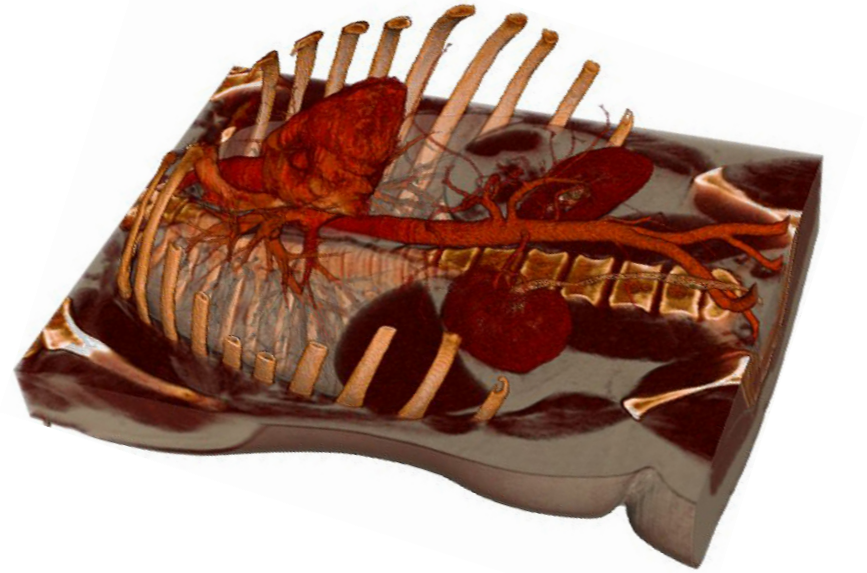
FACULTY OF ENGINEERING AND ARCHITECTURE

E016712: Computer Graphics

Medical Visualization Part 1

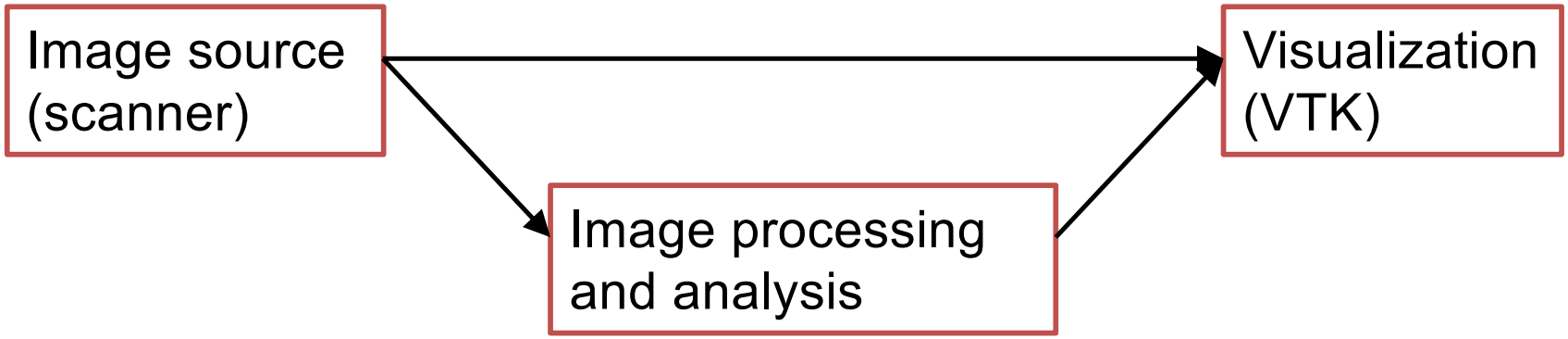


Lecturers: Aleksandra Pizurica and Danilo Babin

GHENT UNIVERSITY

Medical image visualization and analysis

- 2 paths leading to visualization

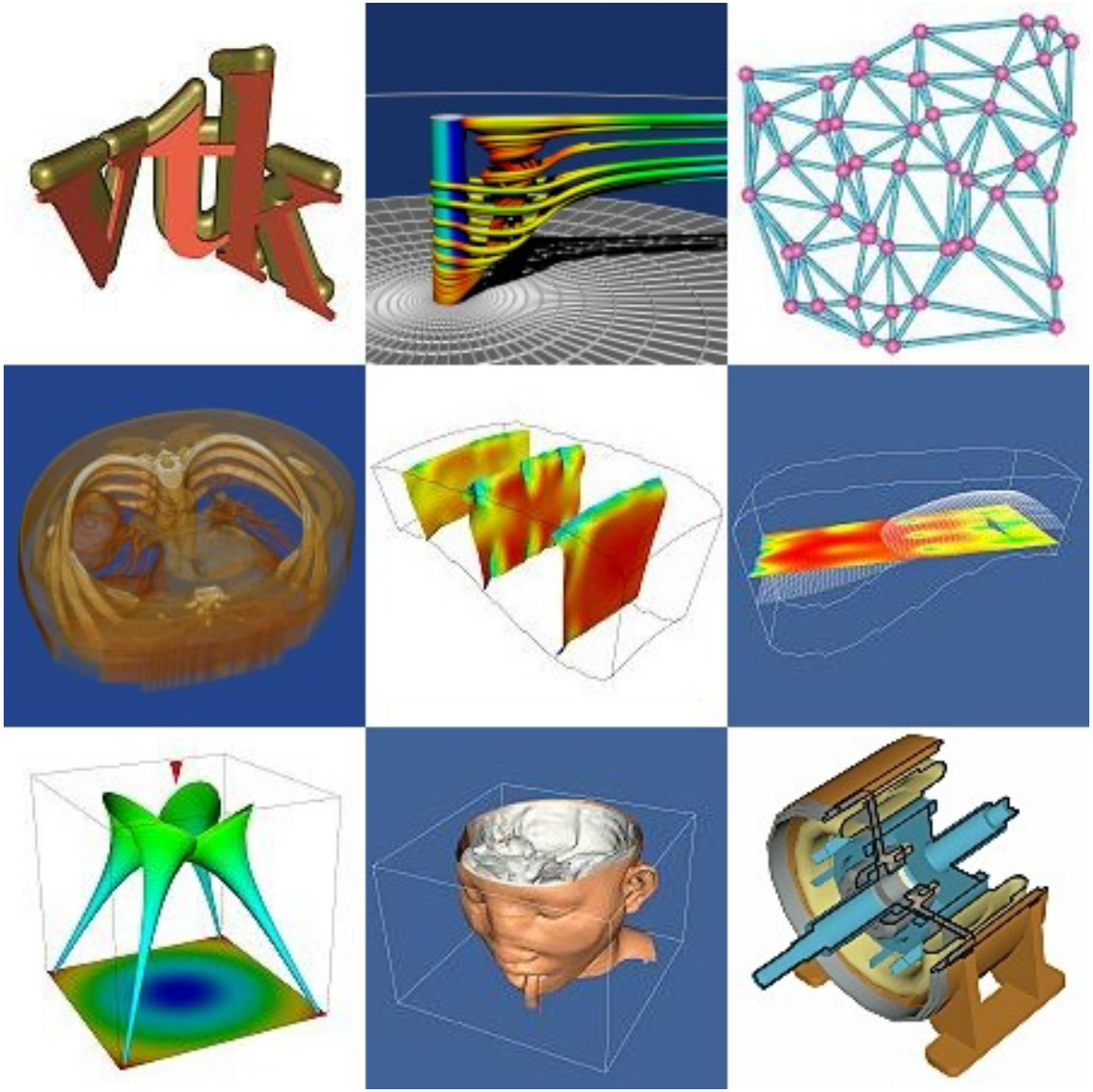


Outline

- Presentation outline:
  - Visualization Toolkit (VTK)
  - Imaging modalities & visualization

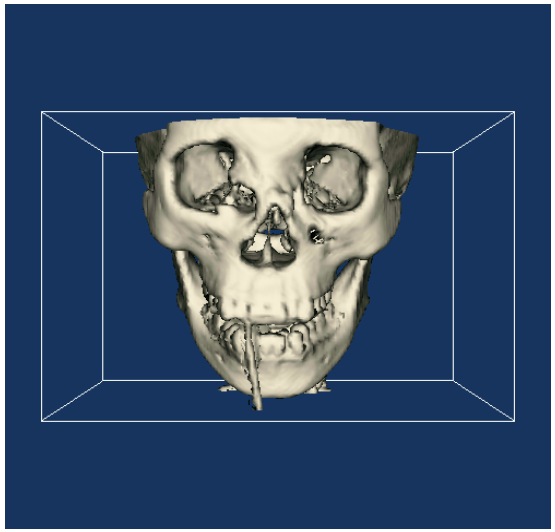
Visualization Toolkit (VTK)

- Open source (BSD)
- 3D visualization
- Image processing
- Object Oriented design
- C++, Tcl, Python, Java.
- VTK + Qt

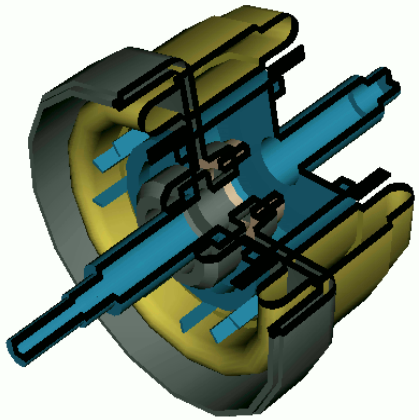


Visualization Toolkit (VTK)

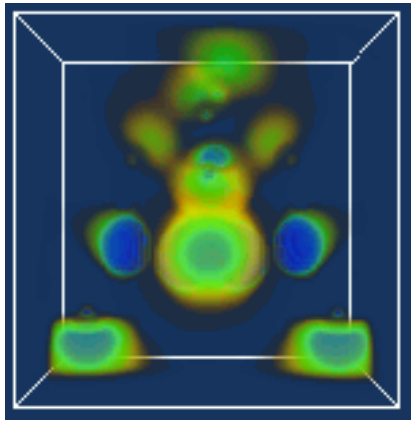
Medical Visualization

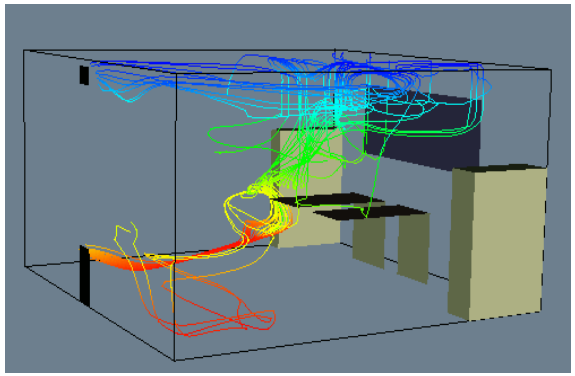


Modeling

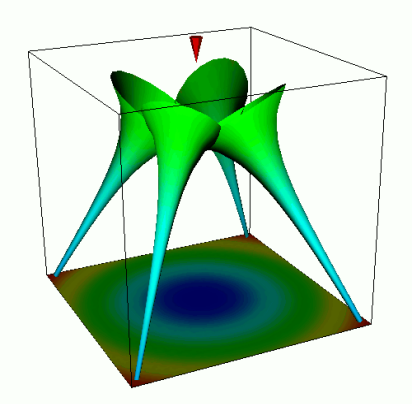


Volume Rendering





Flow Visualization



Tensor Visualization

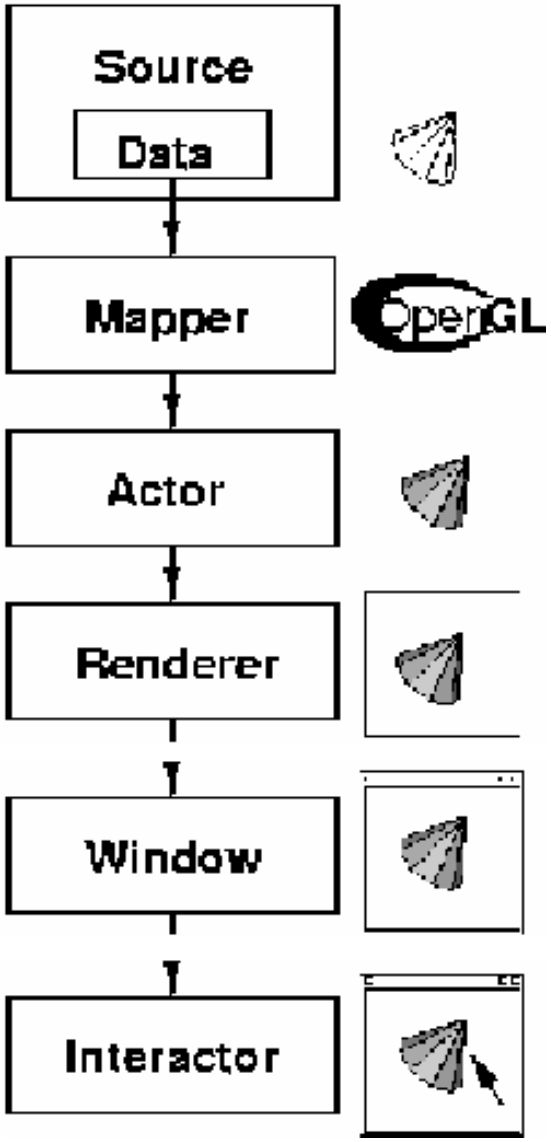
VTK in medical visualization

- Siemens syngo.via Frontier uses Fraunhofer MeVisLab as plugin basis (VTK supported).

- OsiriX DICOM Viewer (Mac only) – extremely popular with radiologists.

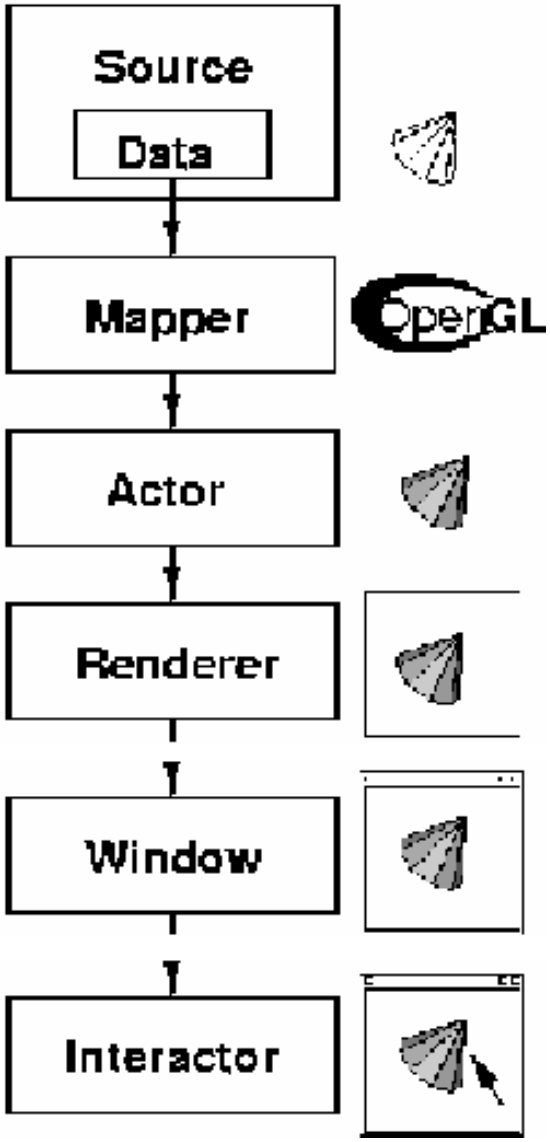
- Horos (free open source branch of Osirix)
- 3D Slicer
- ParaView
- BioImage Suite
- …

VTK: pipeline



- Reads data from a file or creates the data from scratch.
- Moves the data from VTK to OpenGL.
- Object properties (color, position…).
- Projects 3D scene to the screen.
- The window with title bar.
- Enables mouse and keyboard user interaction.

VTK: pipeline code




```
vtkSmartPointer< vtkSphereSource > sphere =
vtkSmartPointer<vtkSphereSource>::New();

vtkSmartPointer< vtkPolyDataMapper > mapper =
vtkSmartPointer<vtkPolyDataMapper> ::New();
mapper->SetInputConnection(sphere->GetOutputPort());

vtkSmartPointer< vtkActor > actor = vtkSmartPointer< vtkActor >::New();
actor->SetMapper(mapper);

vtkSmartPointer< vtkRenderer > renderer = vtkSmartPointer< vtkRenderer > ::New();
renderer->AddActor(actor);

vtkSmartPointer< vtkRenderWindow > renWin = vtkSmartPointer<
vtkRenderWindow>::New();
renWin->AddRenderer(renderer);

vtkSmartPointer< vtkRenderWindowInteractor > iren =
                vtkSmartPointer<vtkRenderWindowInteractor >::New();
Iren->SetRenderWindow(renWin);

renWin->Render();
Iren->Start();
```

Imaging modalities & visualization

- Imaging modalities (selected ones):
  - X-ray based: CT, DSA, 3DRA
  - Magnetic Resonance Imaging (MRI)
  - Ultrasound, IVUS, OCT
  - Hyperspectral

- Visualization
  - Multiplane reconstruction
  - Surface rendering (marching cubes)
  - Volume rendering
    - Texture mapping
    - Maximum intensity projection
    - Ray casting

X-ray angiography

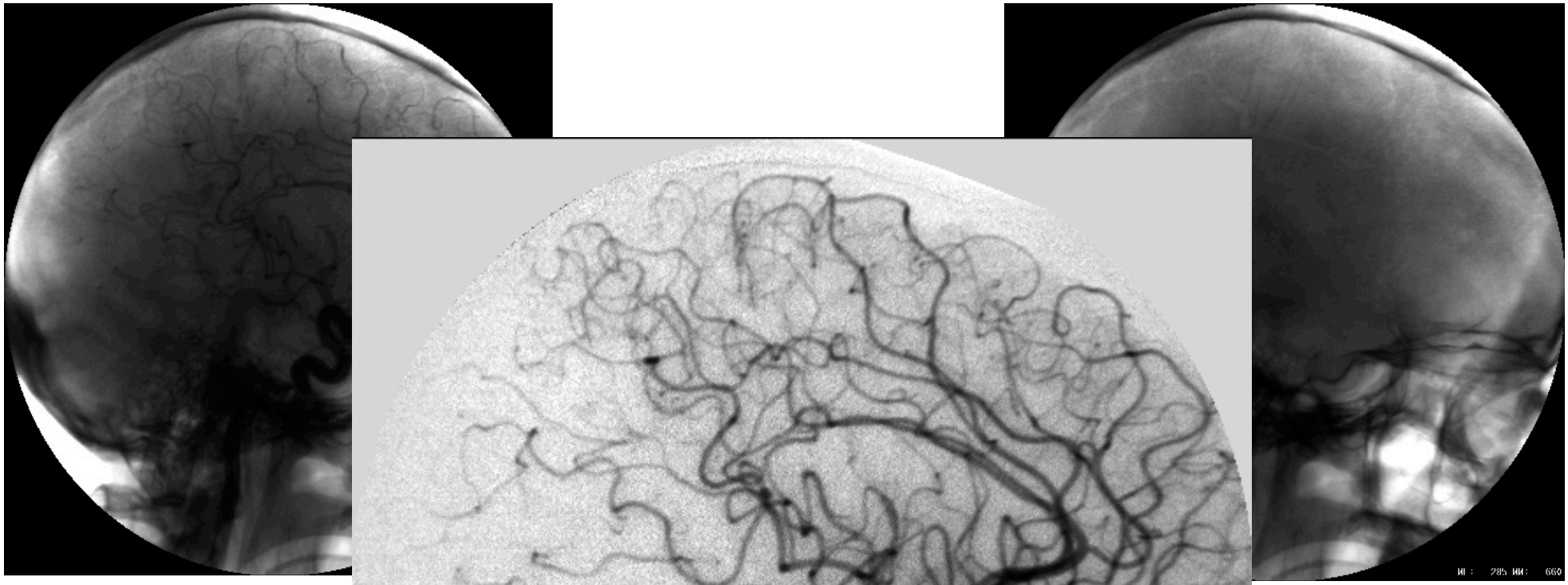
- X-rays developed by Röntgen in 1895.

- The way to visualize vessels: inject contrast agent that is well visible on x-ray (angiography).

- Problem: bones (skull, chest) occlude visibility of important blood vessels.

- Solution: subtraction of contrasted injected and non-contrast injected images (digital subtraction angiography).

Digital Subtraction Angiography (DSA)



Contrast-enhar

ray

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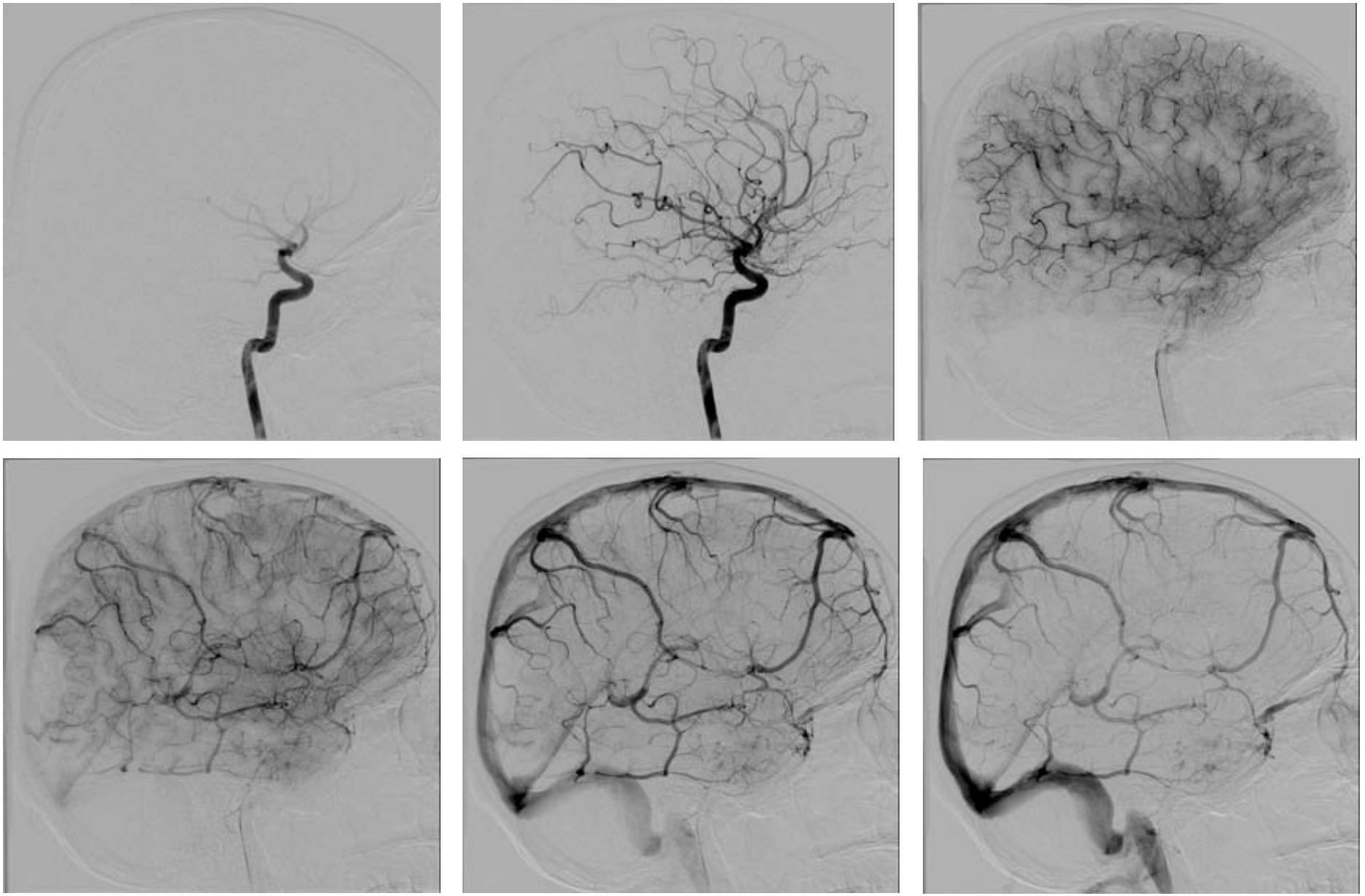
DSA

DSA (2D + time): tracking contrast fluid propagation

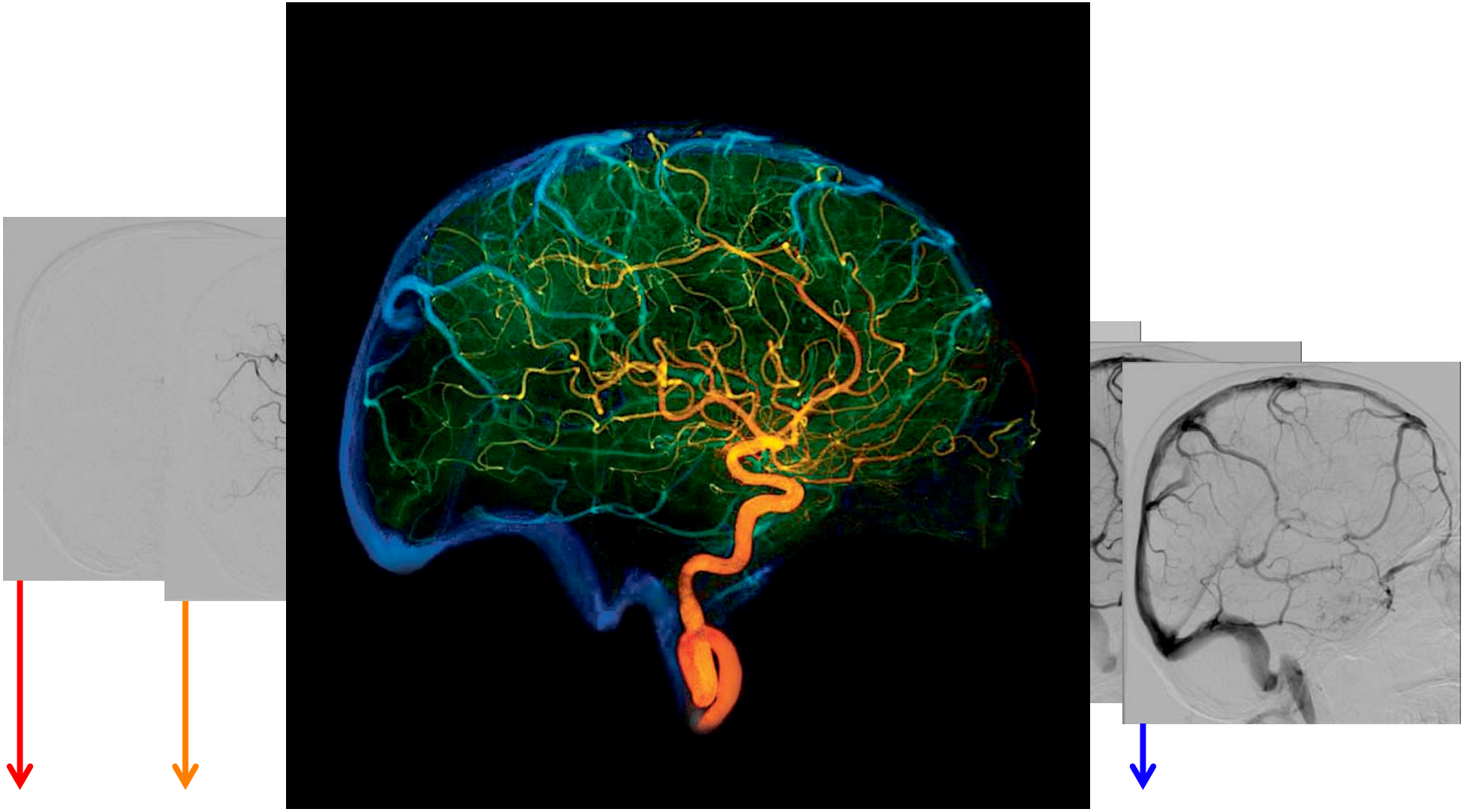


DSA (2D + time): tracking contrast fluid propagation

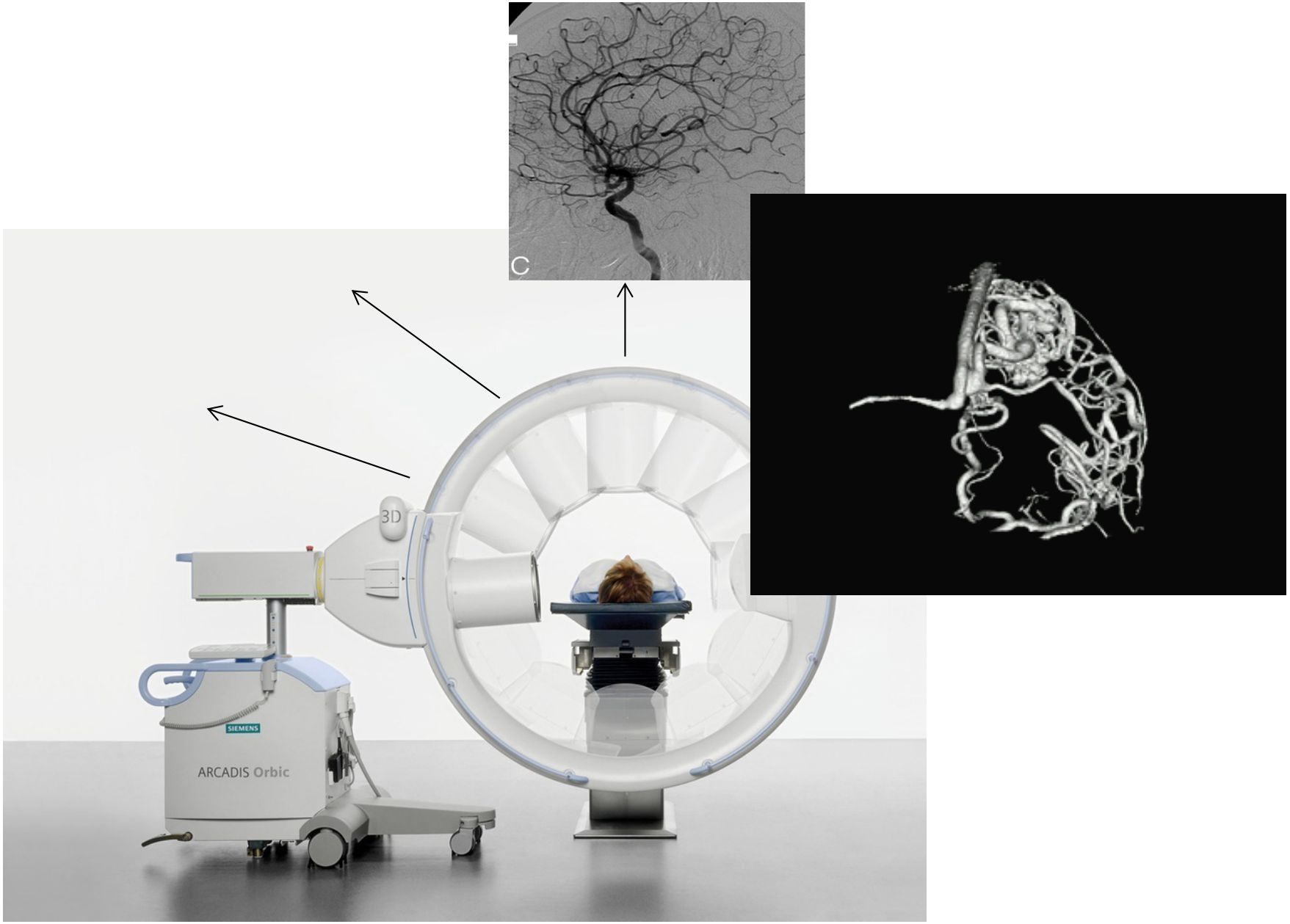
- Problem: as temporal resolution increases (more images), more time is needed for physicians to analyze images.

- Solution: represent the whole time series on a single color-coded image by giving each time frame a color code.

Color DSA (Siemens syngo iFlow)



3D Rotational Angiography (3DRA)

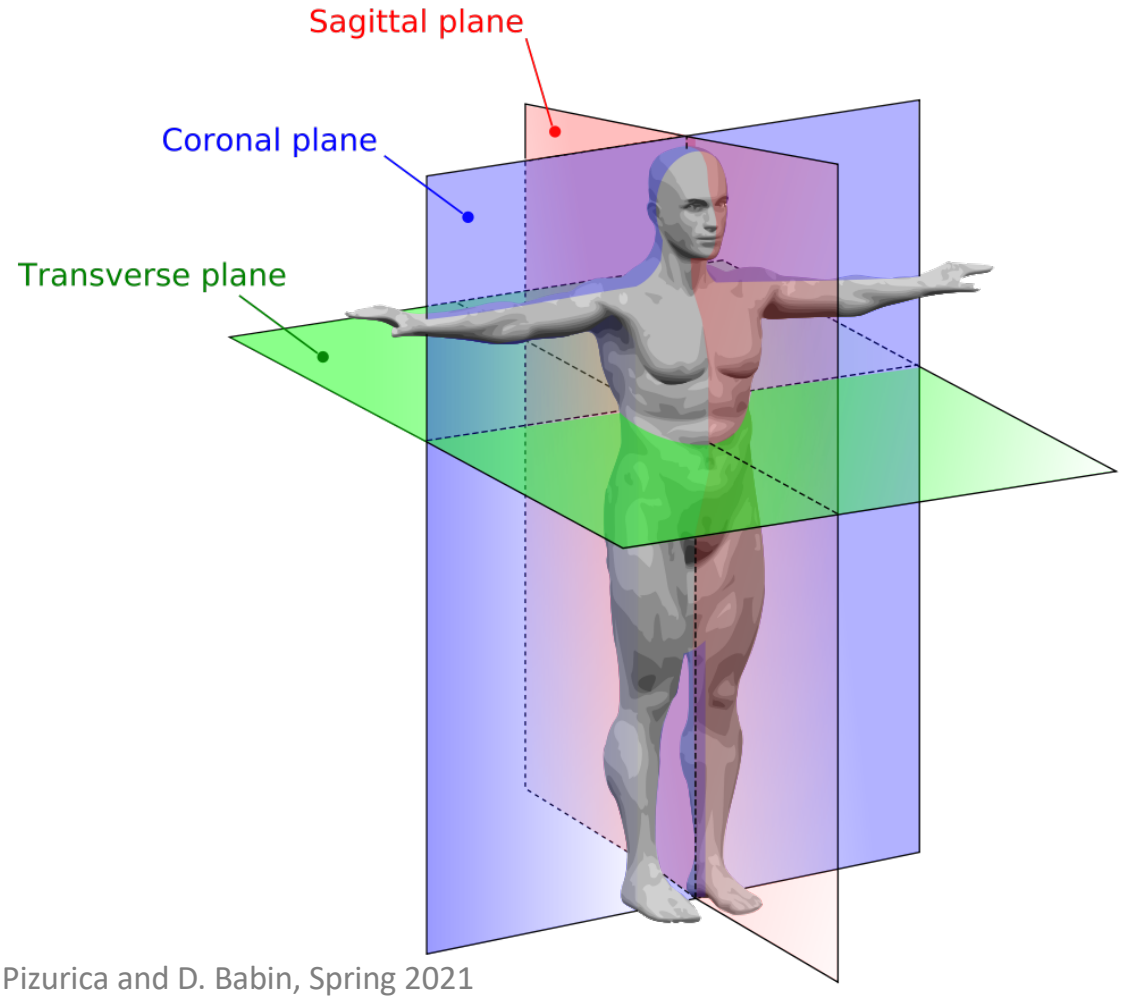


Visualization of 3D images

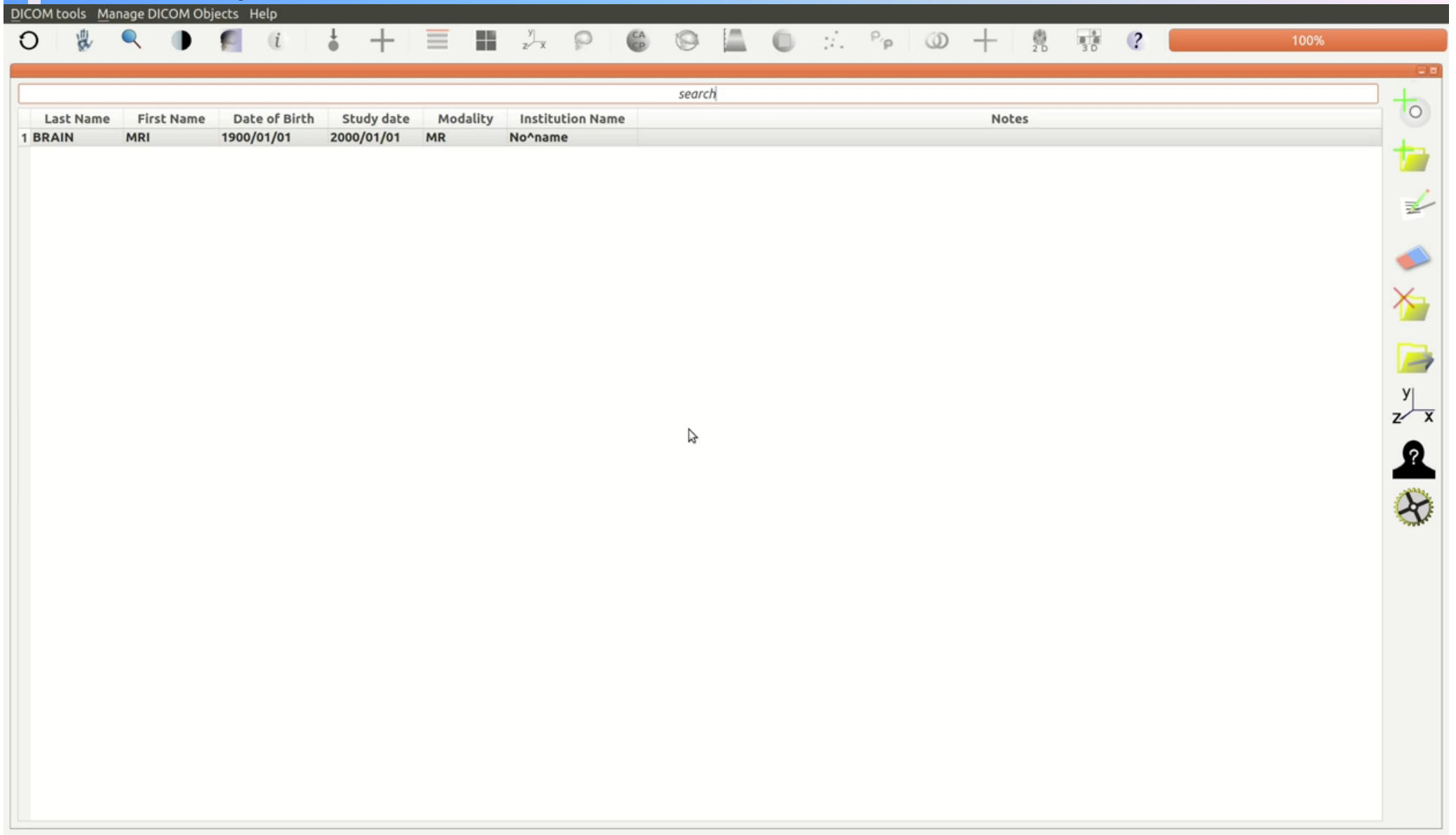
- Visualization
  - Multi-planar reconstruction
  - Surface rendering (marching cubes)
  - Volume rendering
    - Texture mapping
    - Maximum intensity projection
    - Ray casting

Multi-planar reconstruction

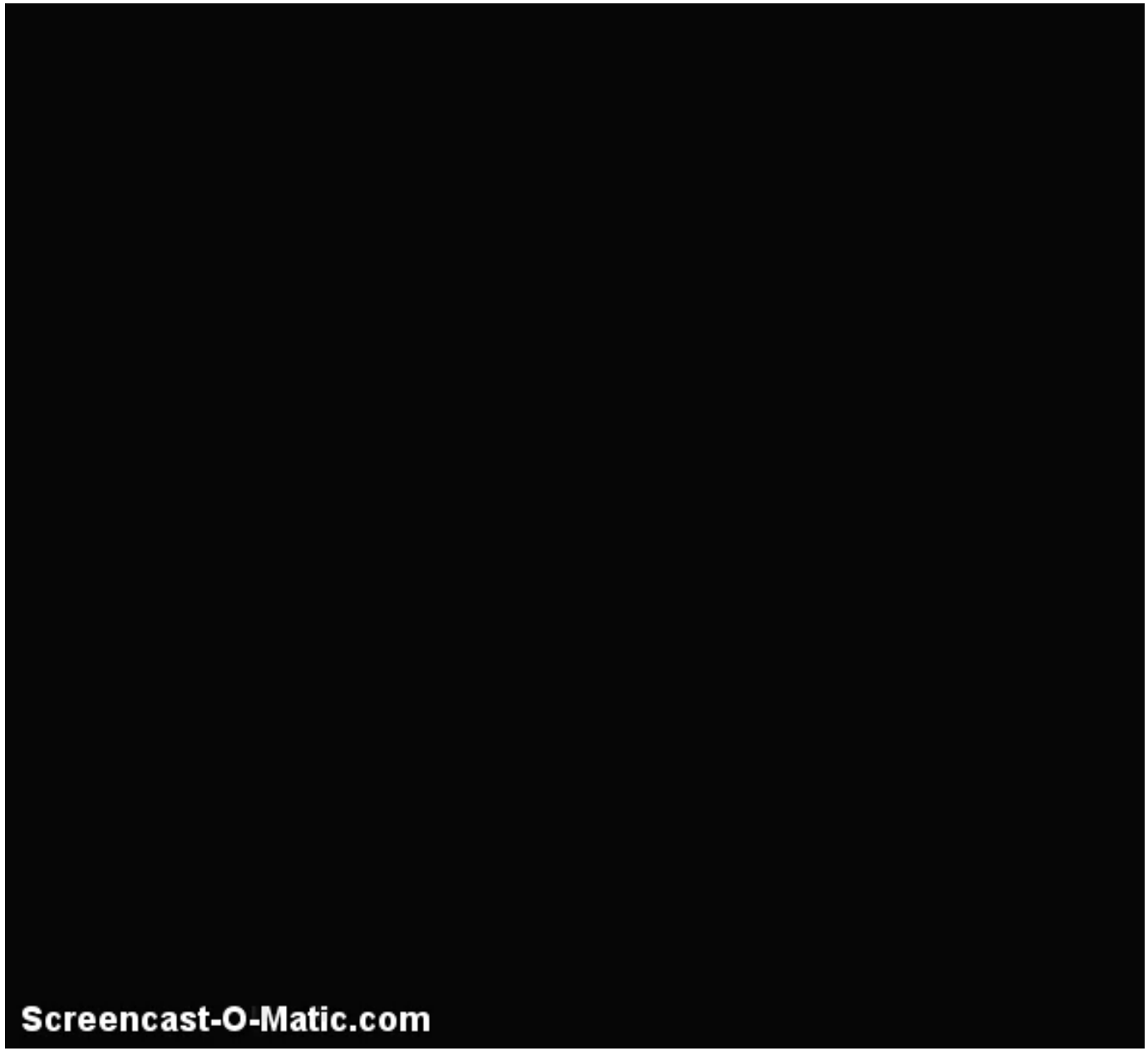
- Cutting through the volume of the 3D image with 2D planes
- Three plane directions: transversal, coronal and sagittal
- Oblique: slicing in any plane orientation



Multi-planar reconstruction



Multi-planar reconstruction in 3D



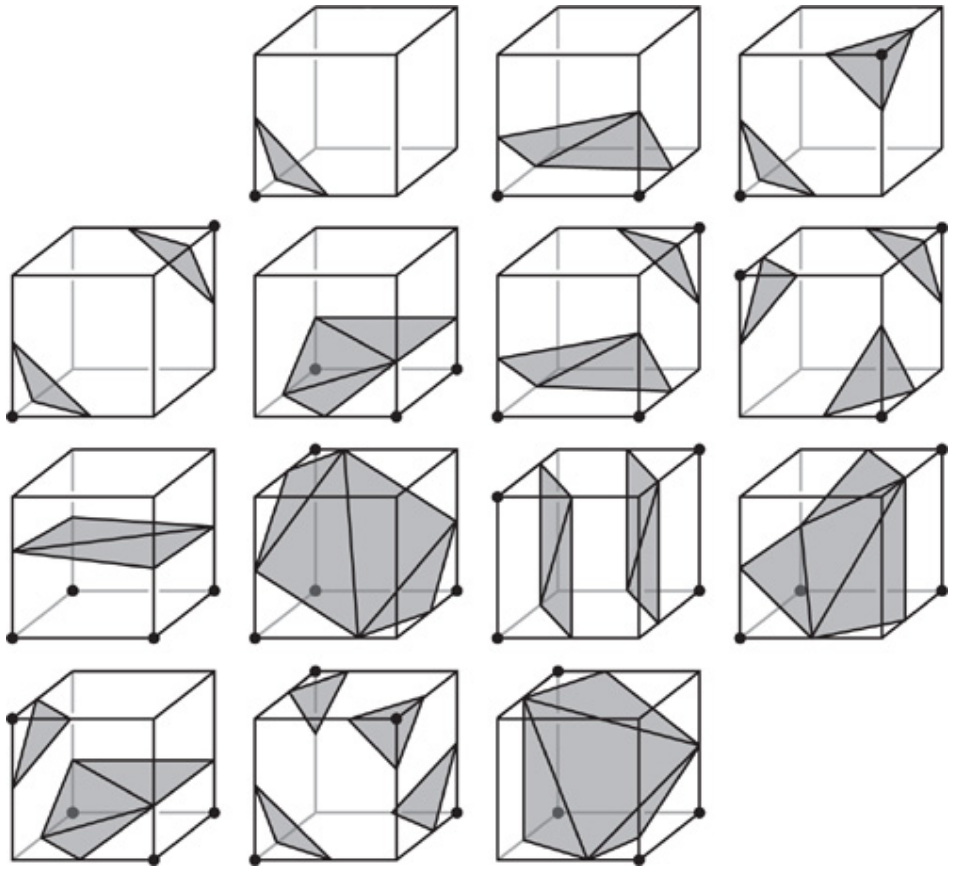
Multi-planar reconstruction: VTK code

- VTK has vtkImagePlaneWidget for this purpose

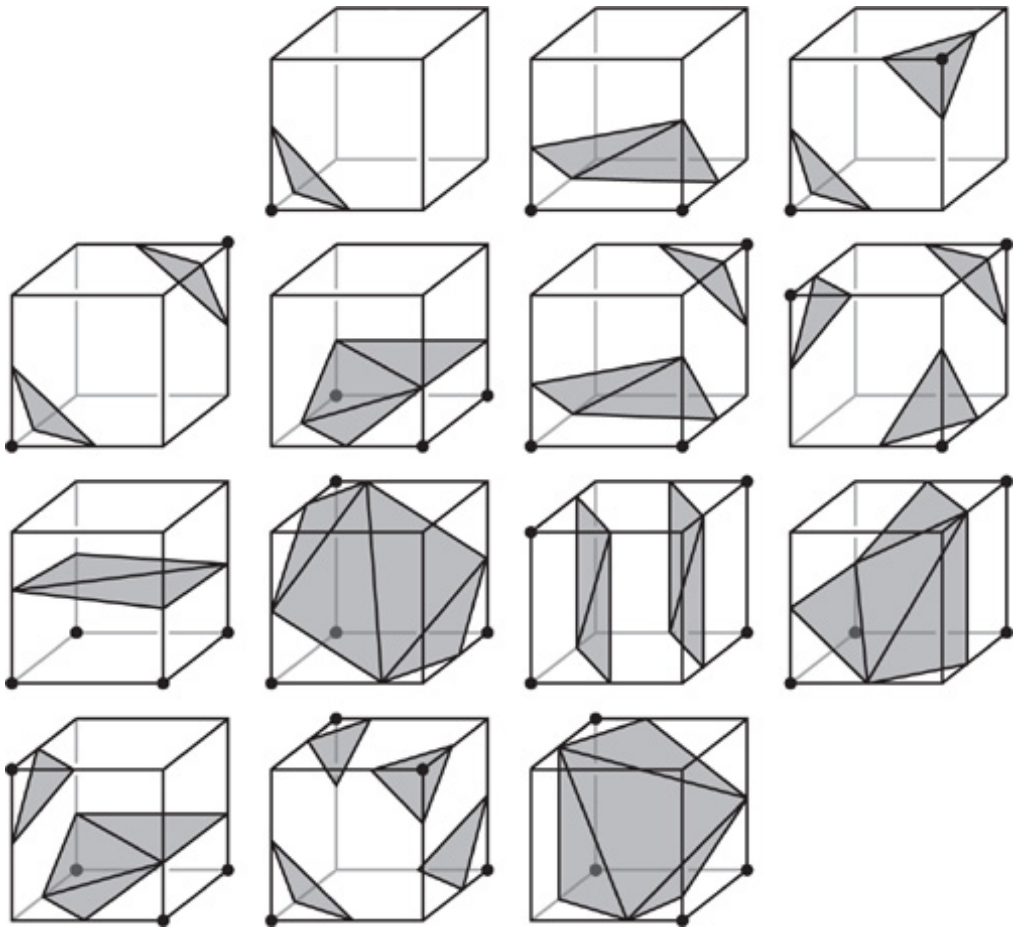
```
vtkSmartPointer<vtkImagePlaneWidget> transversal_plane =
        vtkSmartPointer<vtkImagePlaneWidget>::New();

transversal_plane->SetInteractor(interactor);

transversal_plane->SetInput(image);

transversal_plane->SetPlaneOrientationToZAxes();

transversal_plane->SetSliceIndex(0);
```

Surface reconstruction

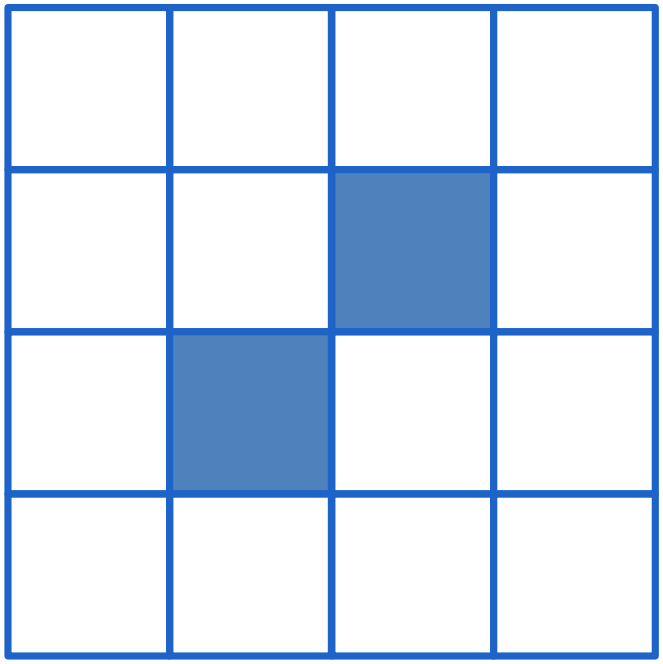
- Showing an iso-surface mesh from (segmented) image
- Basic meshing is performed using Marching Cubes algorithm



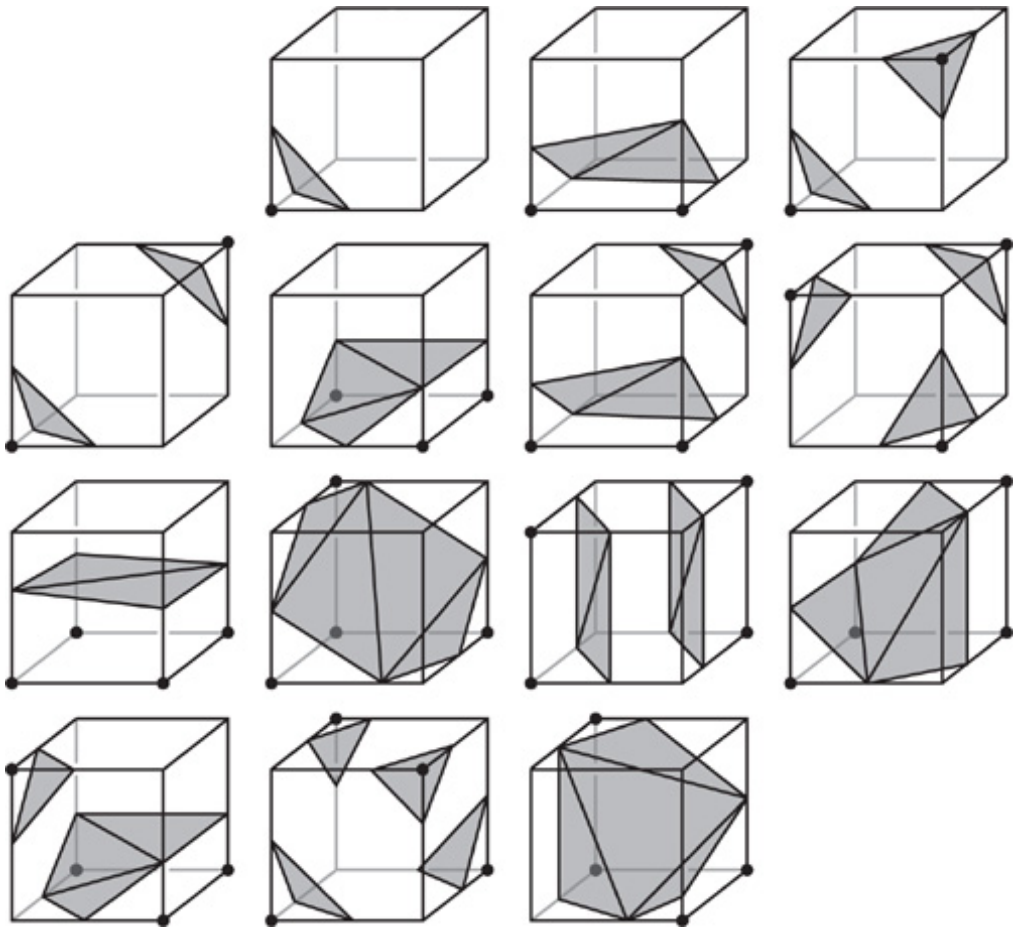
Surface reconstruction



For the image below, what is the result of the marching cubes algorithm?



Surface reconstruction



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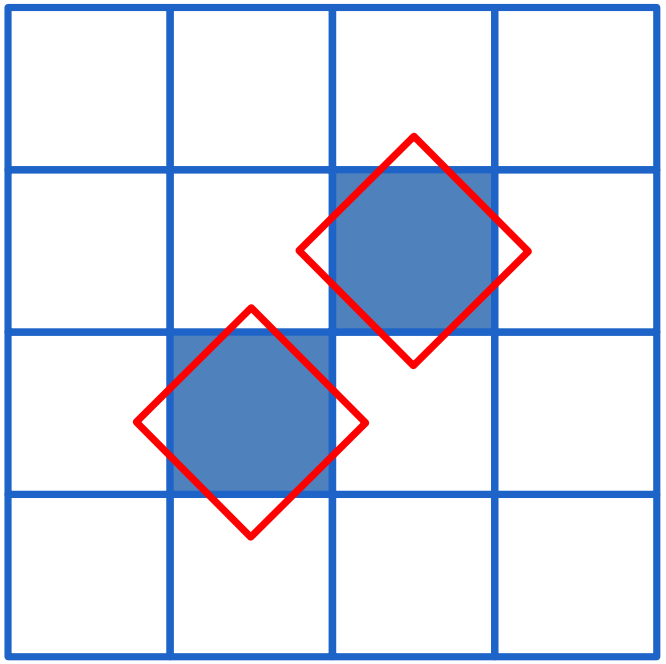
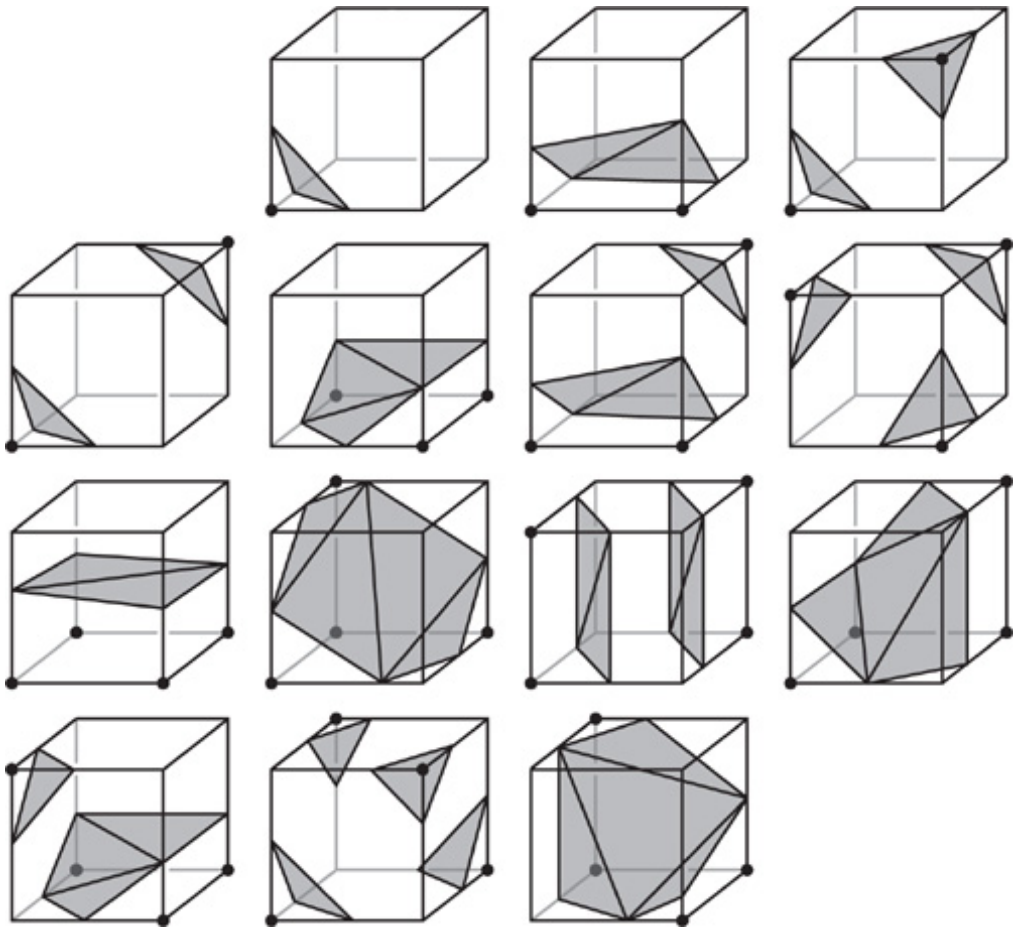


Surface reconstruction



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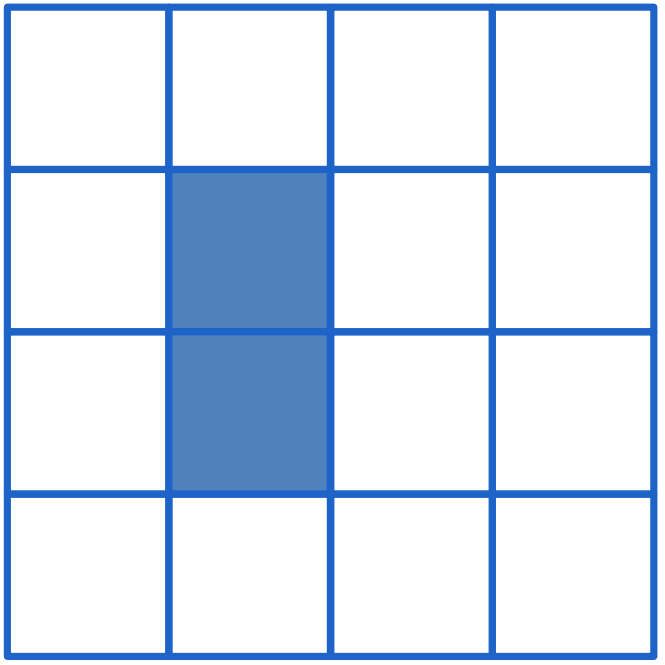
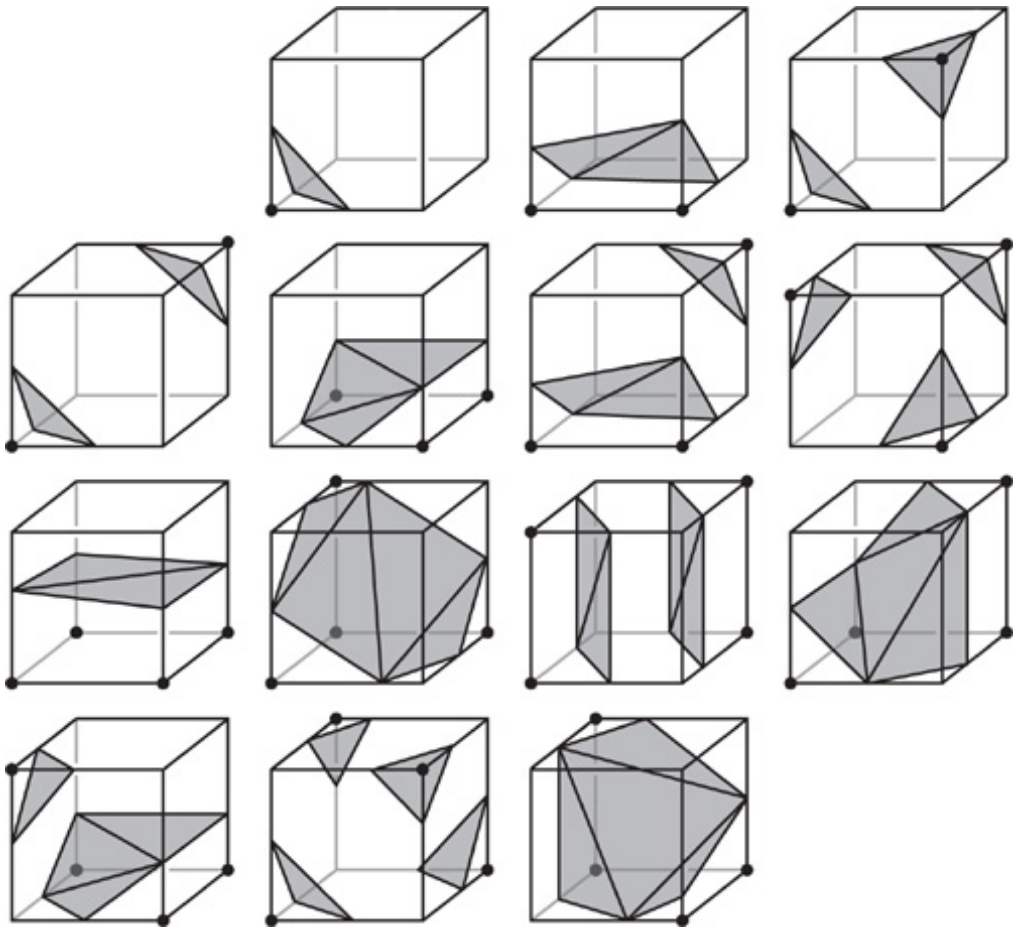


Surface reconstruction



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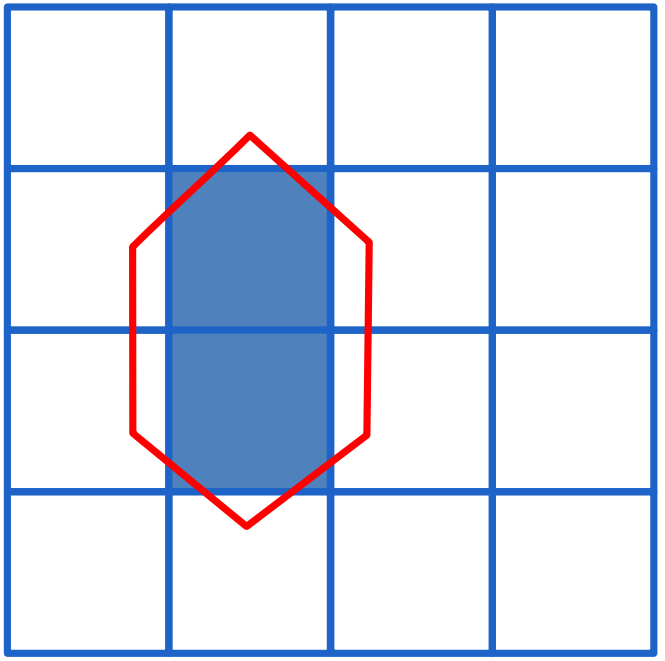
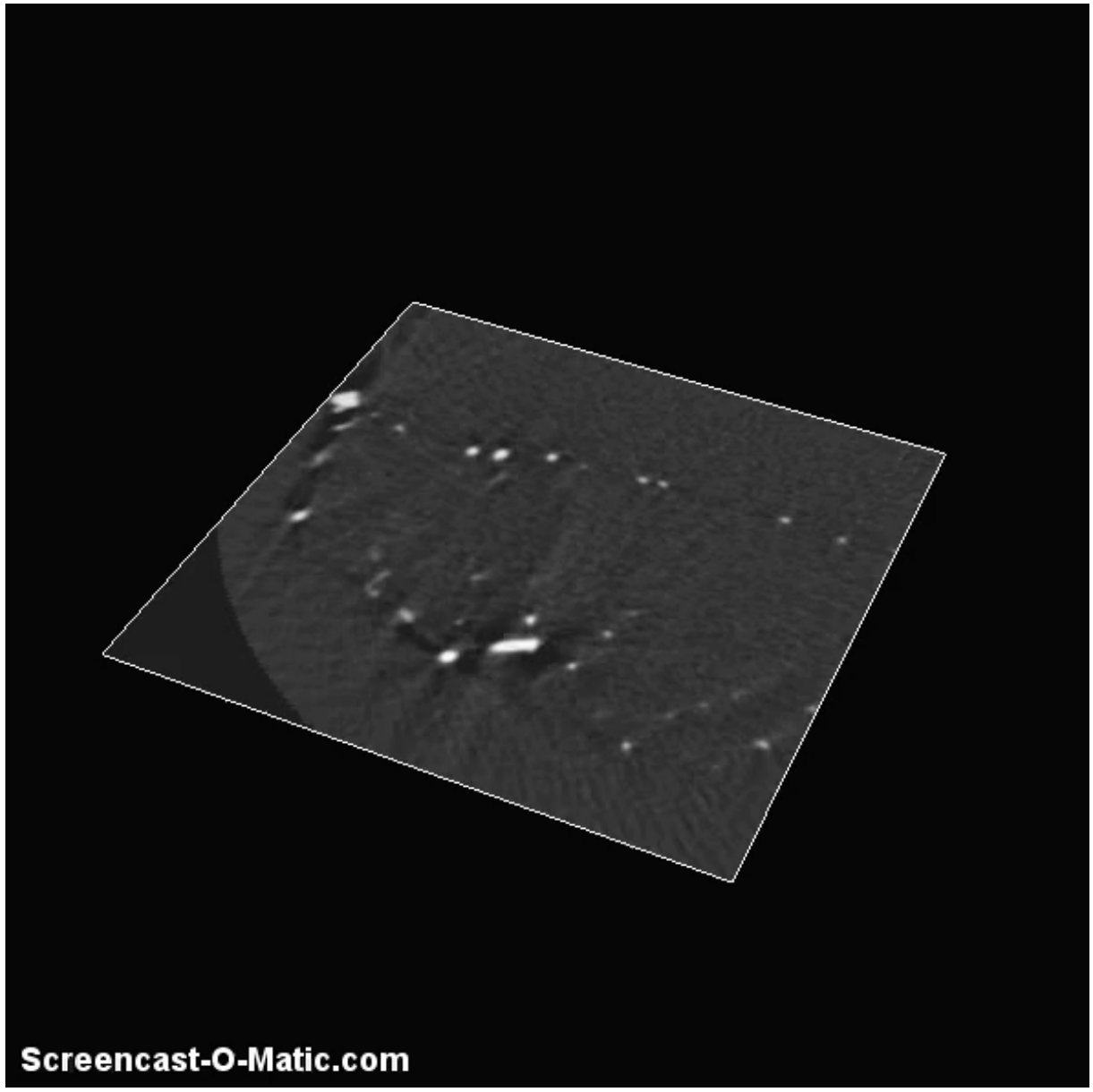


Surface reconstruction: VTK Demo



Surface reconstruction: VTK Code

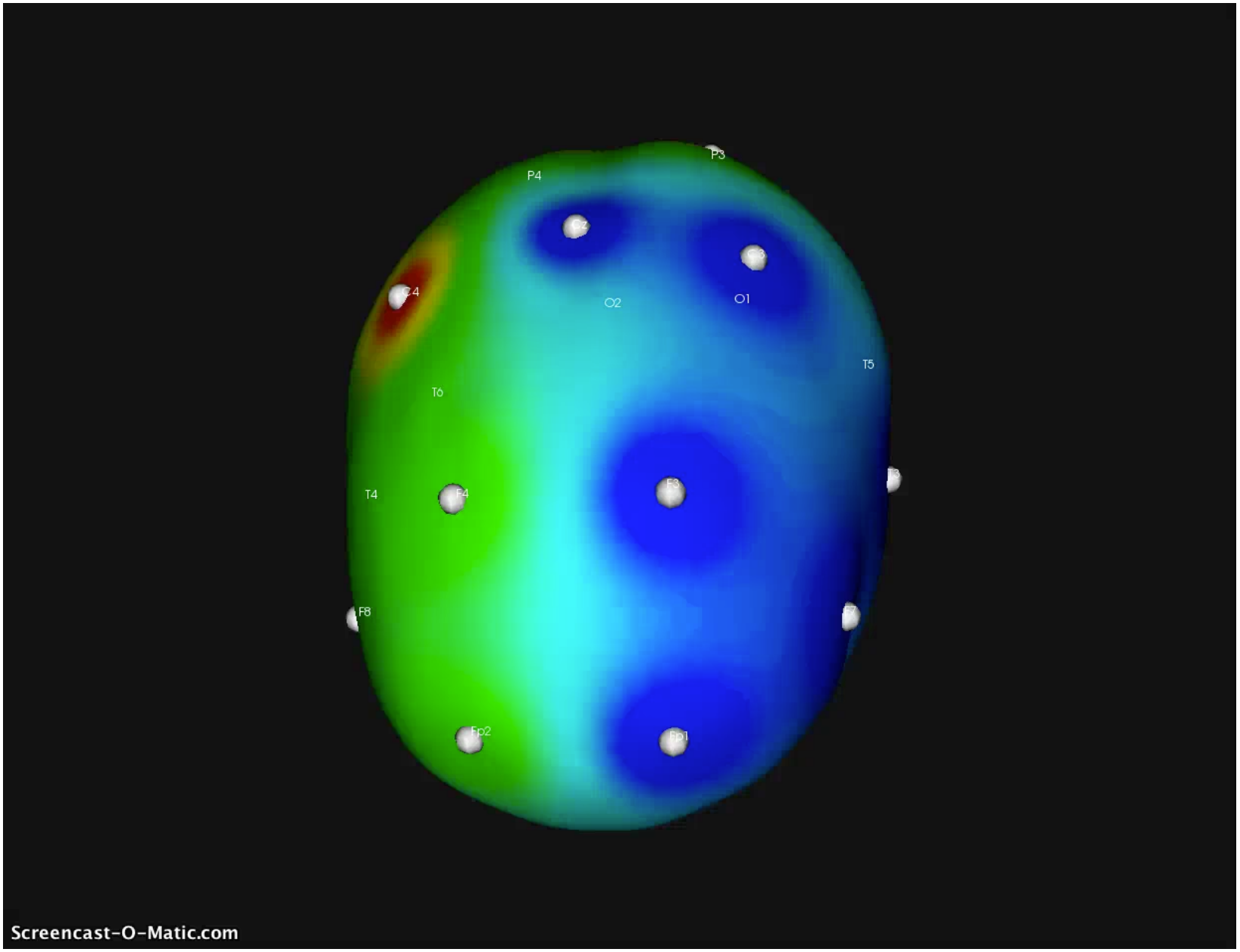
- VTK has vtkContourFilter for this purpose

```
vtkSmartPointer<vtkContourFilter> filter =
        vtkSmartPointer<vtkContourFilter>::New();

filter->SetInputData((vtkDataObject*)(image));

filter->SetValue(0,value);

filter->Update();

mapper->SetInputData(filter->GetOutput());
```

Mapping color values to 3D mesh

- Visualize scalars on mesh surface using a color map
- Application: Electroencephalography (EEG)

Mapping color values to 3D mesh

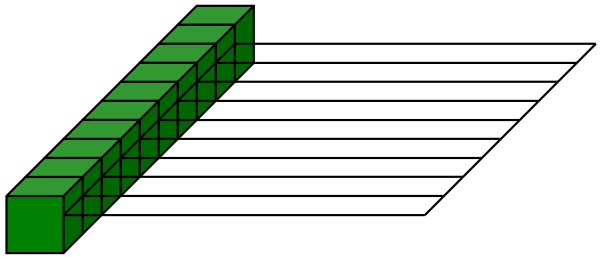


Mapping color to VTK poly data points

```
vtkSmartPointer<vtkPolyData> poly_data =
        vtkSmartPointer<vtkPolyData>::New();
vtkSmartPointer<vtkPolyDataMapper> mapper =
        vtkSmartPointer<vtkPolyDataMapper>::New();
vtkSmartPointer<vtkUnsignedCharArray> poly_data_point_scalars =
        vtkSmartPointer<vtkUnsignedCharArray>::New();

poly_data_point_scalars->SetNumberOfComponents(1);
for(int i=0; i<poly_data->GetNumberOfPoints(); i++){
double scalar_value = i;
poly_data_point_scalars->InsertNextTuple(&scalar_value);
}

poly_data->GetPointData()->SetScalars(poly_data_point_scalars);
mapper->SetInputData(poly_data);
mapper->SetColorModeToMapScalars();
mapper->SetScalarRange(0, 100);
```

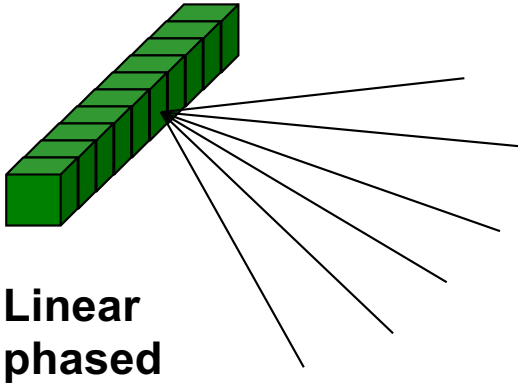
Ultrasound imaging

- Ultrasound is frequency over 20kHz
- Resolution increases with frequency (1.5MHz for 1mm)
- Penetration decreases with frequency



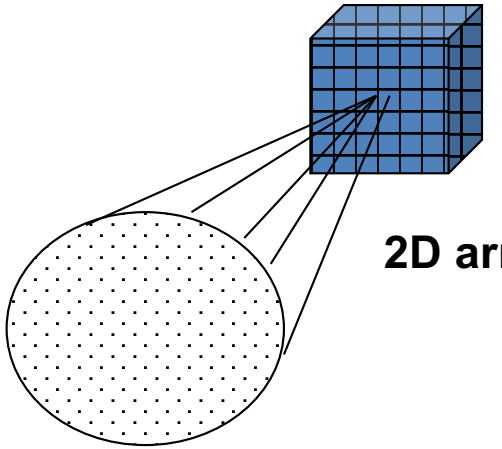
Linear

- High frequency: good resolution, shallow penetration
- Low frequency: low resolution, deep penetration



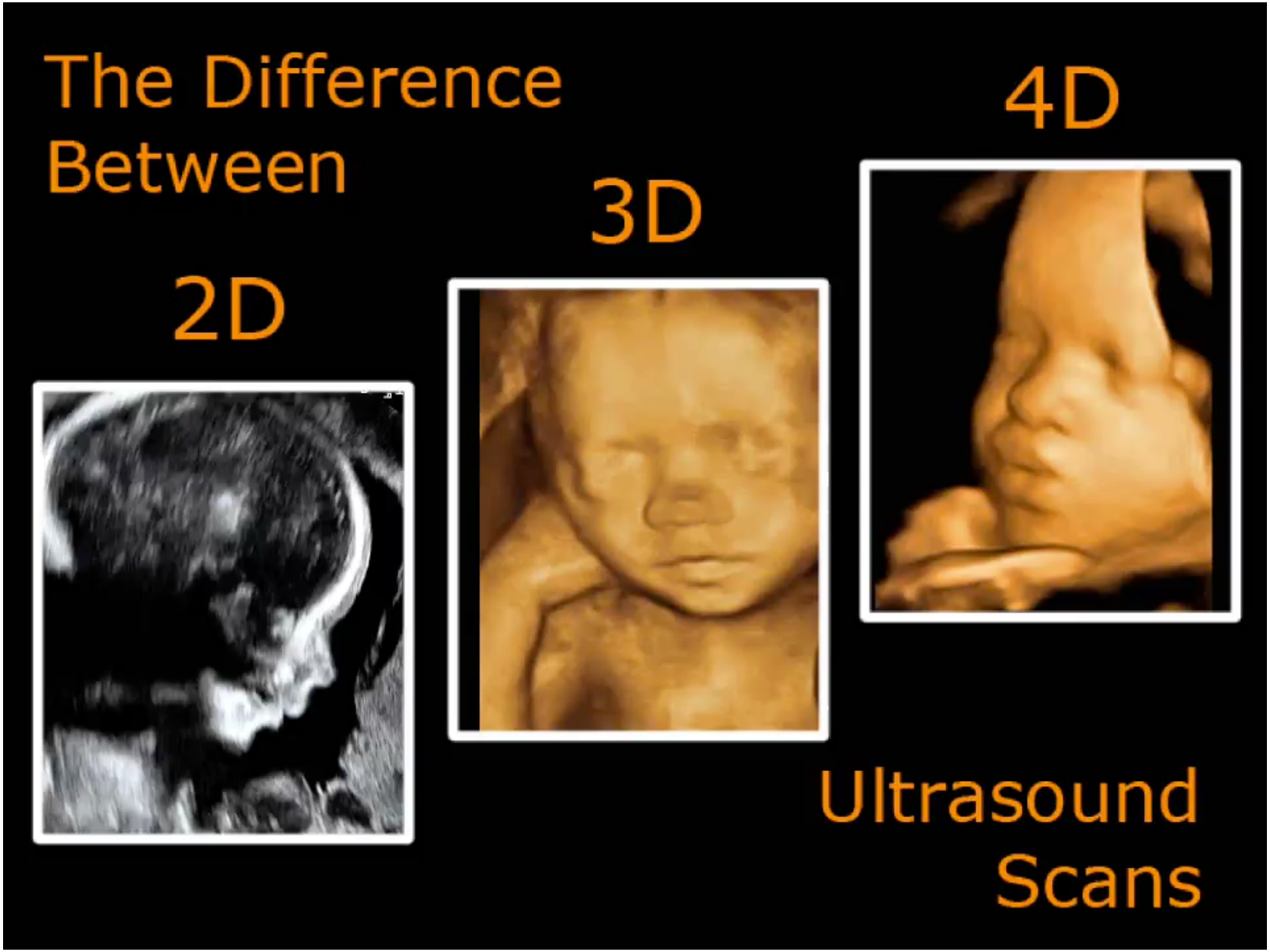
Linear phased

- Cardiology, gynaecology: 2-8 MHz
- Ophthalmology, peripheral vessels: 20MHz
- Intra-arterial: 20-50MHz



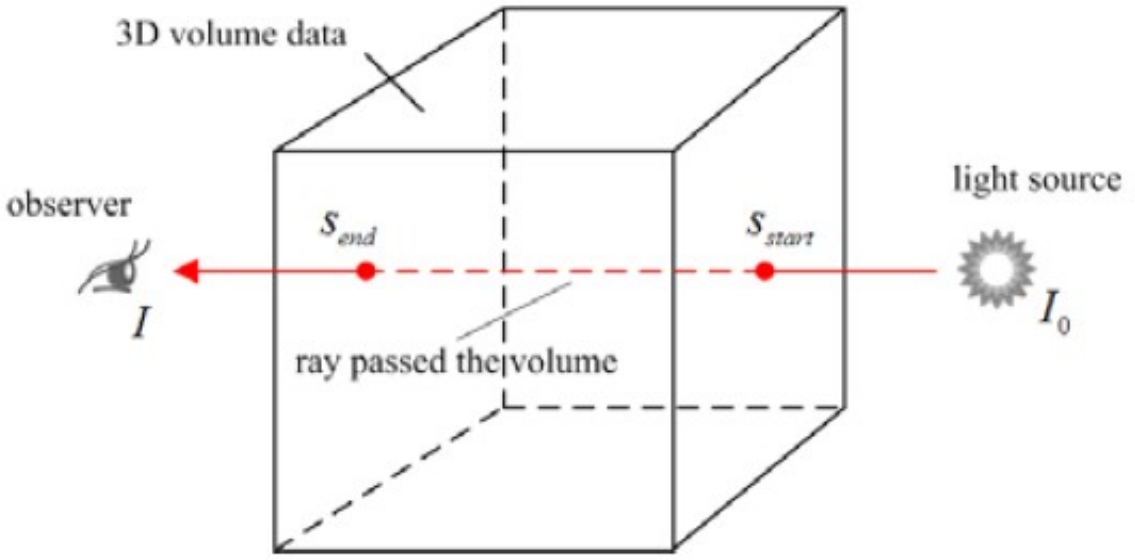
2D array

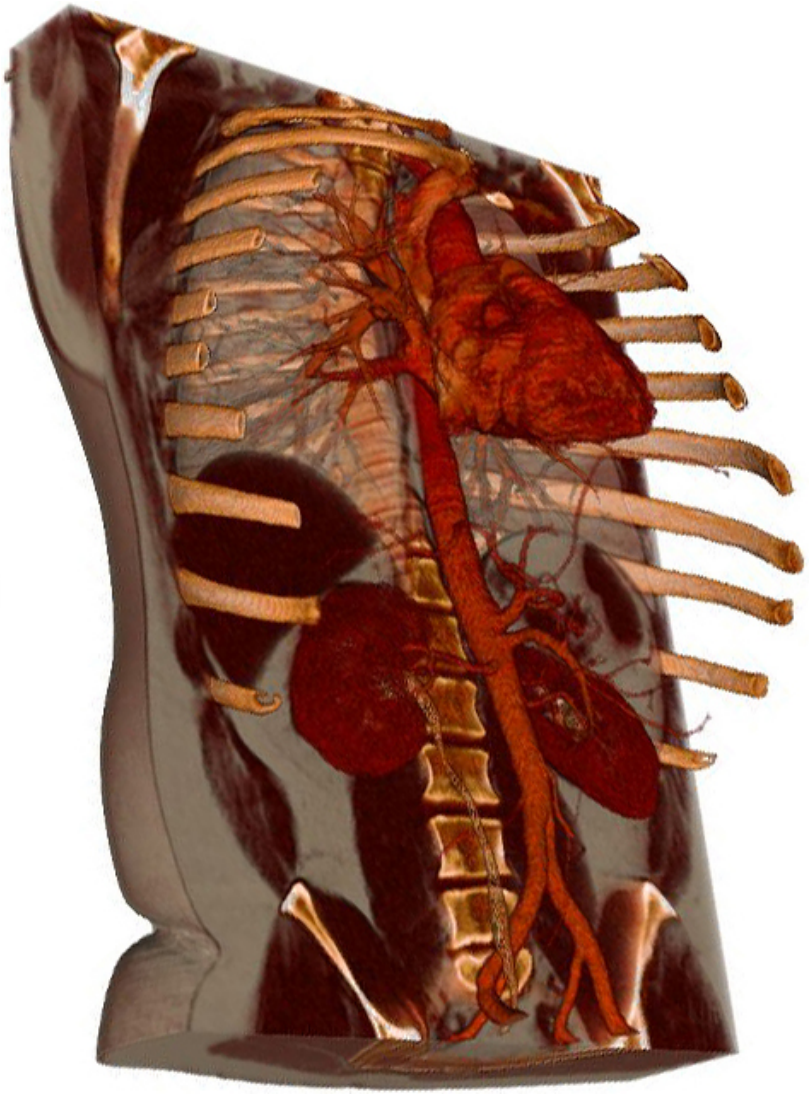
Ultrasound imaging



Volume rendering

- Ray casting
- Maximum Intensity Projection (MIP)
- Texture rendering
- Important: setting transfer function!





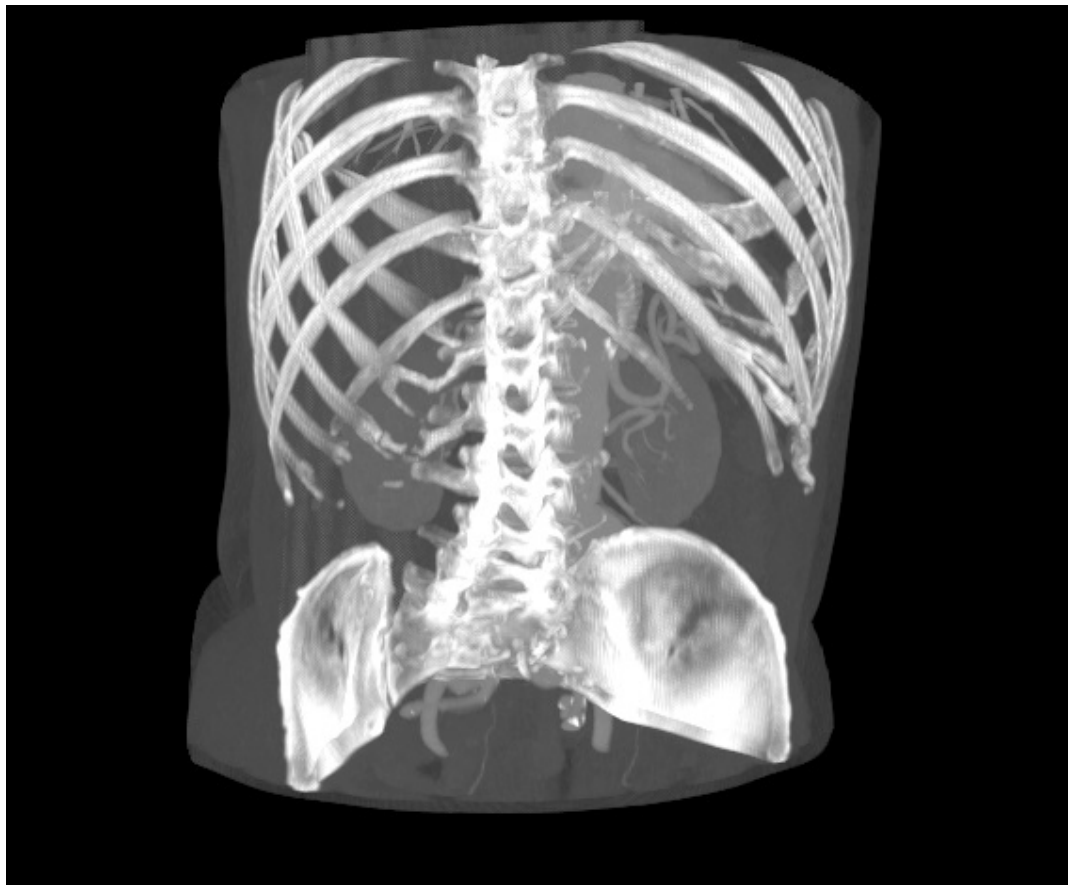
Volume rendering: Maximum intensity projection

- Display the maximum intensity of voxel along the ray path.

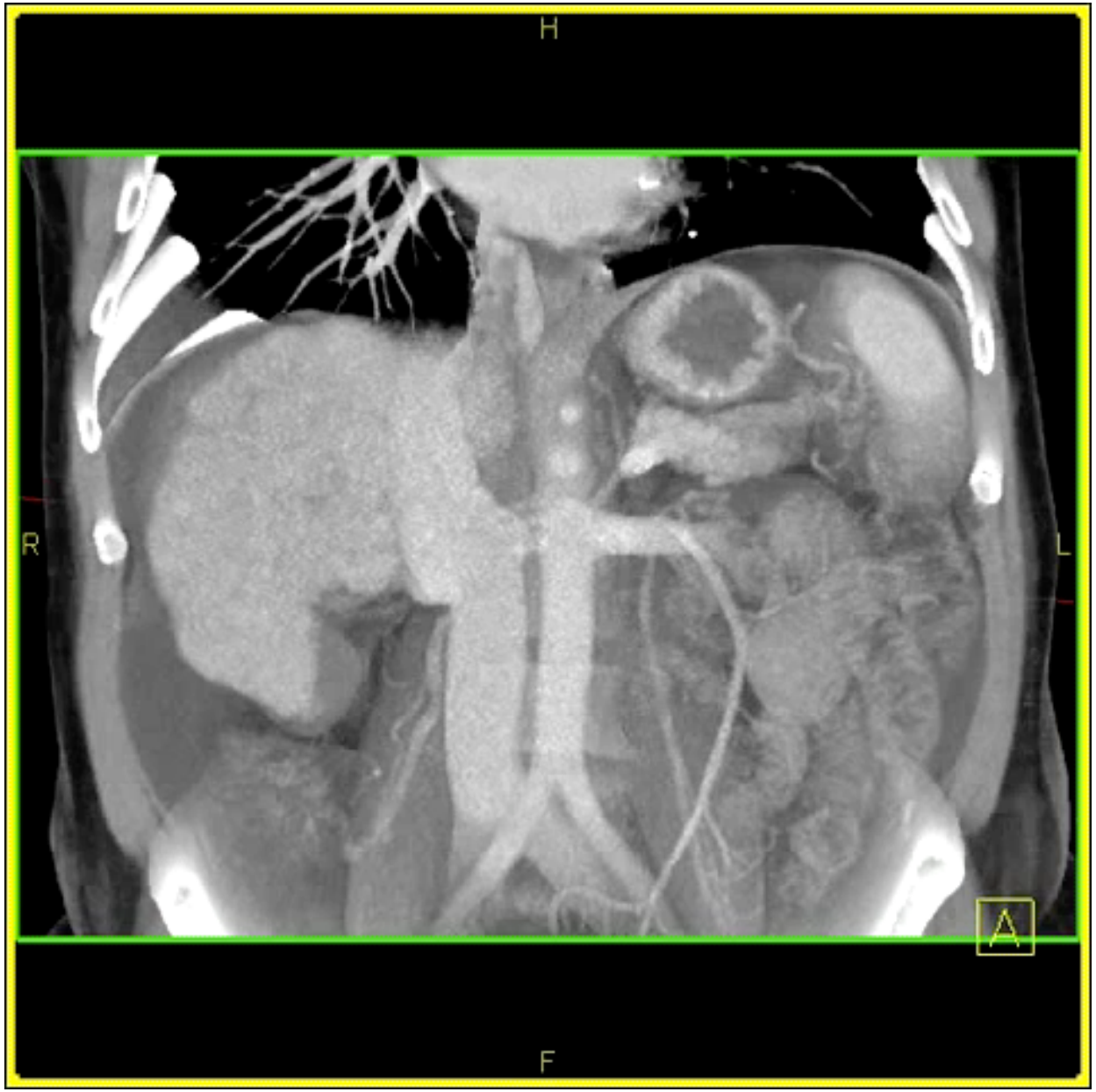
- Problem: if performed on the whole volume, the result is a simple x-ray-like (similar to x-ray) image

- Solution: use variable width slices to perform MIP

- Limitation of MIP: object orientation unclear.



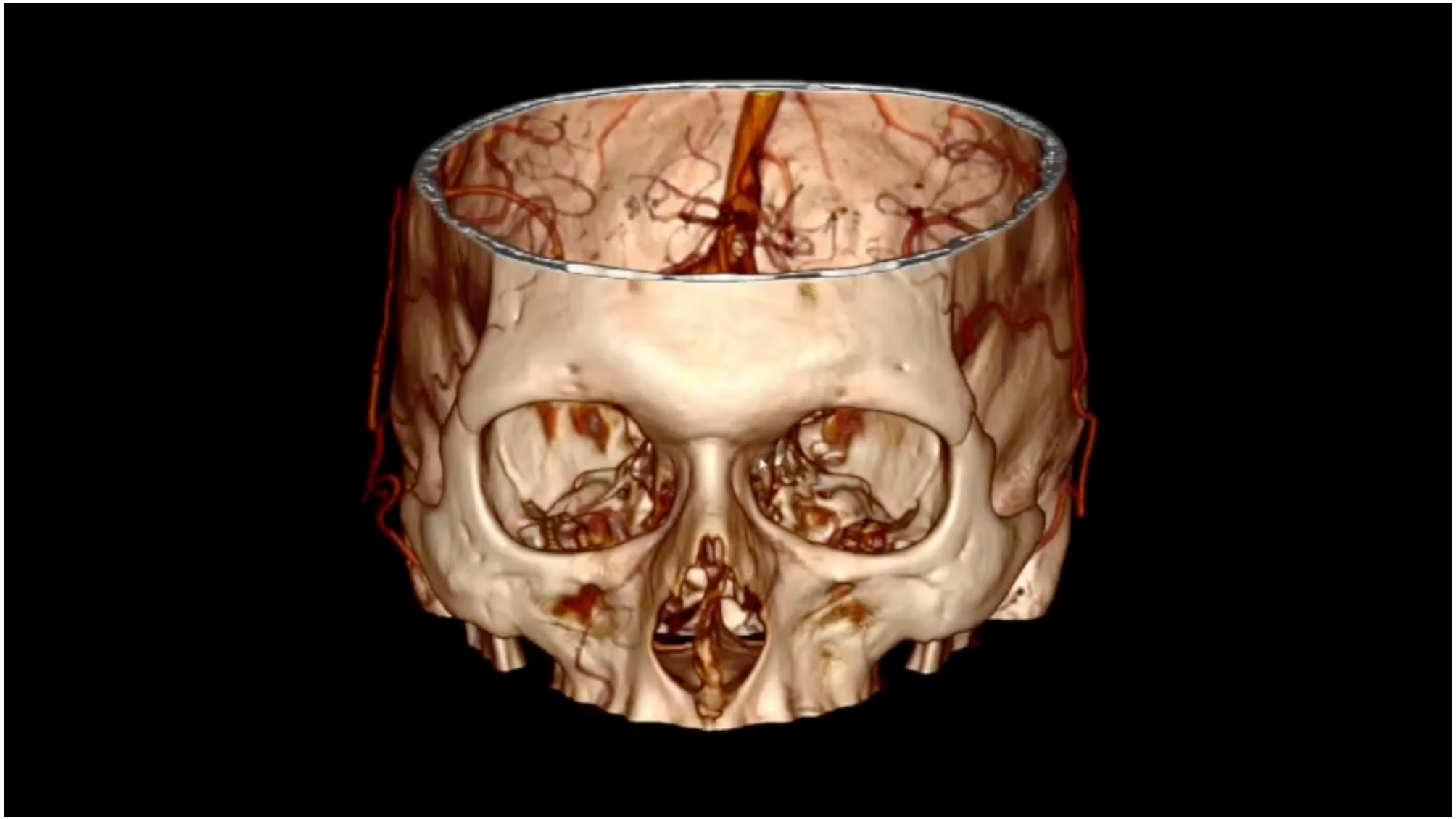
Volume rendering: Maximum intensity projection



Volume Rendering - ray casting

- Transfer functions (color and opacity) define how a given pixel intensity is mapped.
- Visualization apps implement interactive transfer function adjustment (using mouse movement)
- Level of Detail (LOD) can be used to reduce computational demand when rotating/moving the scene by reduction of render resolution.

Volume Rendering



Volume Rendering: Ray casting code

- Define how intensities map to colors and opacity

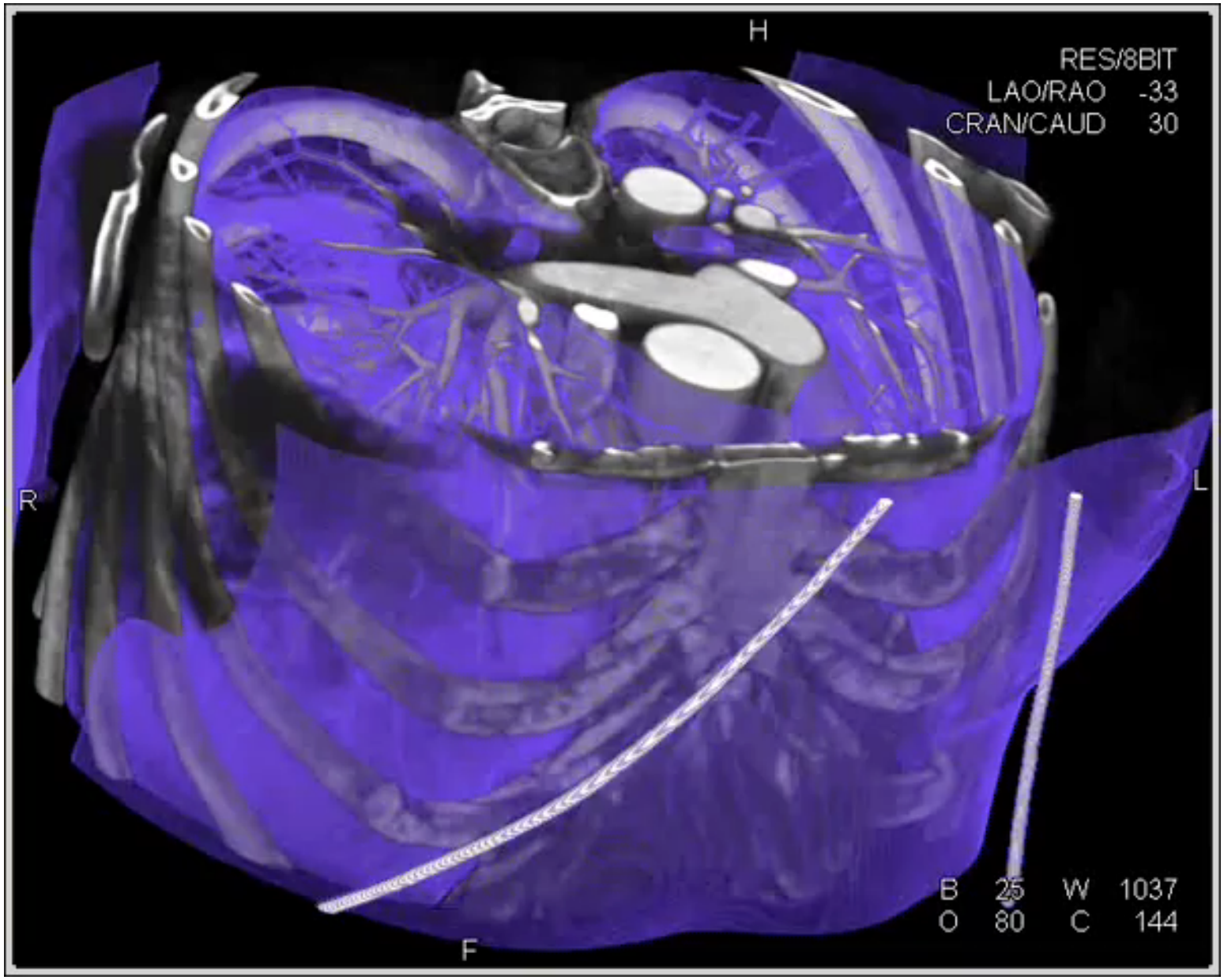
```
vtkSmartPointer<vtkPiecewiseFunction> opacity =
        vtkSmartPointer<vtkPiecewiseFunction>::New();
opacity->AddPoint(0.0,0.0);
opacity->AddPoint(80.0,1.0);
opacity->AddPoint(80.1,0.0);
opacity->AddPoint(255.0,0.0);

vtkSmartPointer<vtkColorTransferFunction> color =
        vtkSmartPointer<vtkColorTransferFunction>::New();
color->AddRGBPoint(0.0 ,0.0,0.0,1.0);
color->AddRGBPoint(40.0 ,1.0,0.0,0.0);
color->AddRGBPoint(255.0,1.0,1.0,1.0);
```

Volume Rendering: Ray casting code

- Define how intensities map to colors and opacity

```
vtkSmartPointer<vtkSmartVolumeMapper> mapper =
        vtkSmartPointer<vtkSmartVolumeMapper>::New();
mapper->SetBlendModeToComposite();
mapper->SetInputData(imageData);

vtkSmartPointer<vtkVolumeProperty> prp =
        vtkSmartPointer<vtkVolumeProperty>::New();
prp->ShadeOff();
prp->SetInterpolationType(VTK_LINEAR_INTERPOLATION);
prp->SetScalarOpacity(opacity);
prp->SetColor(color);

vtkSmartPointer<vtkVolume> volume =
        vtkSmartPointer<vtkVolume>::New();
volume->SetMapper(mapper);
volume->SetProperty(prp);
renderer->AddViewProp(volume);
```

Combining Visualizations



Combining Visualizations: Coronary OCT