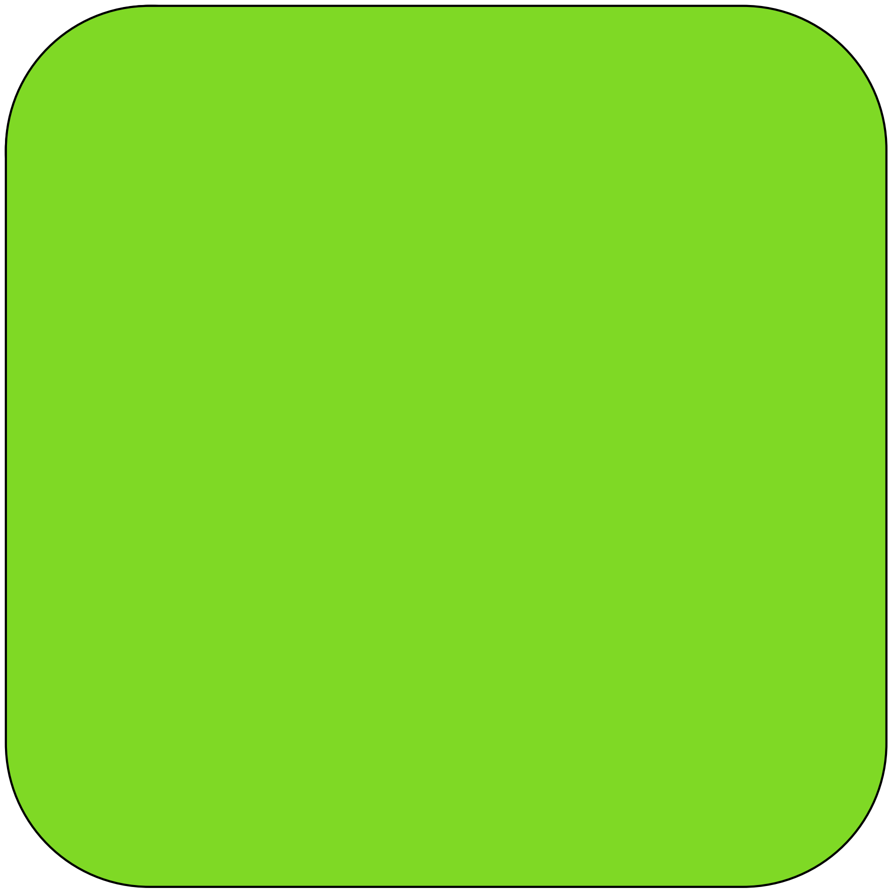
Segmentation methods: Morphology

- Structuring element moves on the object
- Two basic operations:

Erosion

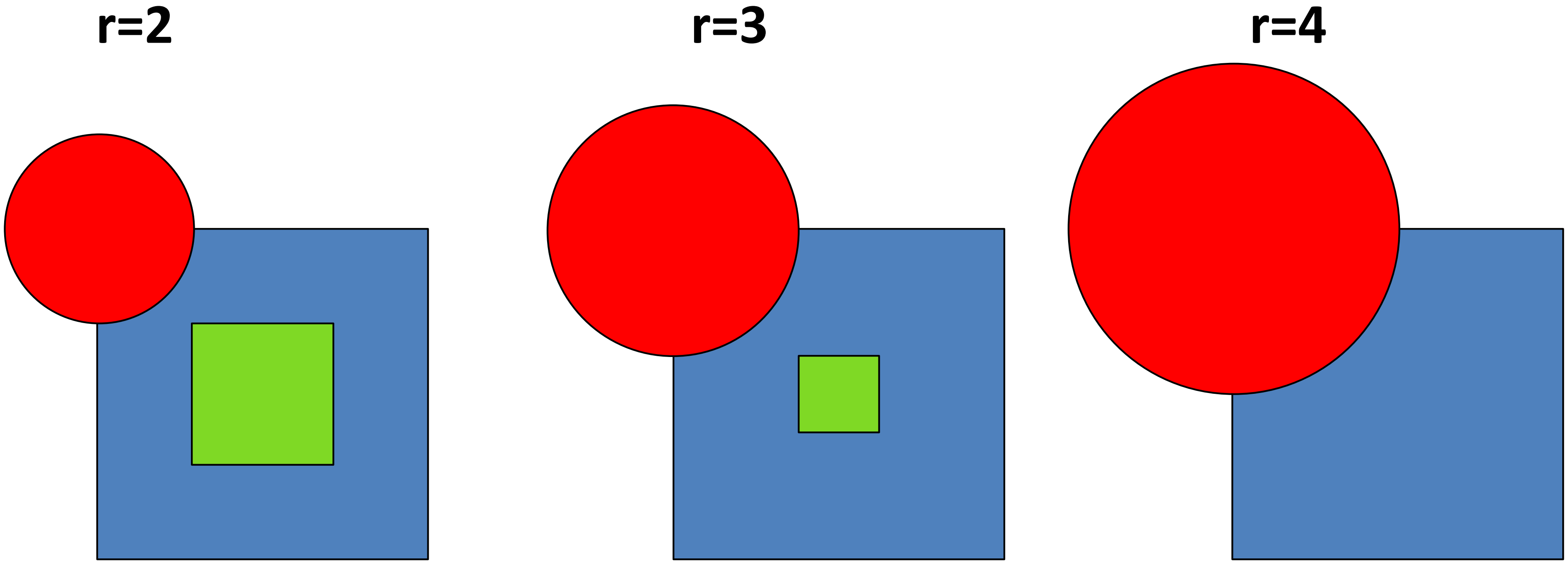


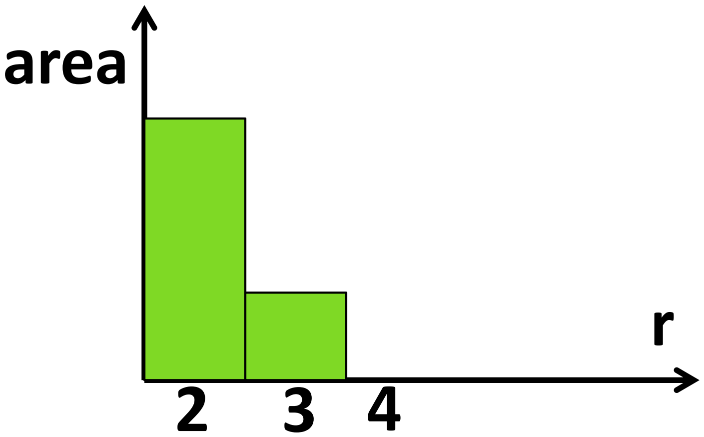
Dilation



Segmentation methods: Morphological profiles

- Use structuring elements of different size:

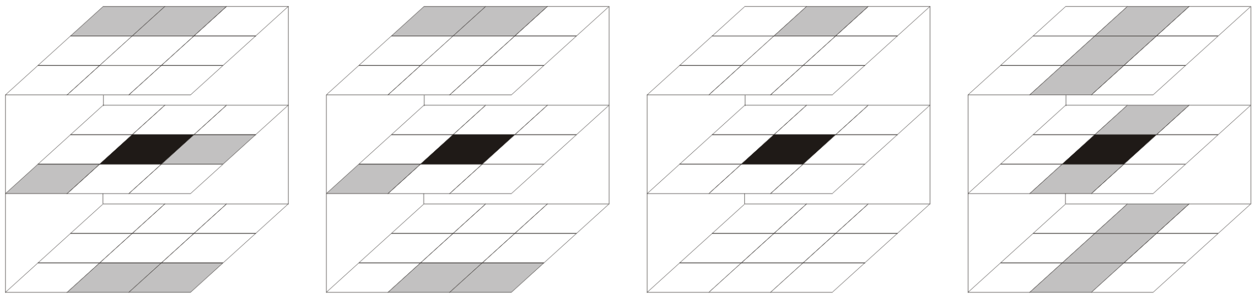




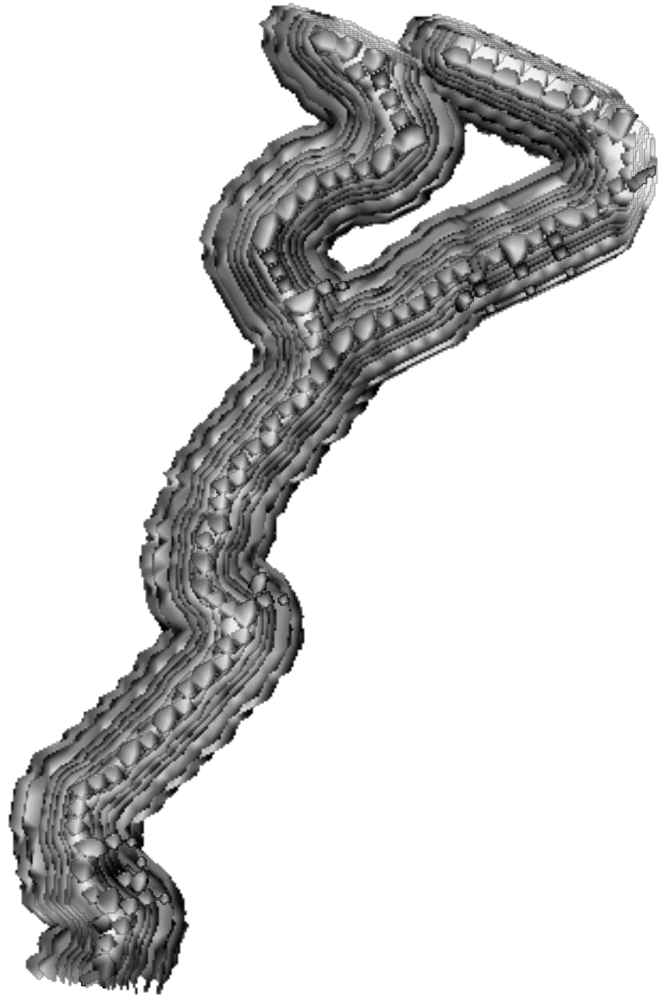
- We are able to determine the size of an object in the image – binary and gray-scale!

Ordered skeletonization

- Extract image of centerlines
- Iterative thinning in a specific order (from vessel borders inwards)
- Remove pixels with preserving connectivity in 26-neighborhood



Pixel redundant | **Pixel not redundant** | **Pixel not redundant** | **Pixel redundant**



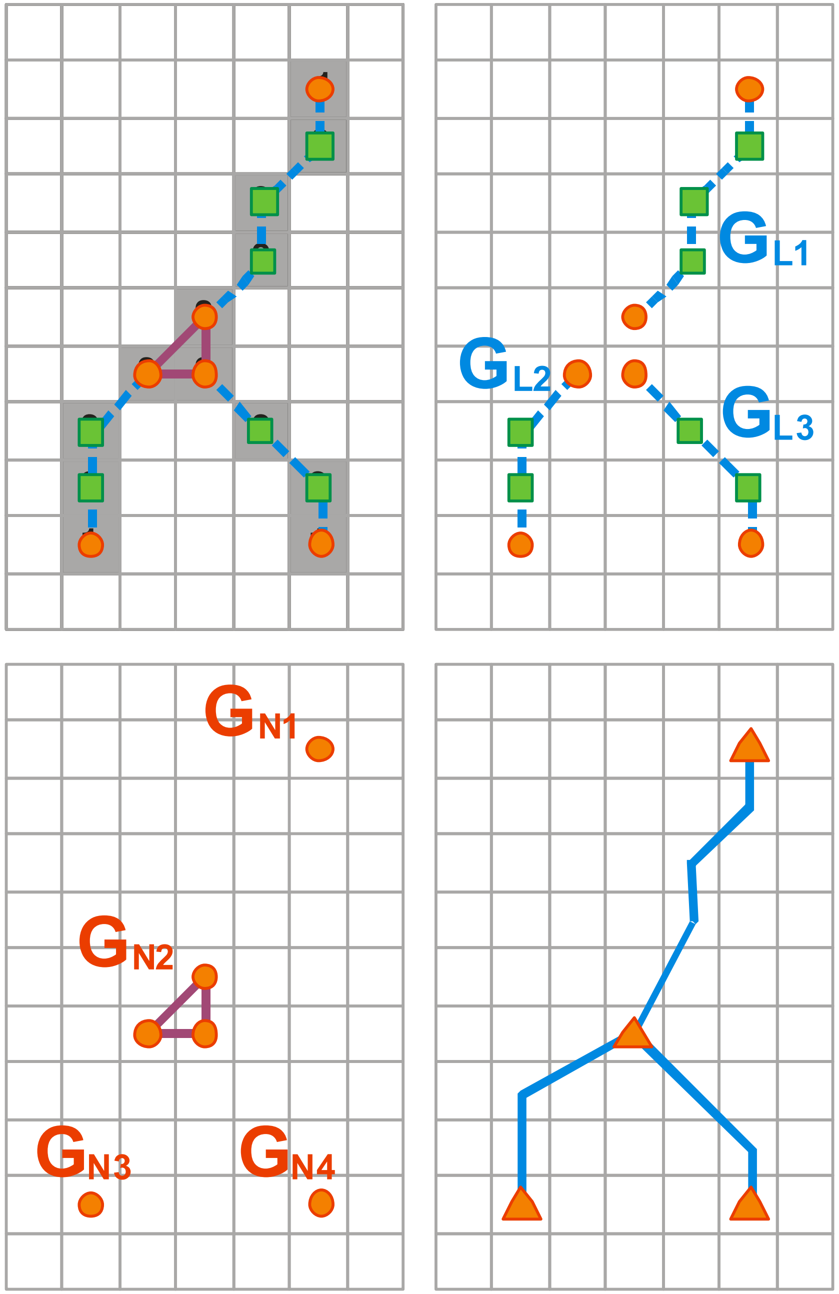
- Result: one pixel wide centerlines!

Ordered skeletonization

- Enables best path calculations (for catheter guidance)
- Allows measurements at each vessel location (e.g. radii, bending angles…)
- Does NOT classify structure into separate vessels
- Does NOT detect vessel bifurcations or malformations

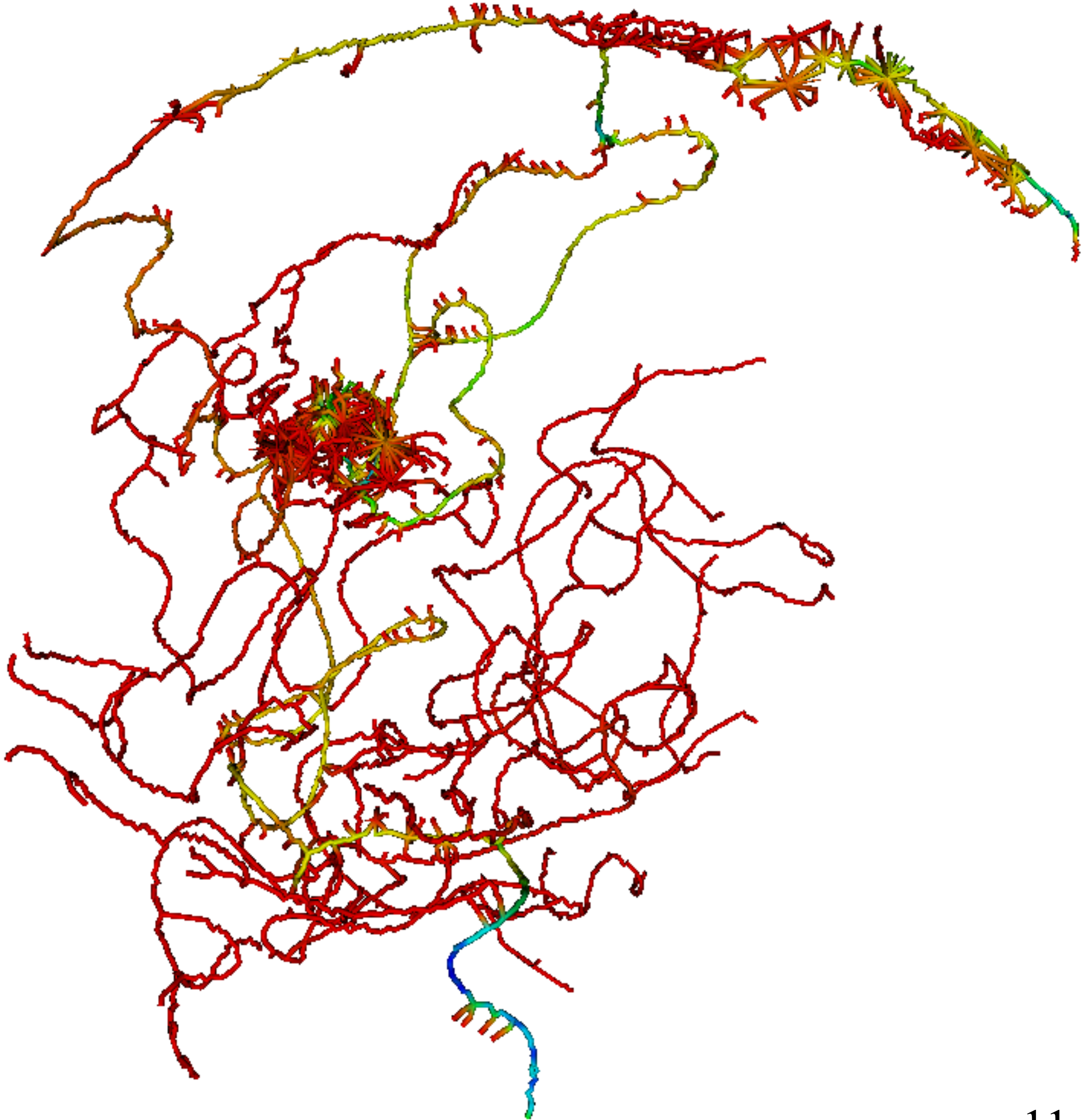
Skeleton building

- Convert image to graph
- Classify vertices by number of neighbors
- Classify edges by vertices they connect
- Make link and node subgraphs
- Create skeleton



Skeleton

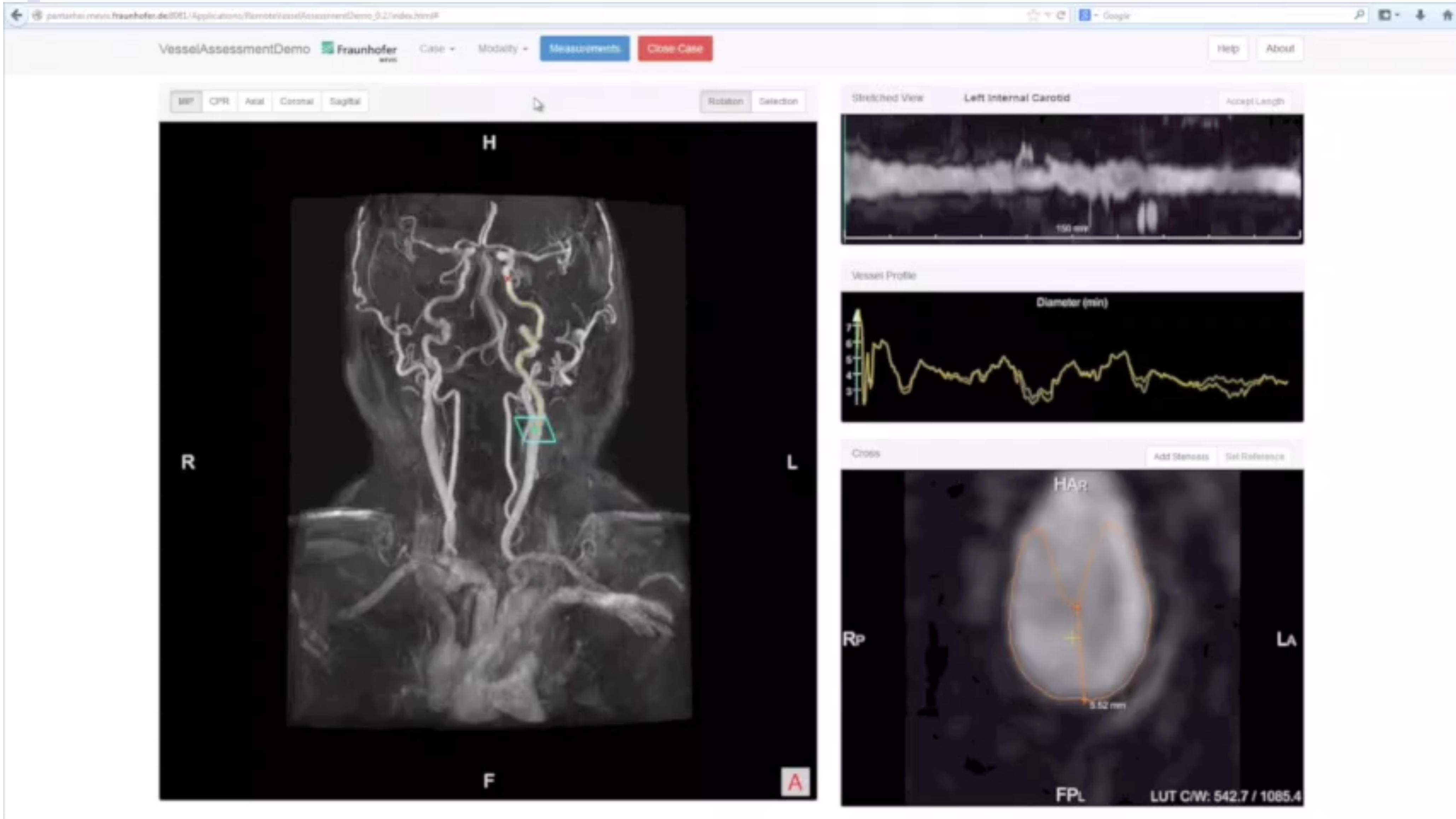
- Allows various path calculations (for catheter guidance)
- Allows automatic AVM detection and extraction
- Classifies the structure into vessel branches and bifurcations
- Better visualization with multiple color mappings



VTK tube filter for centerline visualization

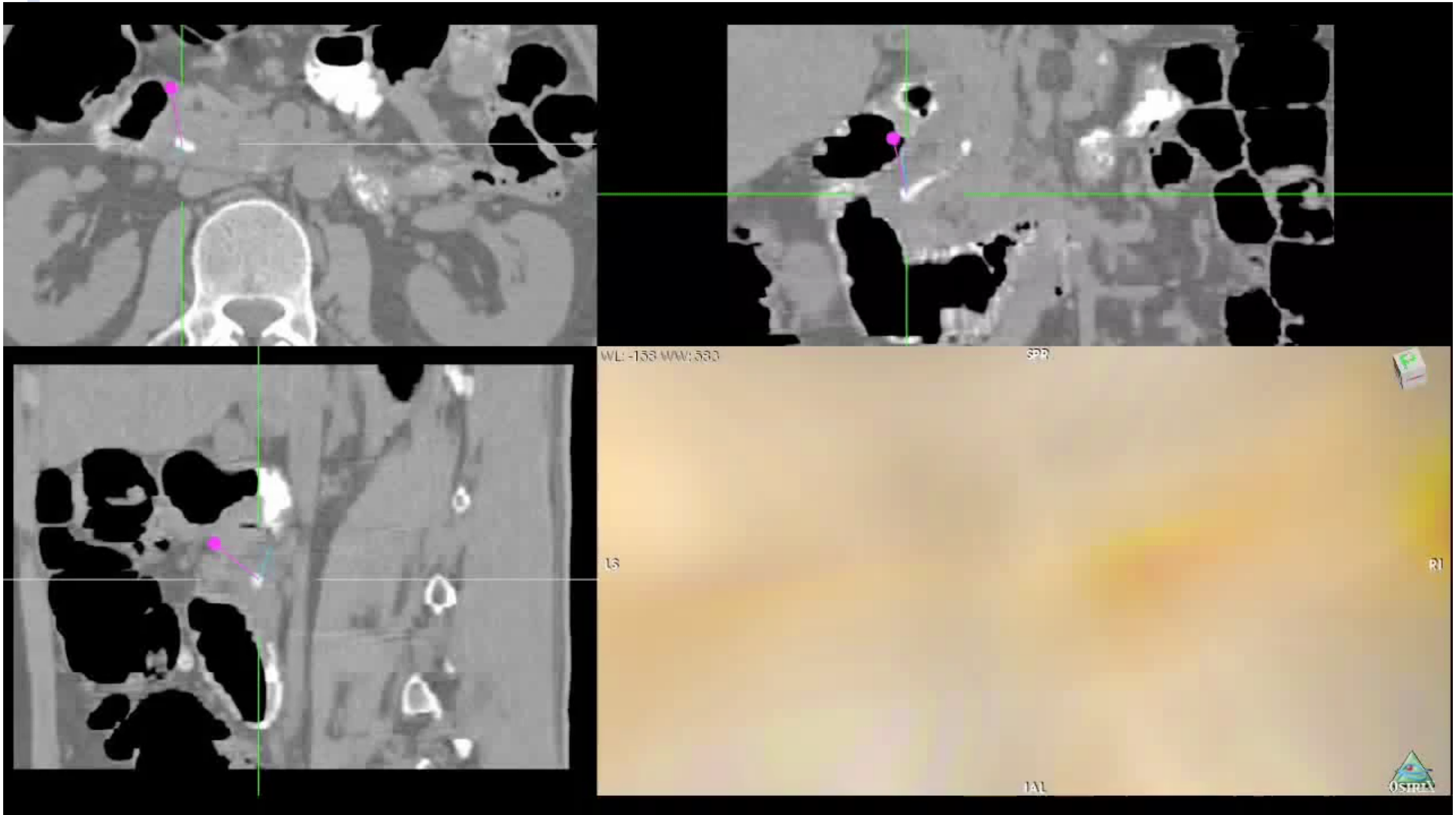
```
vtkSmartPointer<vtkLineSource> lineSource =
vtkSmartPointer<vtkLineSource>::New(); lineSource->SetPoint1(1.0, 0.0, 0.0);
lineSource->SetPoint2(0.0, 1.0, 0.0);

vtkSmartPointer<vtkTubeFilter> tubeFilter =
vtkSmartPointer<vtkTubeFilter>::New();
tubeFilter->SetInputConnection(lineSource->GetOutputPort());
tubeFilter->SetRadius(.025);
tubeFilter->SetNumberOfSides(50);
tubeFilter->Update();

vtkSmartPointer<vtkPolyDataMapper> tubeMapper =
        vtkSmartPointer<vtkPolyDataMapper>::New();
tubeMapper->SetInputConnection(tubeFilter->GetOutputPort());
vtkSmartPointer<vtkActor> tubeActor = vtkSmartPointer<vtkActor>::New();
tubeActor->SetMapper(tubeMapper);

renderer->AddActor(tubeActor);
```

Vessel cross-section visualization



Virtual endoscopy: Pancreatic duct

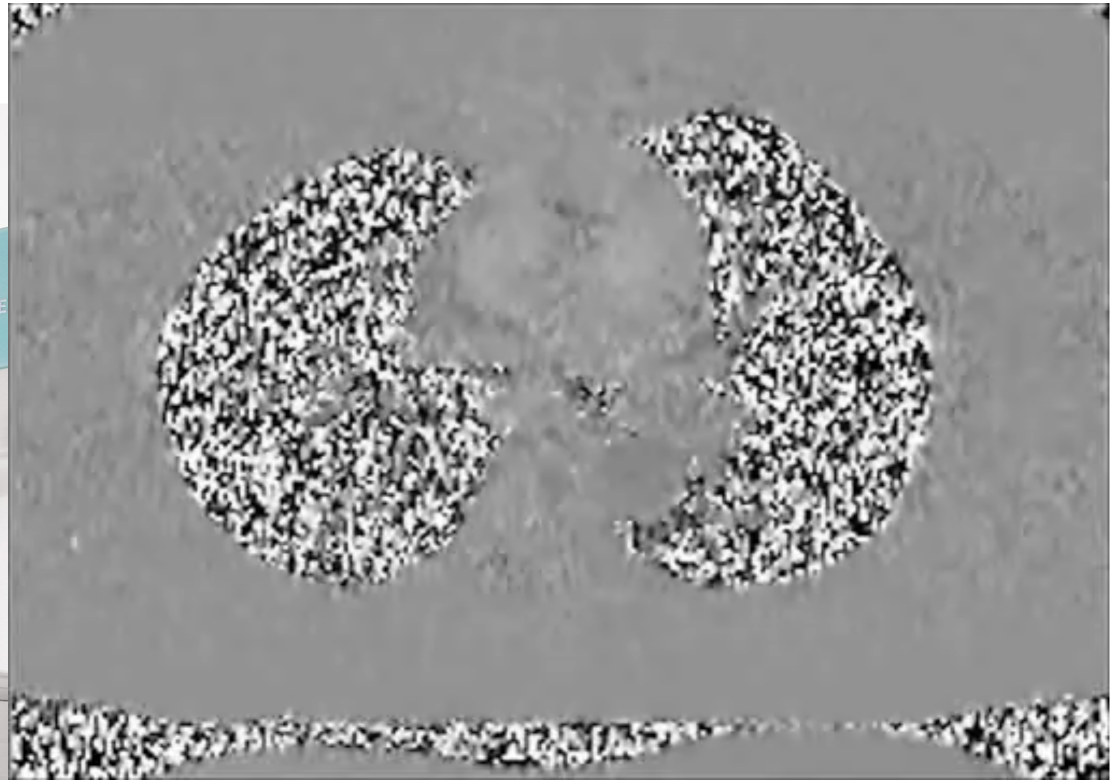
- Follow a centerline while moving through vessels/organs.



Magnetic Resonance Imaging (MRI)

Structural imaging

Functional imaging



Magnetic Resonance Imaging (MRI)

- MRI uses static and variant magnetic field to acquire image slices by modifying nuclear spins.

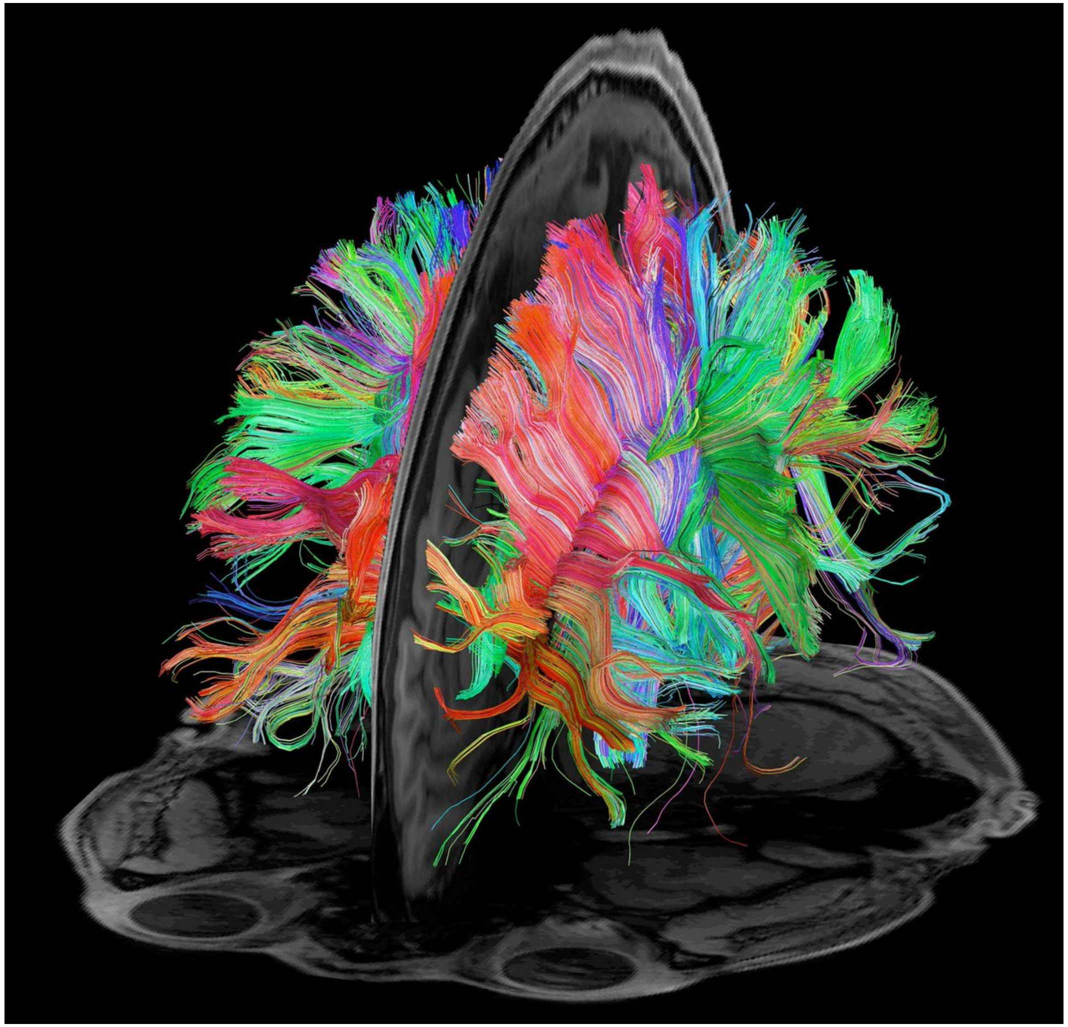
- Functional MRI (fMRI) can measure function: diffusion, oxygenation of blood, blood flow (inversion of incoming blood signal).

- Requires advanced image processing, analysis and visualization.

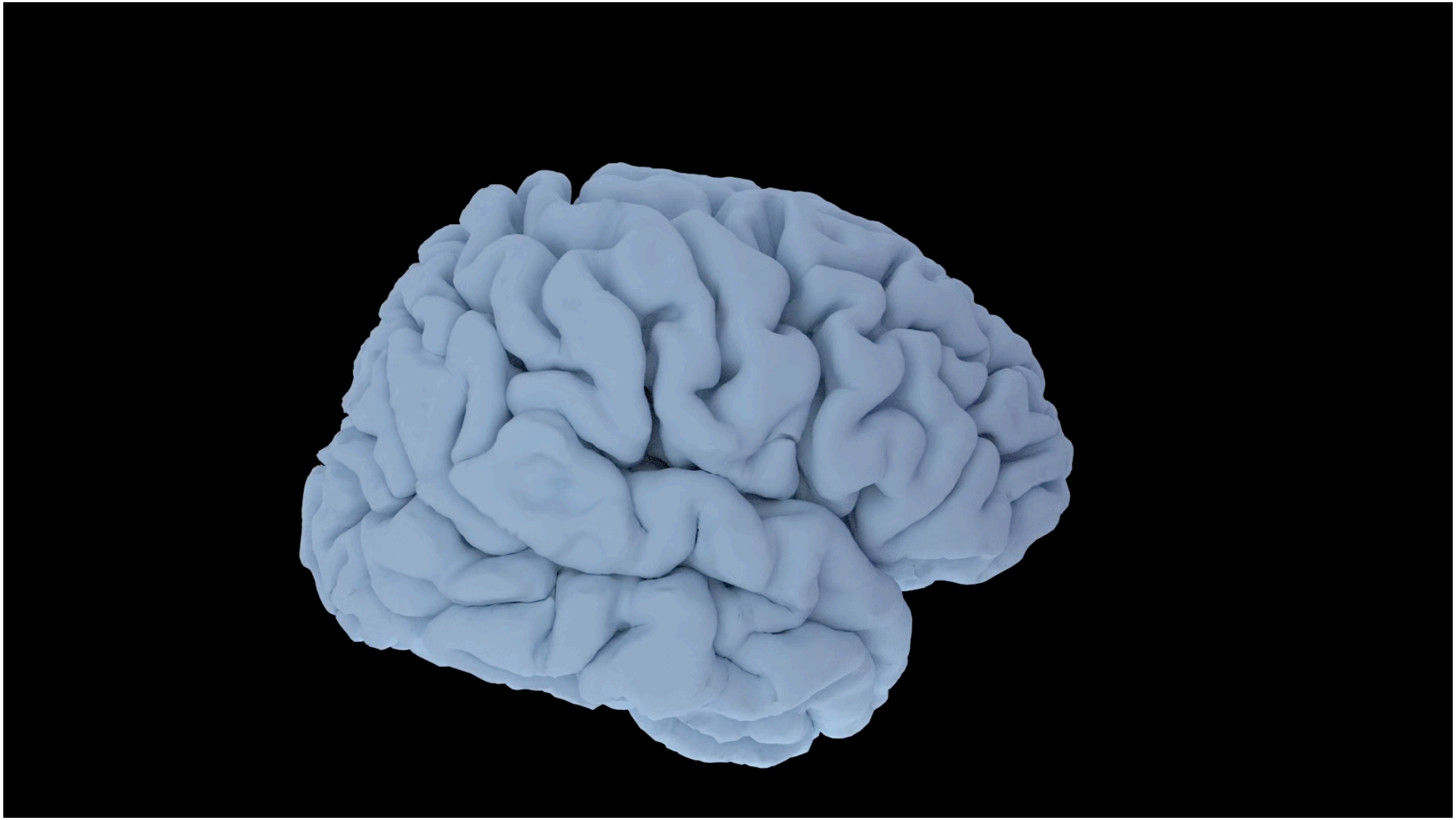
- Visualization
  - Diffusion Tensor Imaging (DTI)
  - Blood flow visualization using Phase-Contast MRI (PC-MRI)

Diffusion tensor imaging (DTI)

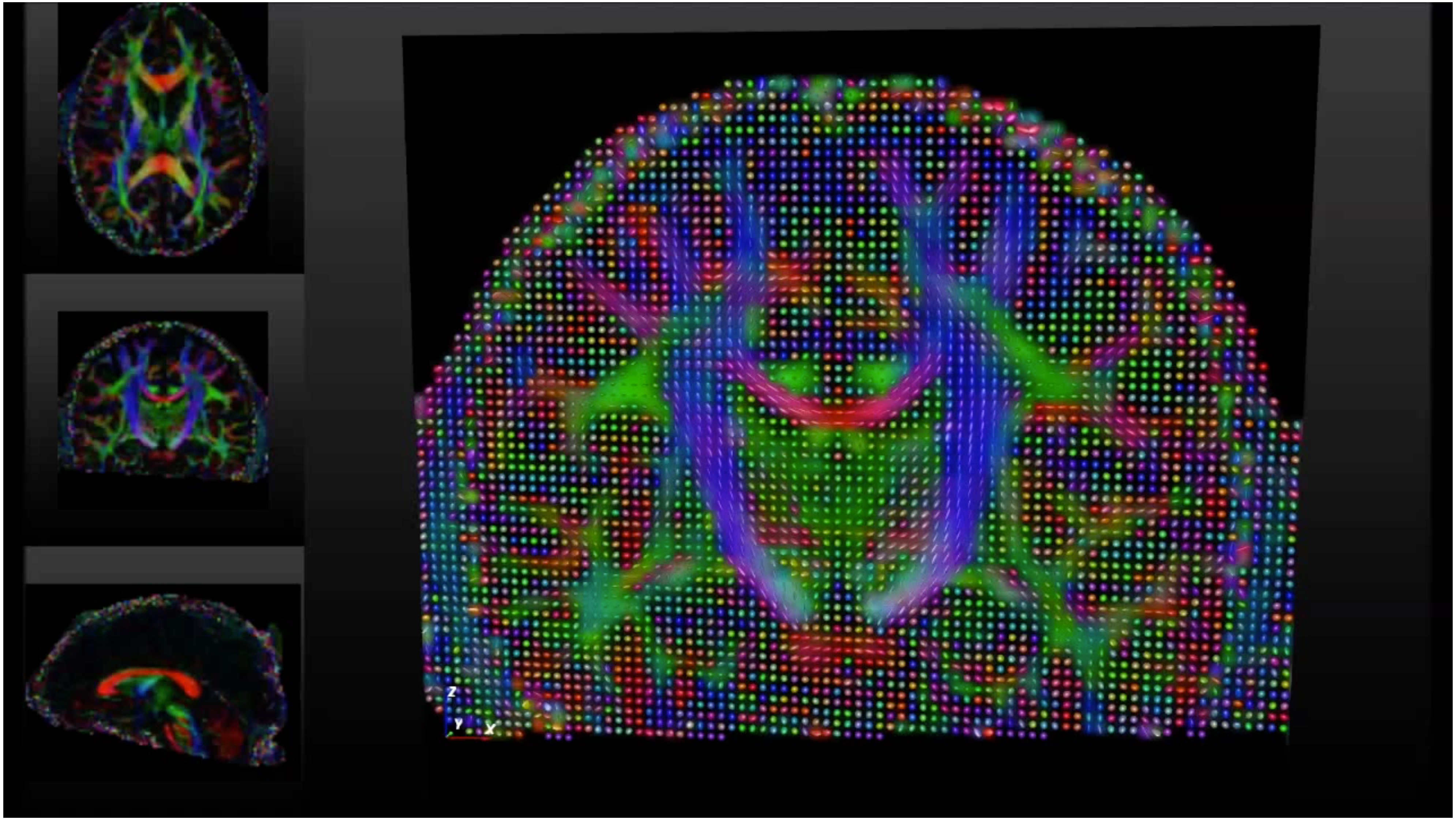
- fMRI can measure diffusion of liquids (water) in brain.
- Diffusion directions correspond to connections (pathways) of brain
- Visualization: calculate the direction of diffusion for each voxel, connect to fibers and color-code according to direction and connectivity.



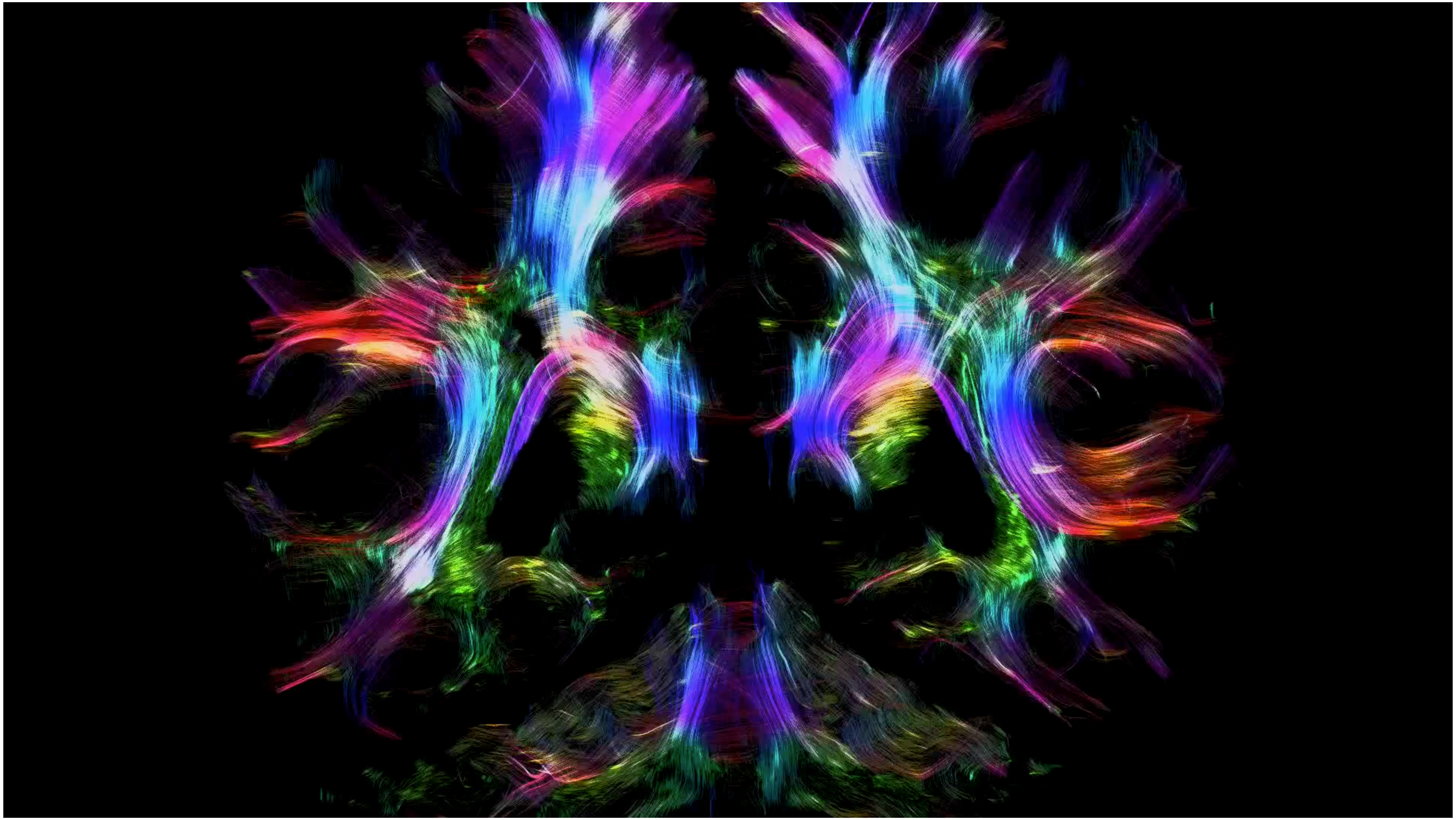
Diffusion tensor imaging (DTI)



DTI: Fiber tracking

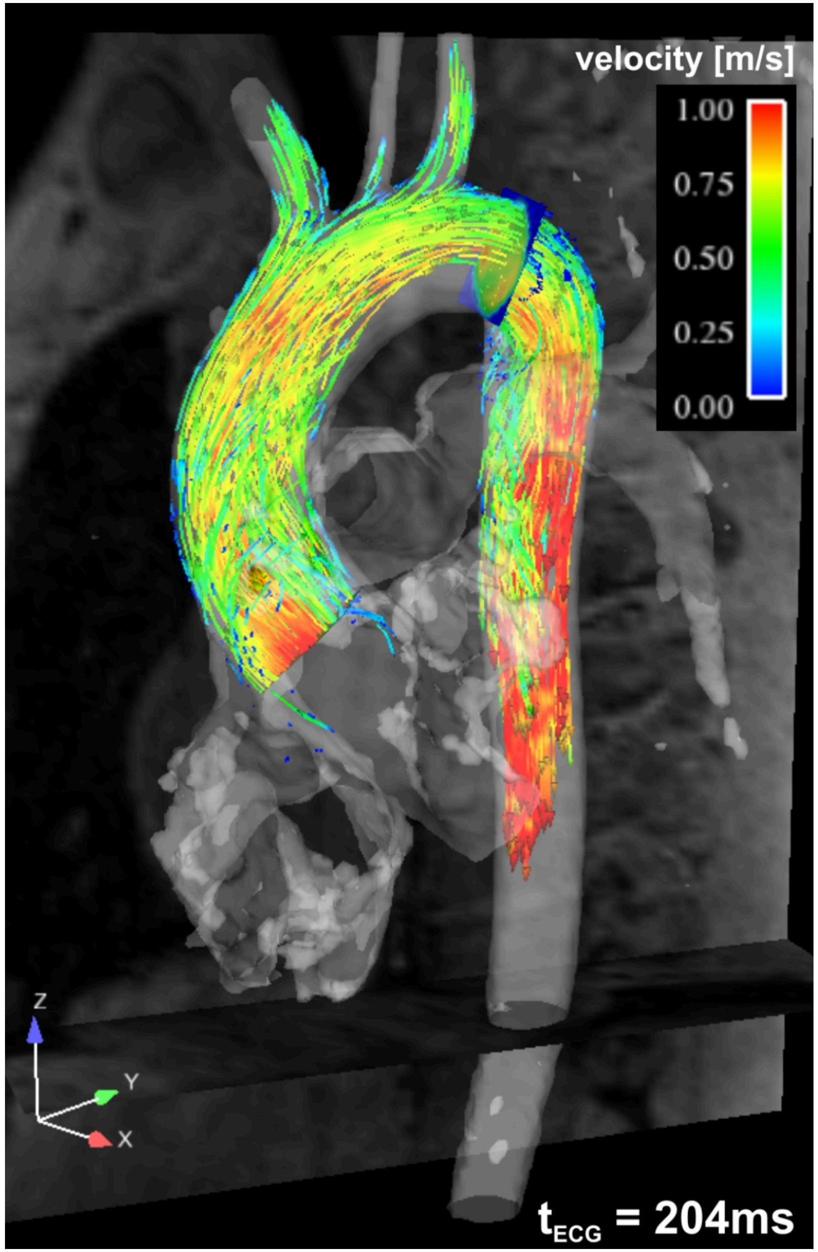


DTI: Slicing

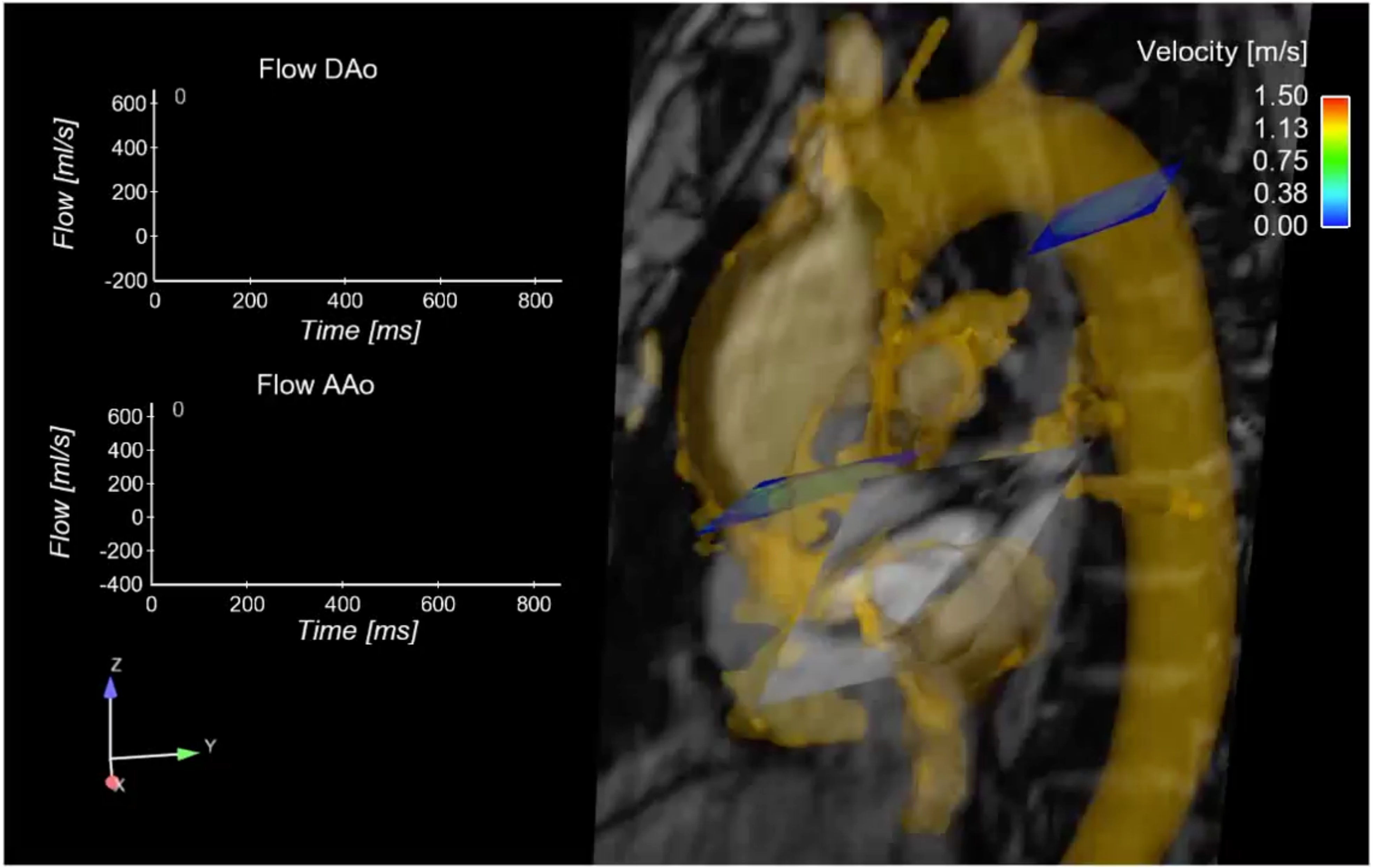


4D blood flow visualization

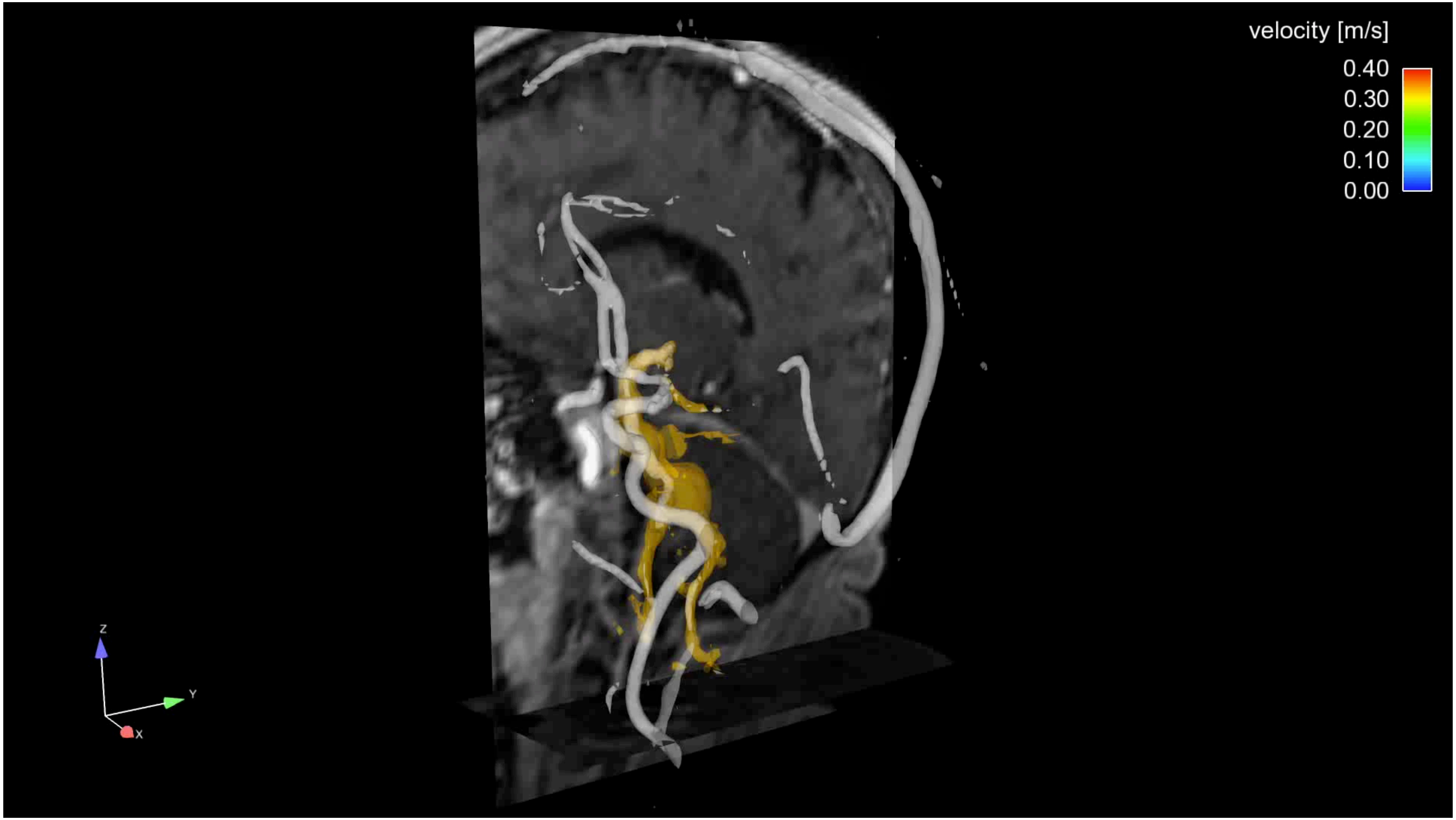
- Phase Contrast MRI can measure blood flow.
- White/black indicate blood flow up/down, intensity is proportional to velocity
- Visualization: calculate the direction of flow for each voxel, connect to flow stream-lines and color-code according velocity.



4D blood flow visualization: flow curves



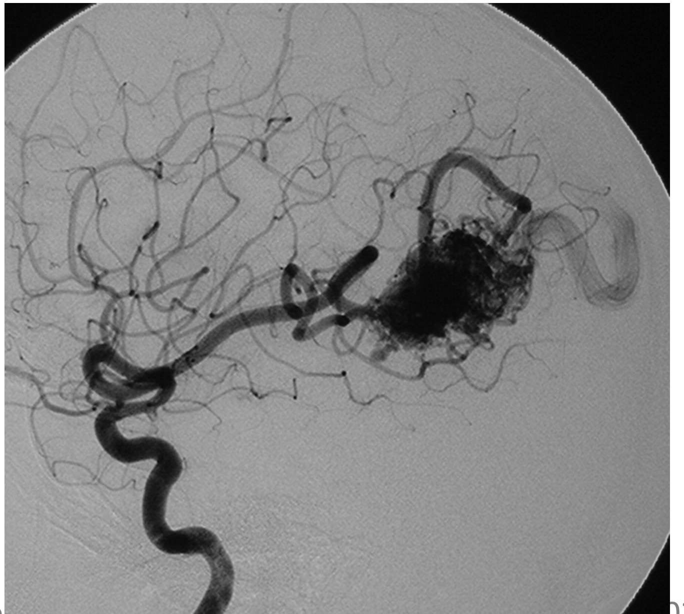
4D blood flow visualization

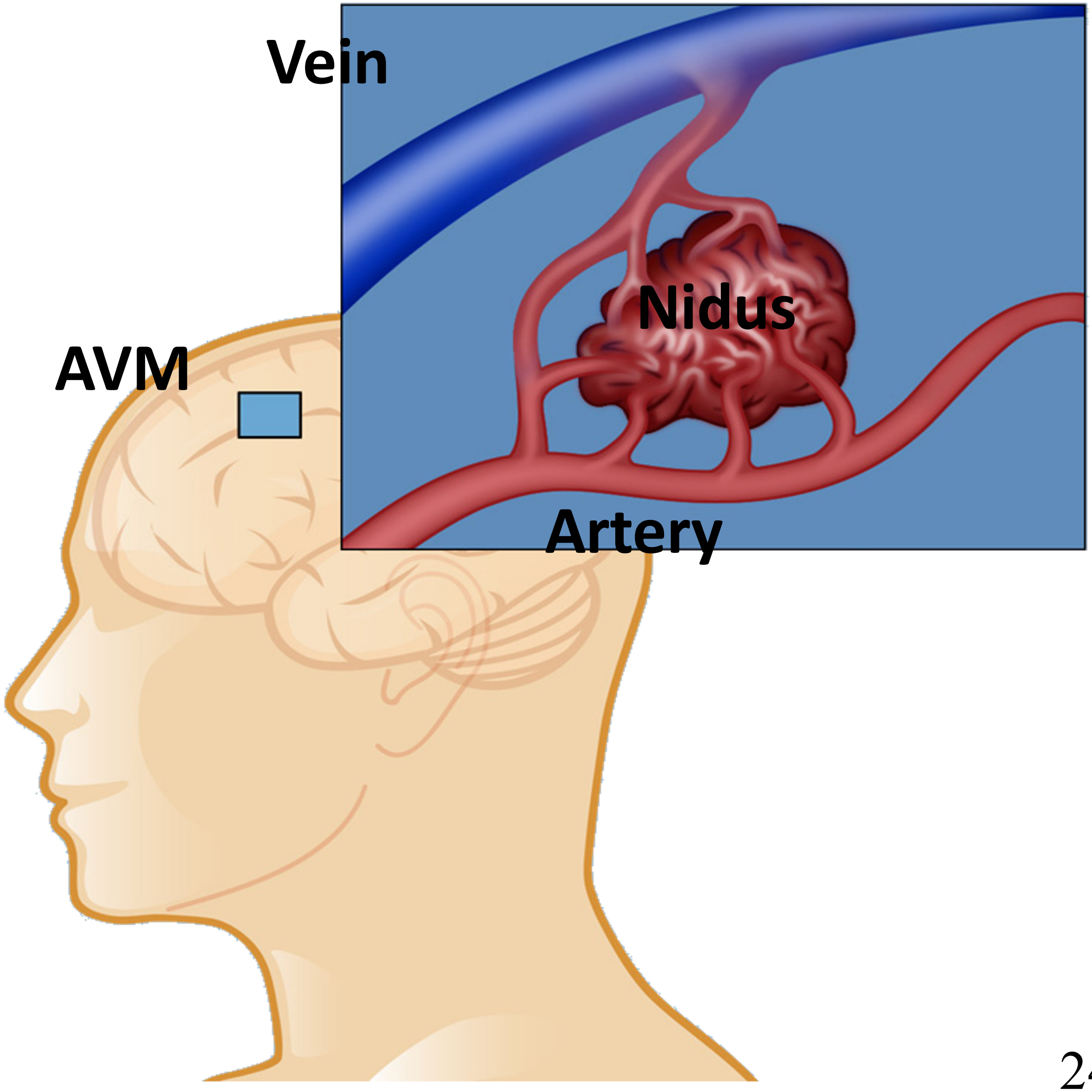


Use case: Arteriovenous Malformation (AVM)

- Direct artery-vein connection (no capillaries)
- Nidus – malformed blood vessels (danger of rupture)

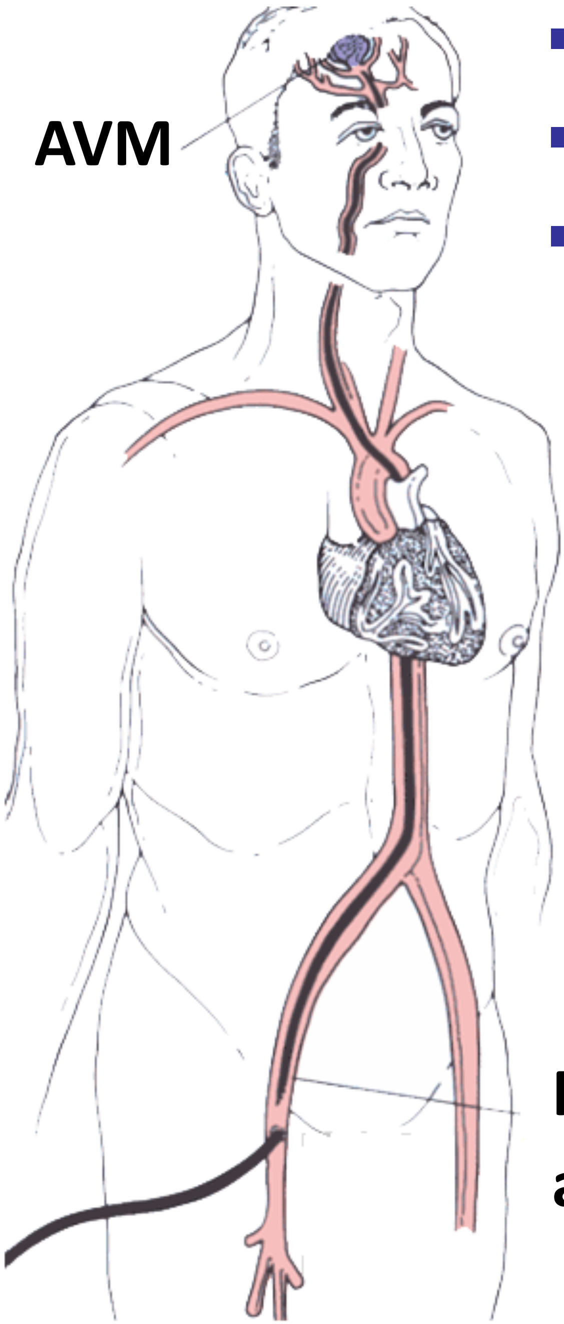
- Treatment:
  - Surgery
  - Embolization
  - Radio-surgery

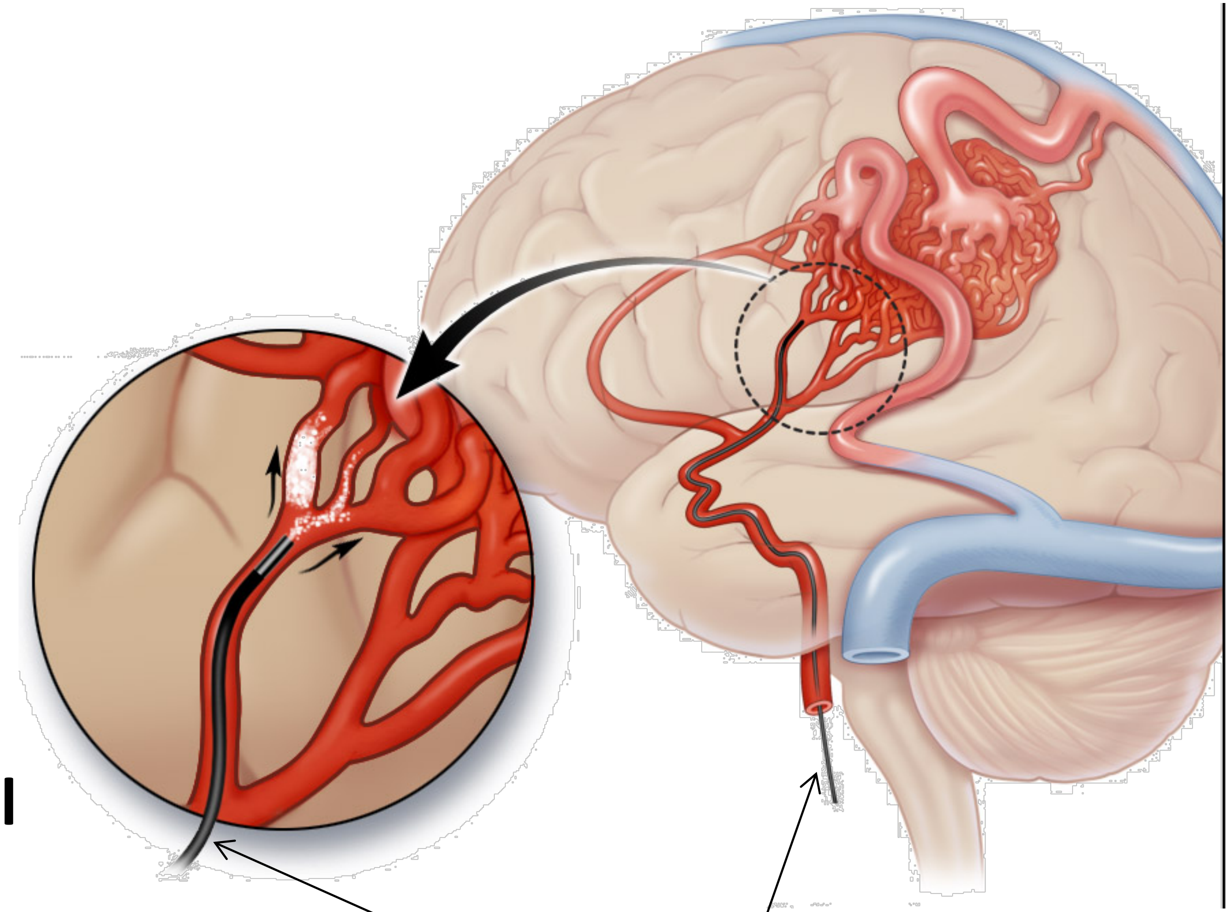




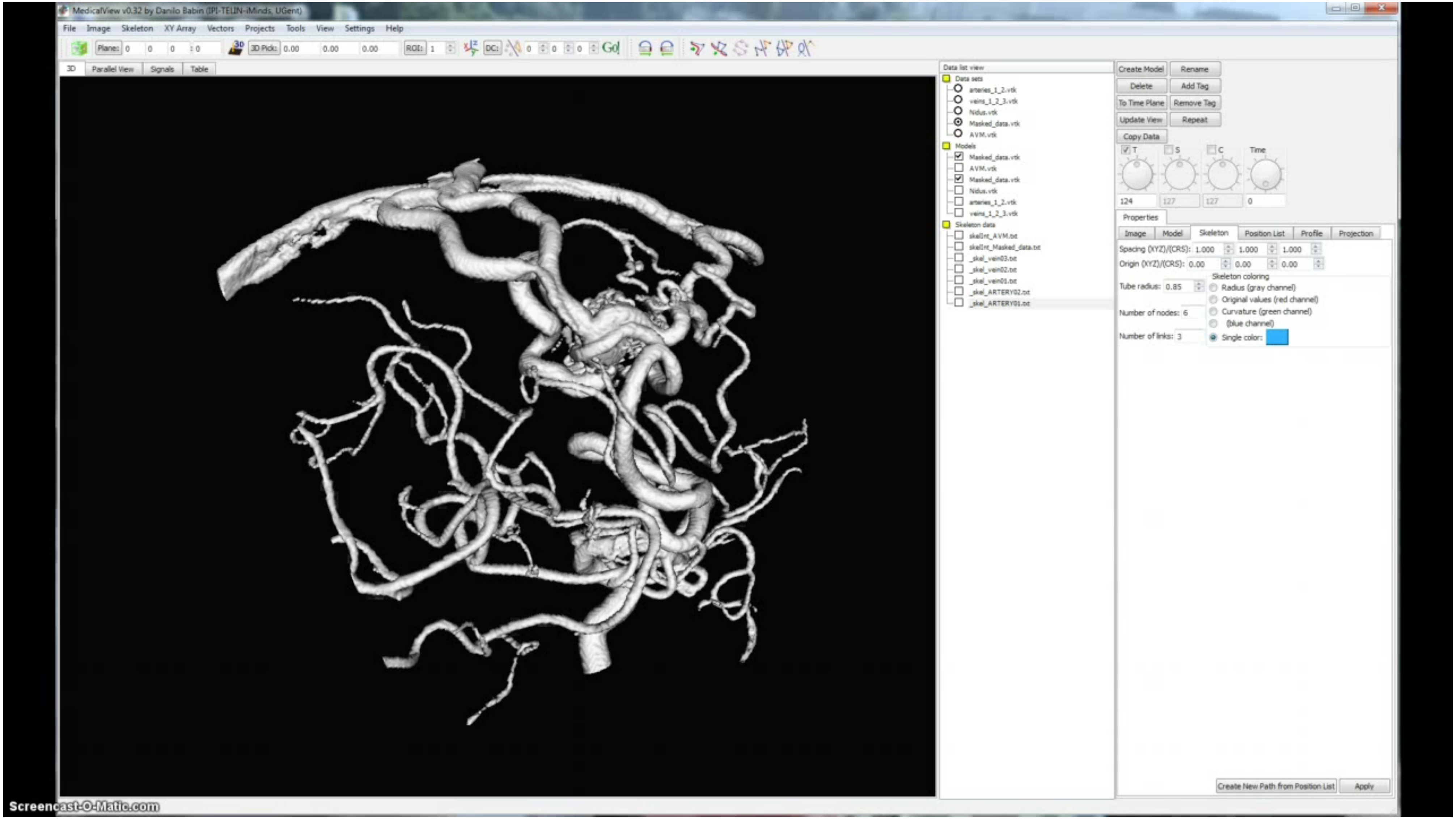
AVM Embolization

- Use a catheter to insert glue to the AVM
- Must NOT occlude draining veins!
- Goal: AVM model extraction and decomposition

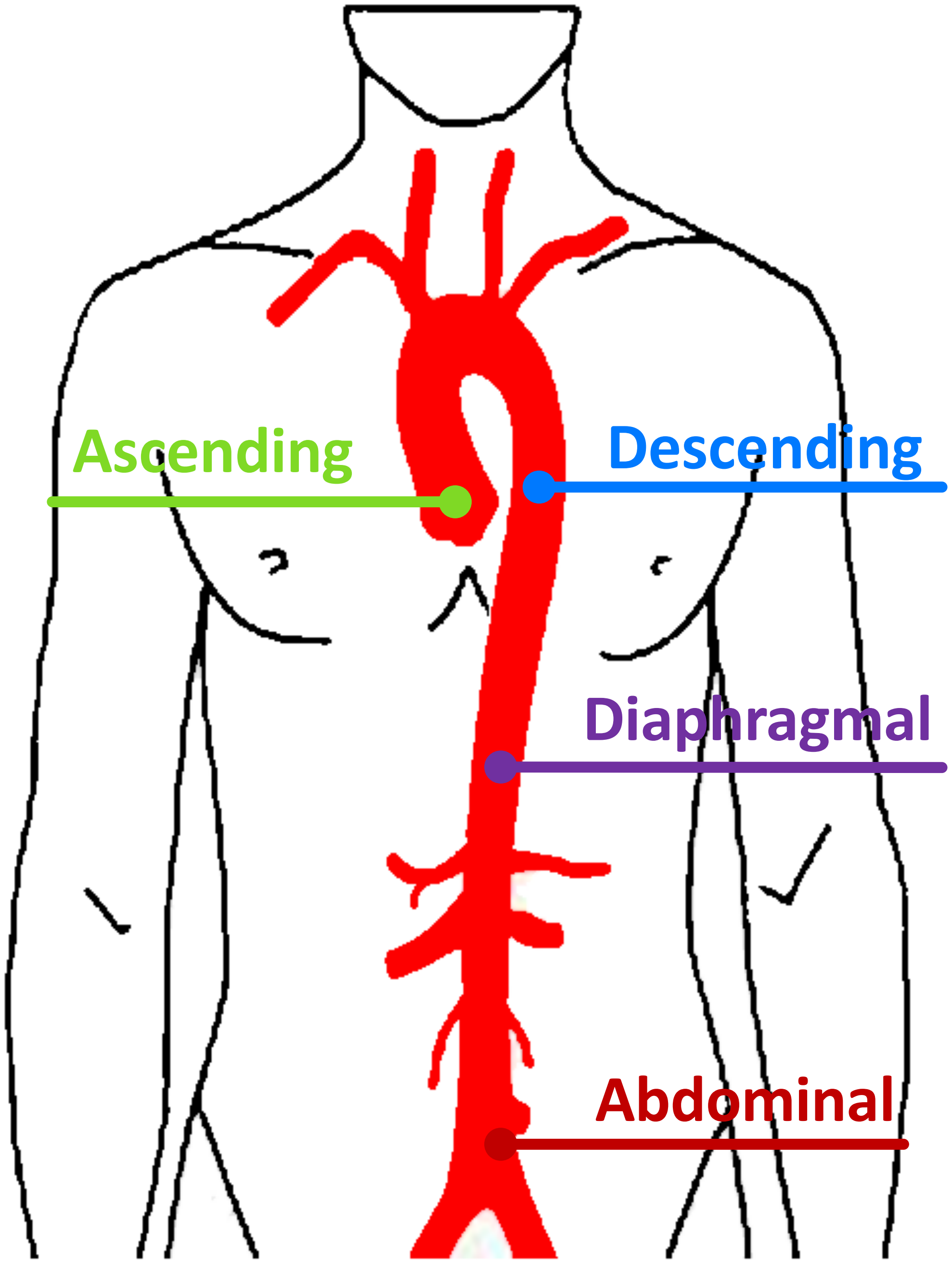




AVM decomposition demo



Aortic stiffness

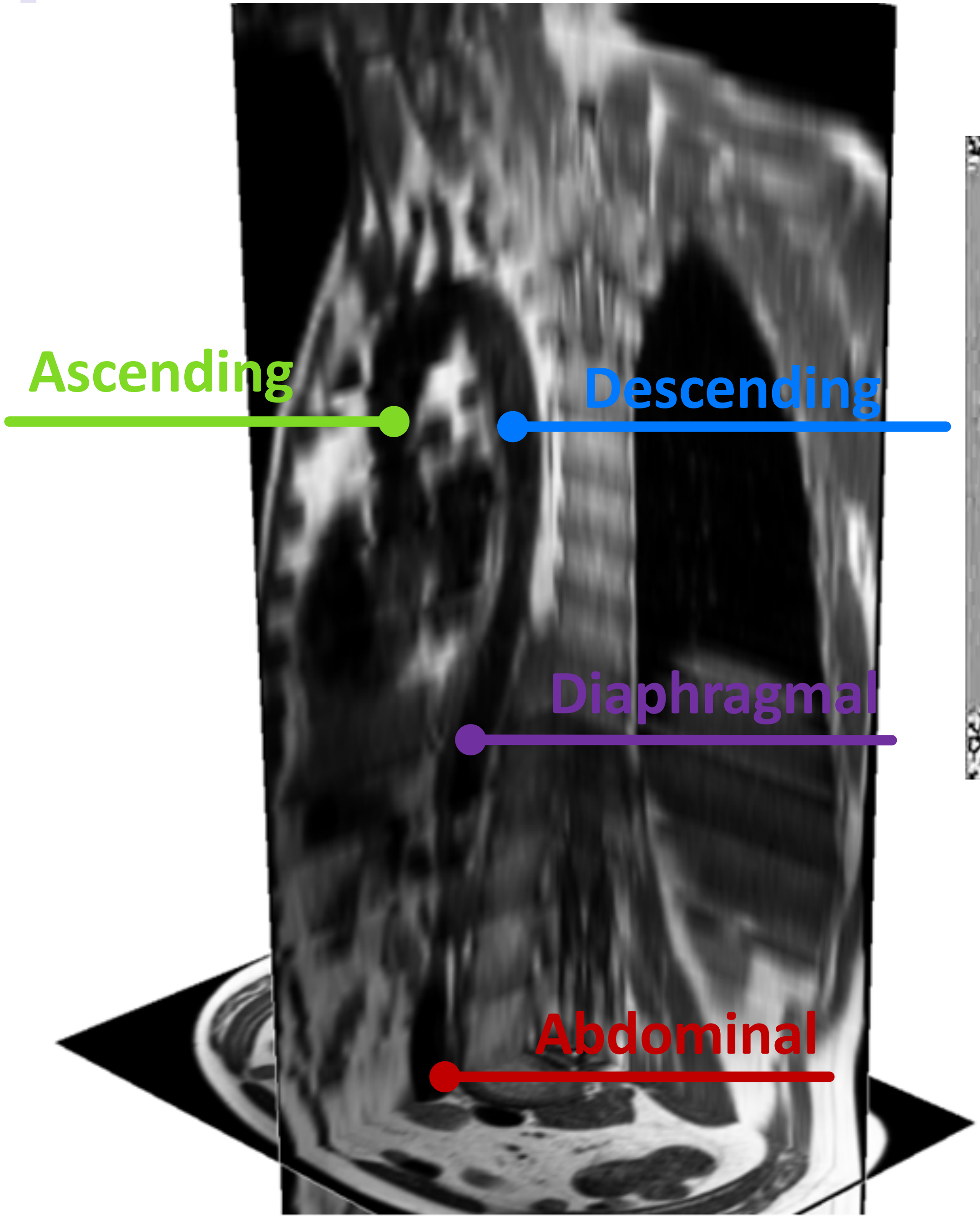


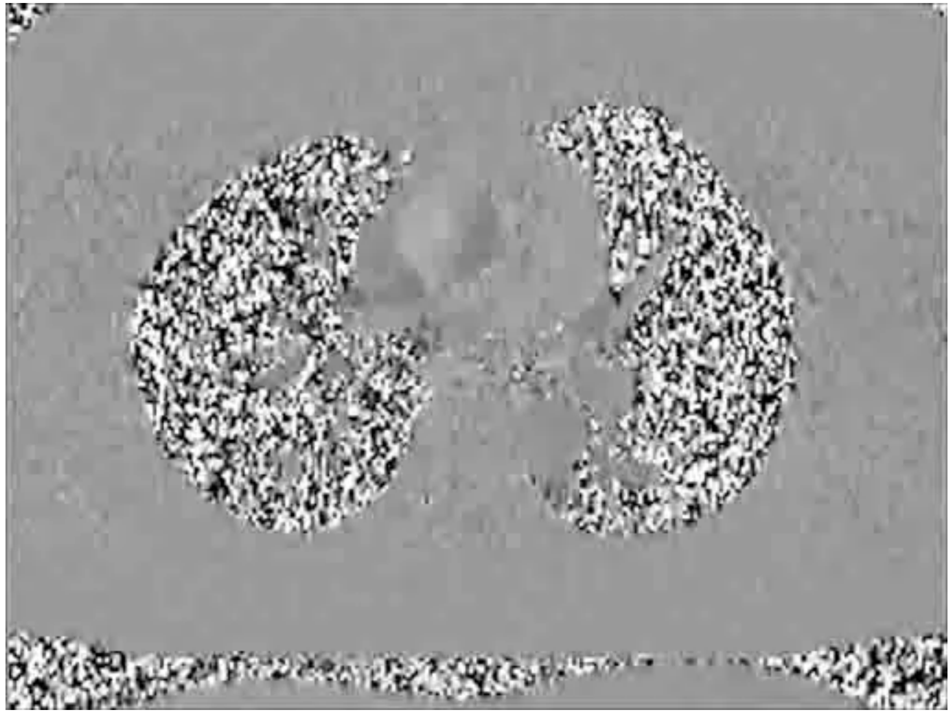
- Overall cardiovascular health indicator
- Predictor of disease outcome (Marfan syndrome, hypertension, diabetes, Turner syndrome…)

- Estimated with pulse wave velocity (PWV) – speed of the pulse wave
- Stiffer aorta yields higher PWV

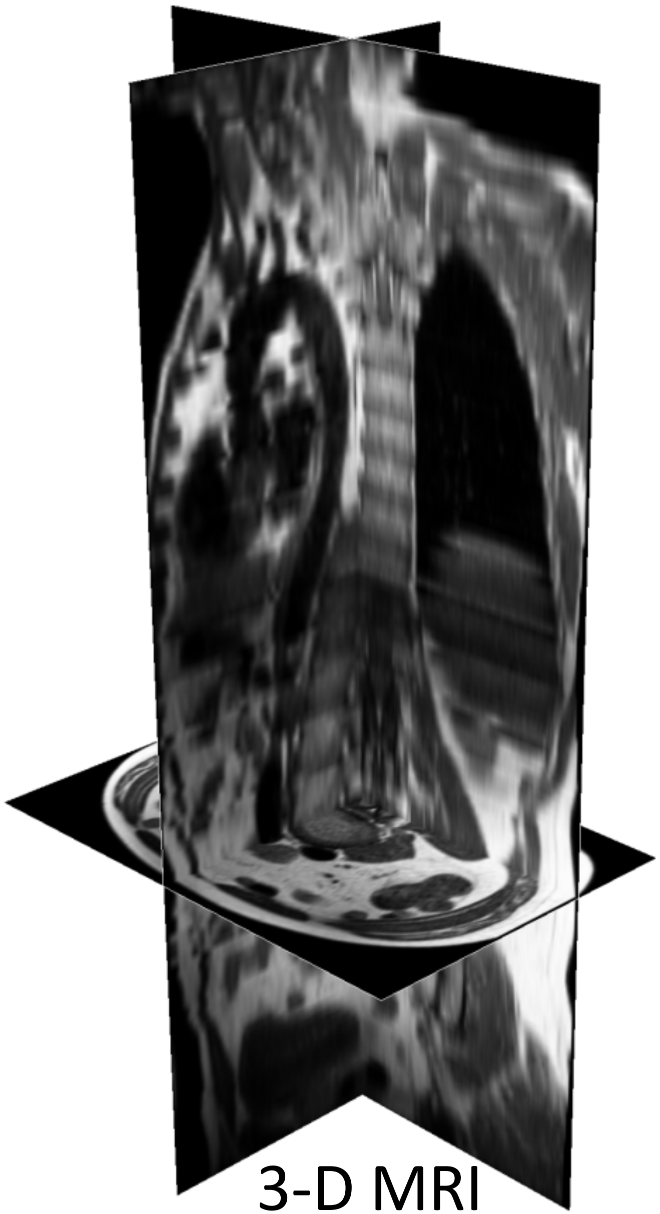
- Goal: measure PWV

Aortic stiffness: Pulse Wave Velocity (PWV)

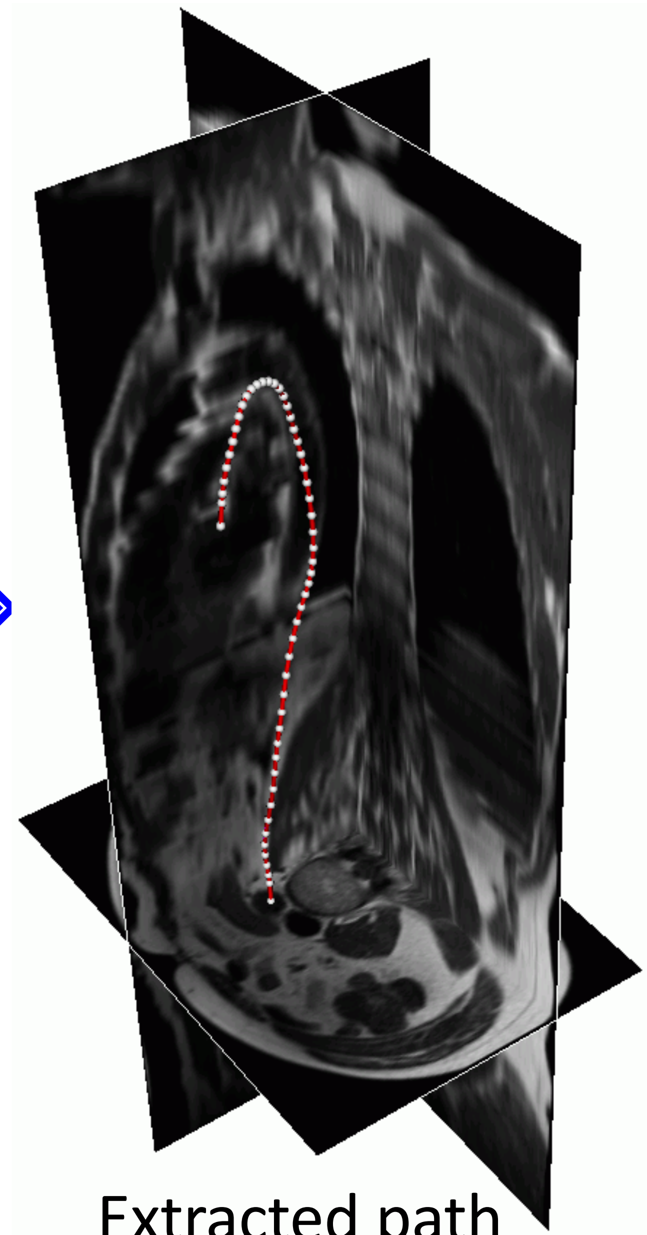




Aortic centerline extraction

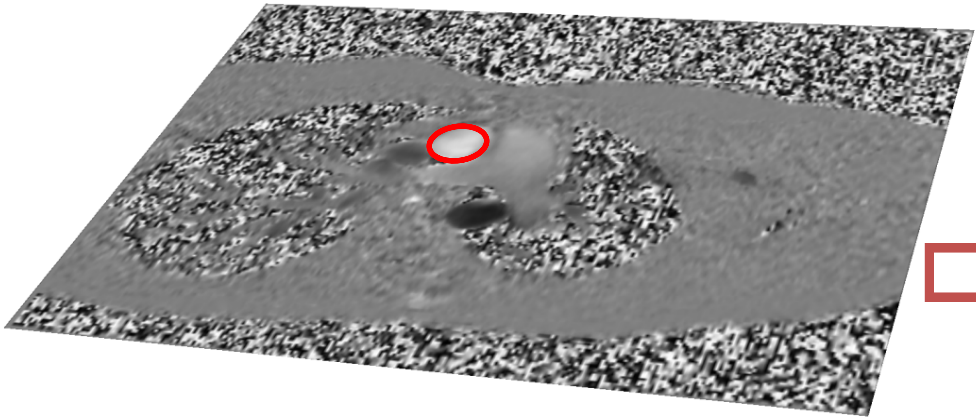


3-D MRI

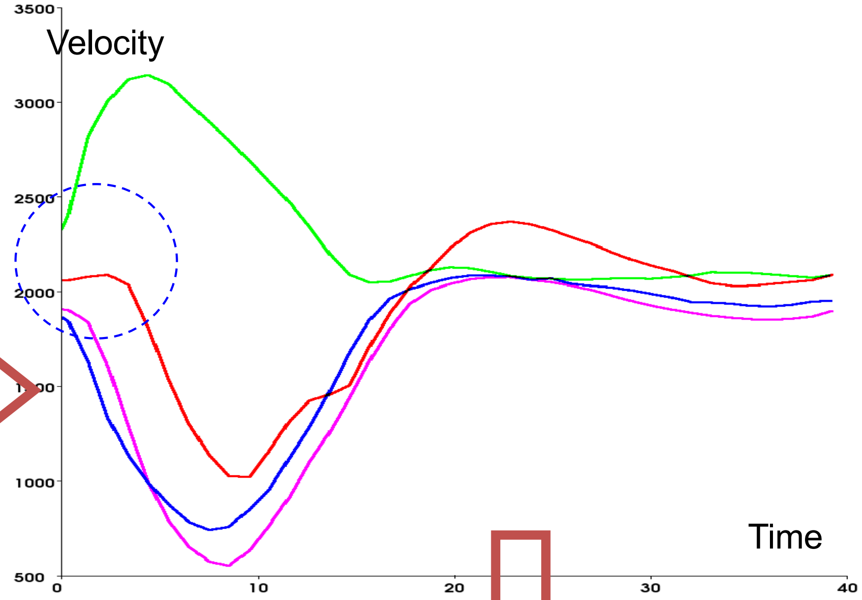


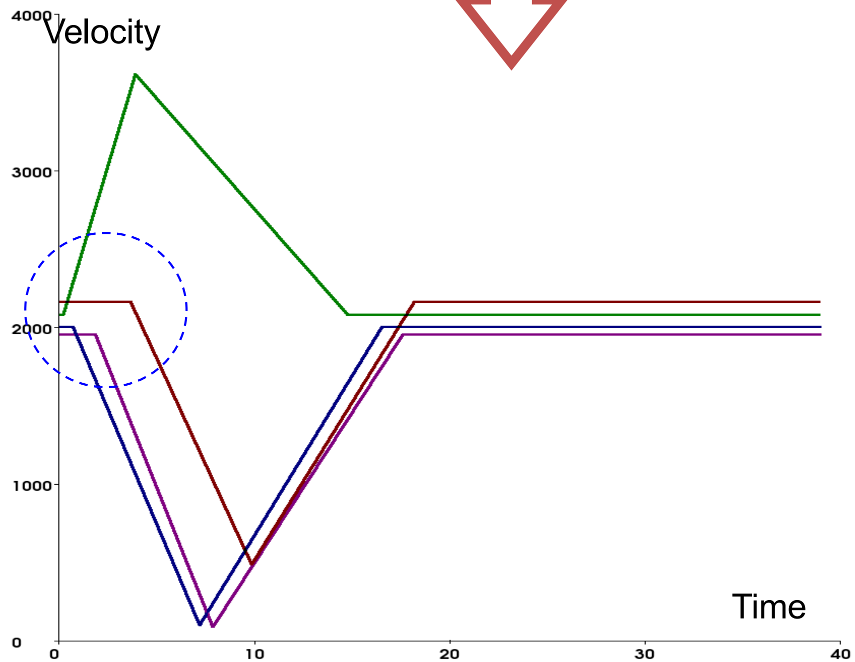
Extracted path

Velocity curves

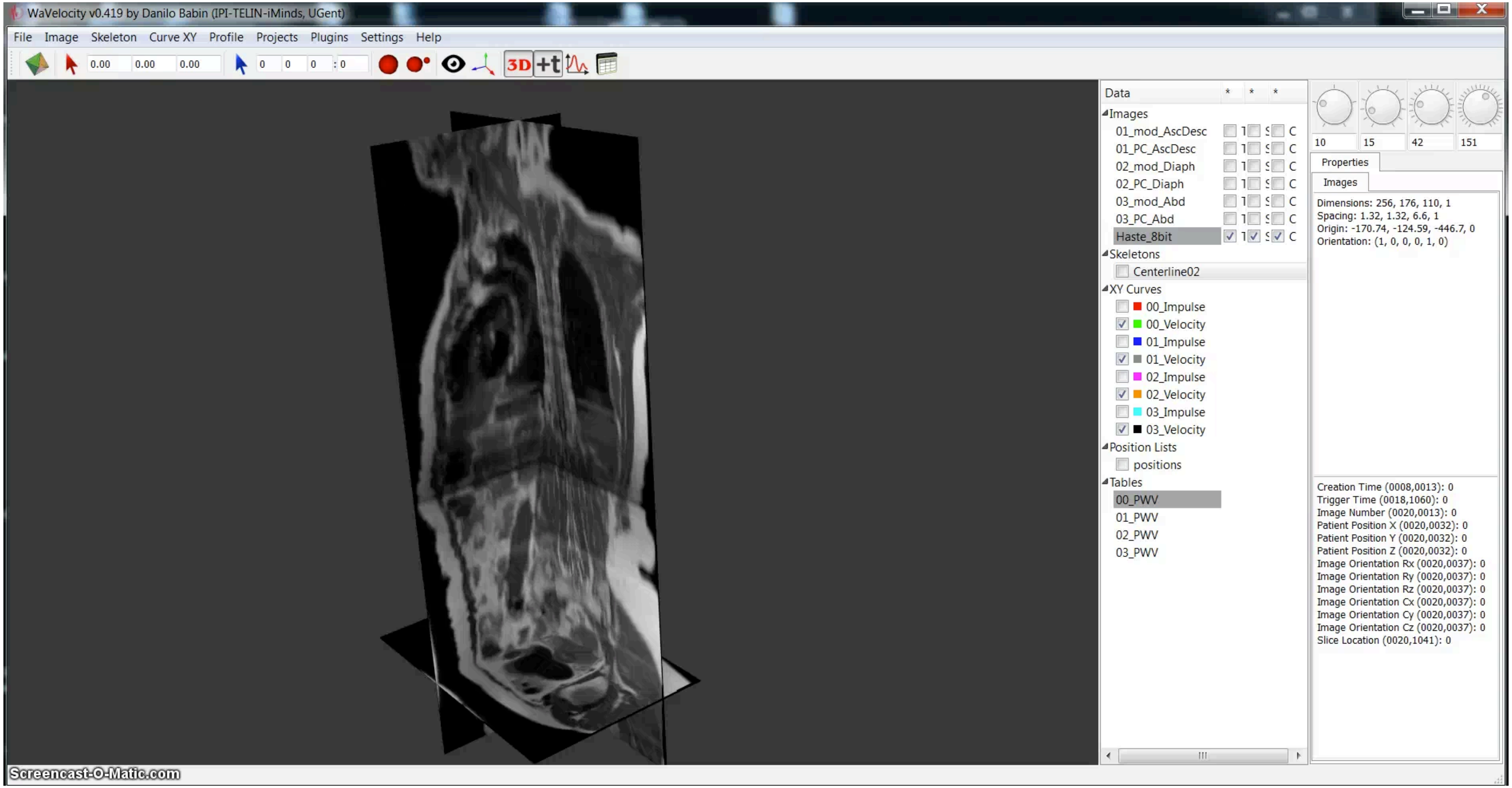


Phase-contrast



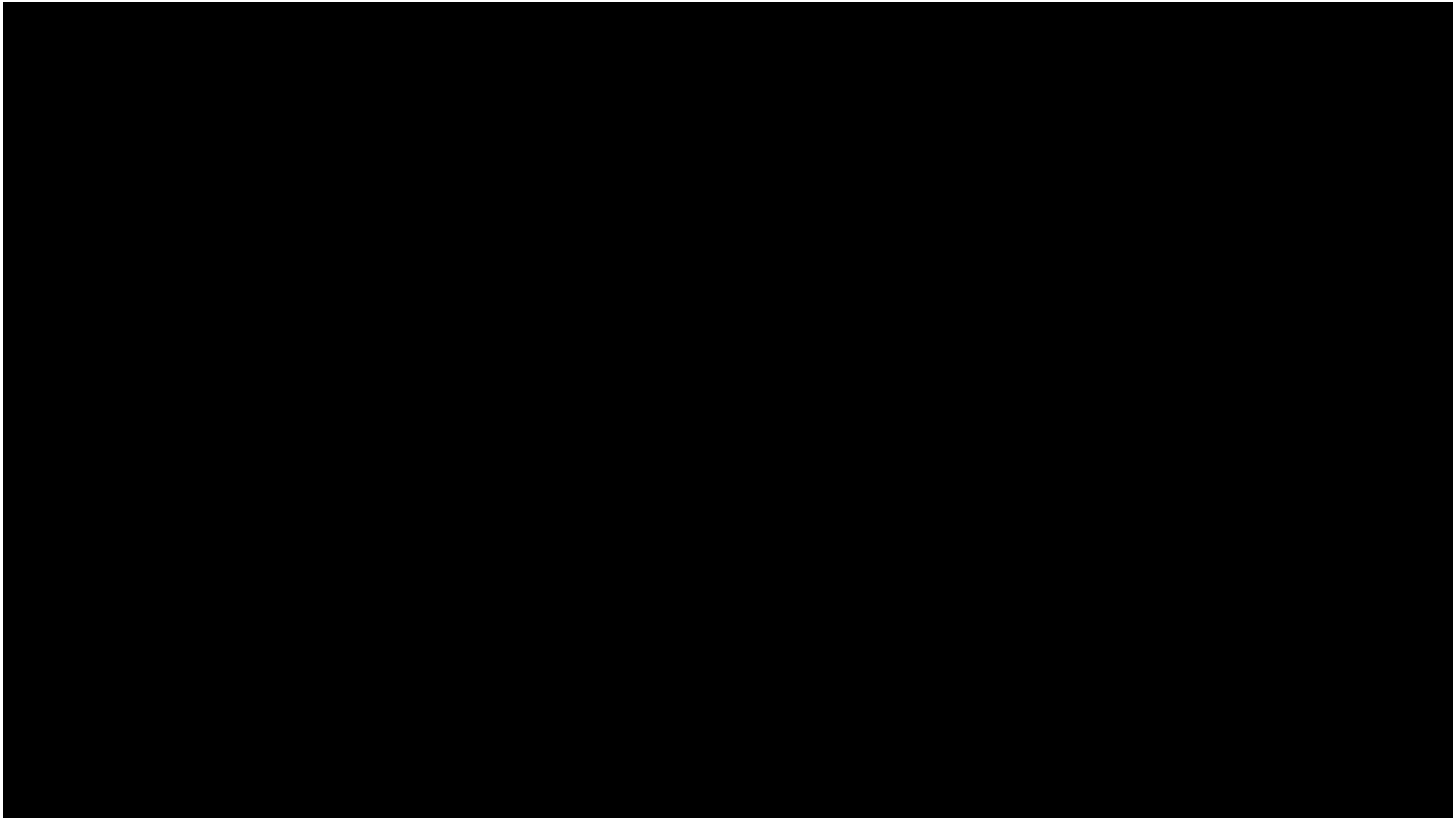


Pulse Wave Velocity demo



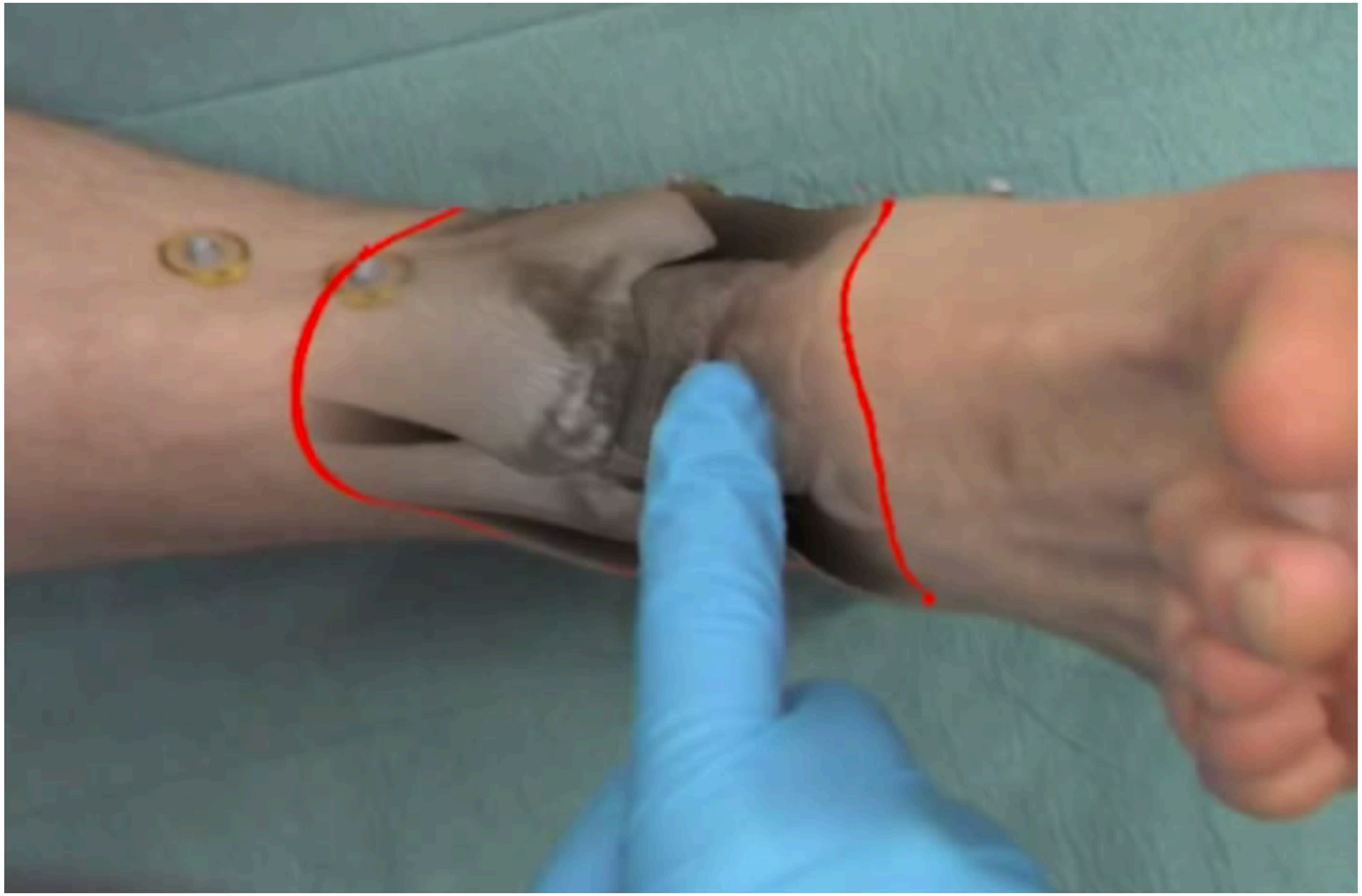
Virtual reality: education & examination

Virtual reality: training

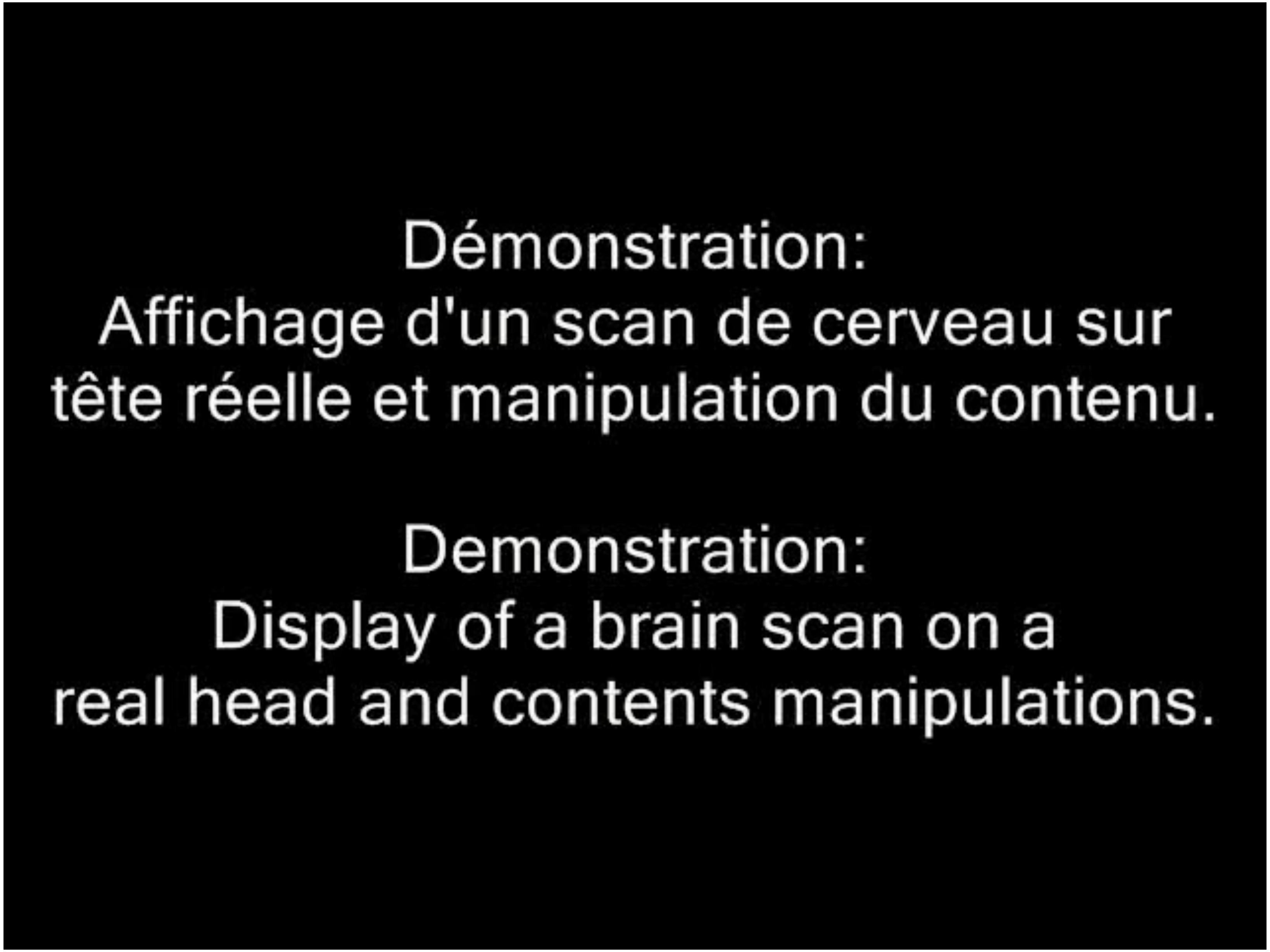


Augmented reality

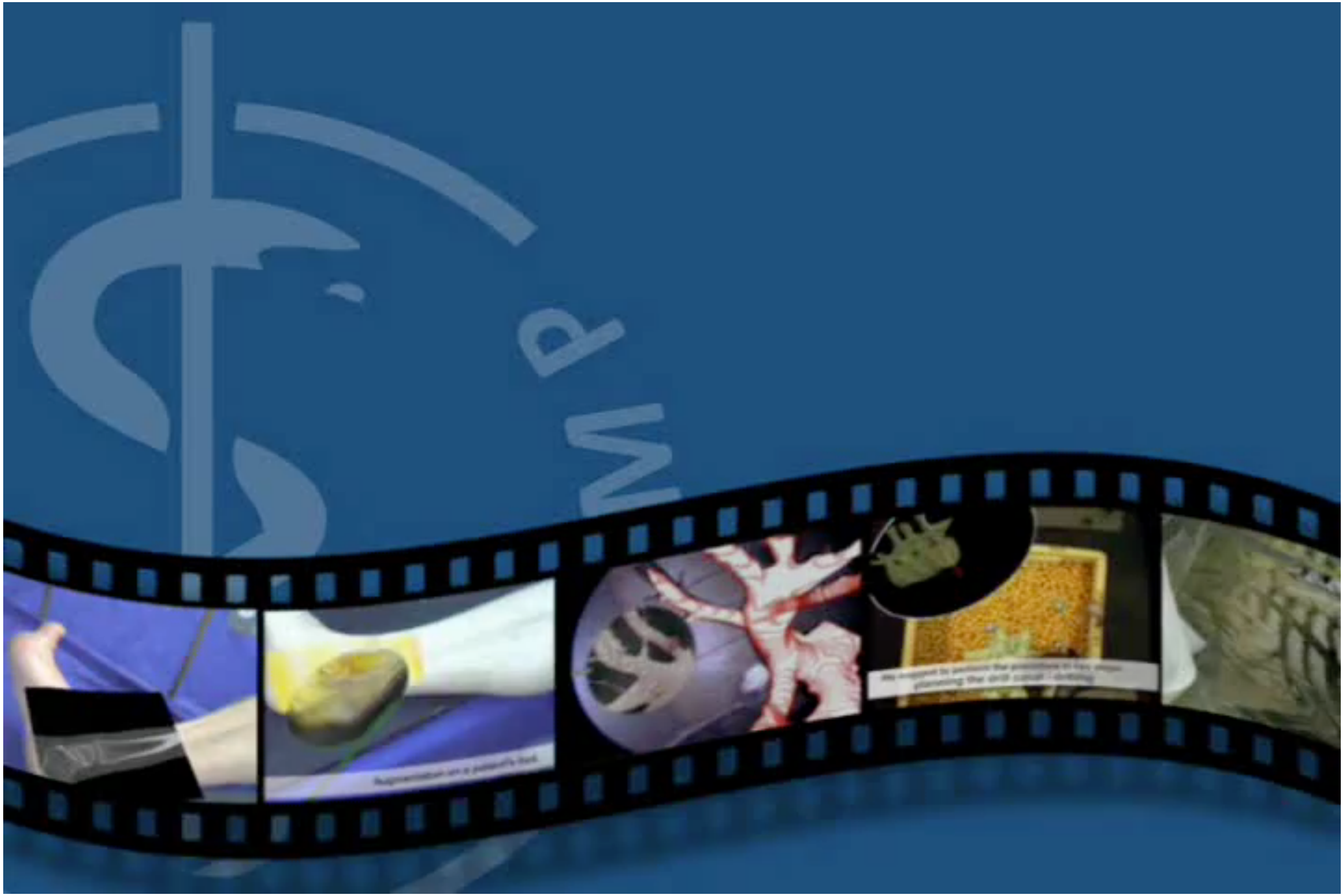
- Map (patient-specific) images to real-time viewing.
- Account for movement, occlusion…



Augmented reality



Augmented reality



Near-infra red (NIR) imaging: vein finder

- NIR imaging detects (de-) oxygenated blood.
- Ideal for finding blood vessels for injections.
- Problem: how to efficiently visualize the veins? Screen solutions have proven difficult (looking at a screen while giving an injection).

Near-infra red (NIR) imaging: vein finder