# Visualization, Lecture

## Volume Visualization, Part 1

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# Overview: Lecture #3

Contents of Volume Visualization, Part 1:

- Introduction
  - About Volume Data
  - Overview of Techniques
- The VolVis Conceptual Framework
- Simple Methods
  - slicing, cuberille

# Volume Visualization

Introduction:

- VolVis = Visualization of Volume data
  - Picture/image 3D→2D
  - Projection (e.g., Maximum Intensity Projection-MIP), slicing, surface extractiontion, volume rendering, …
- Volume Data =
  - 3D -> 1D Data
  - scalar data, 3D data space, space filling (dense-as opposed to sparse)
- User goals:
  - to gain insight into 3D Data
  - depends strongly on what user is interested in (focus + context)

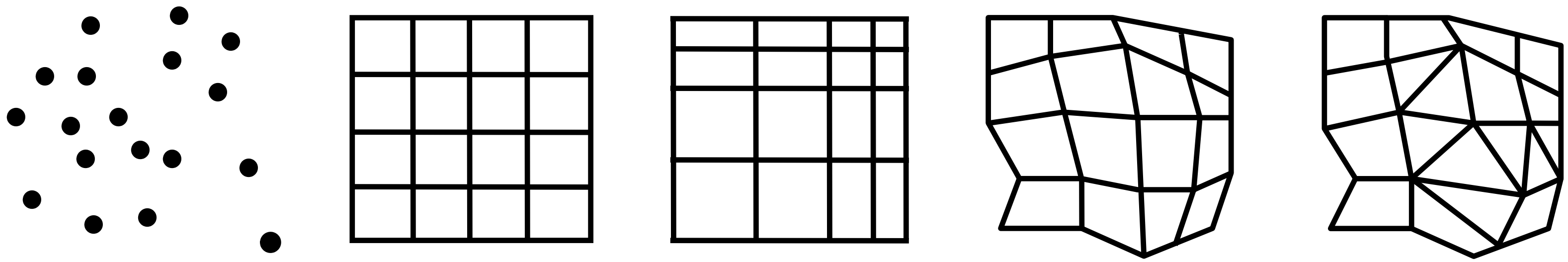
# Volume Data

Where does the data come from?

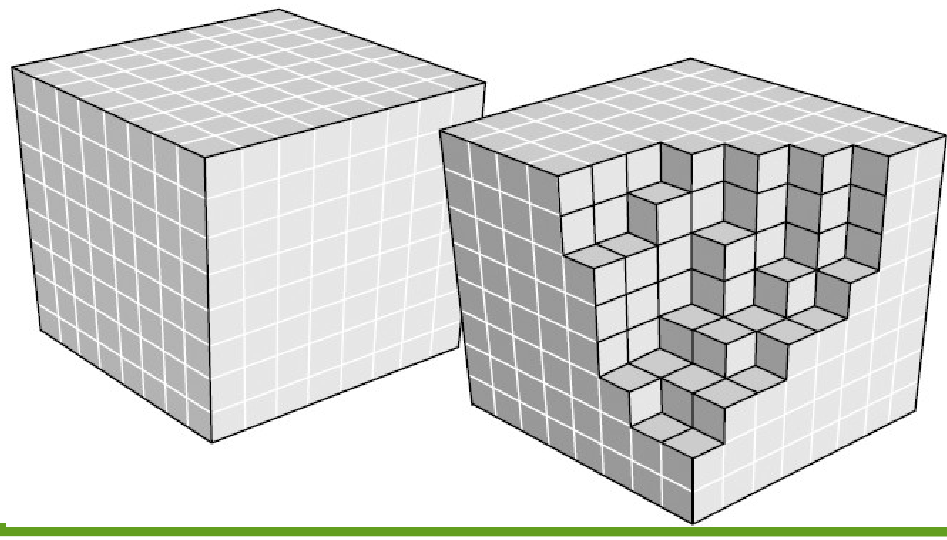
- Medical Applications
  - Computer Tomography (CT)
  - Magnet Resonance Imaging (MRI)
- Material testing/control
  - Industry-CT
- Simulation
  - Finite element methods (FEM)
  - Computational fluid dynamics (CFD)
- And other sources

# Grid data

## Data is often in a 2D/3D grid of values



scattered unstructured | uniform | rectilinear | structured



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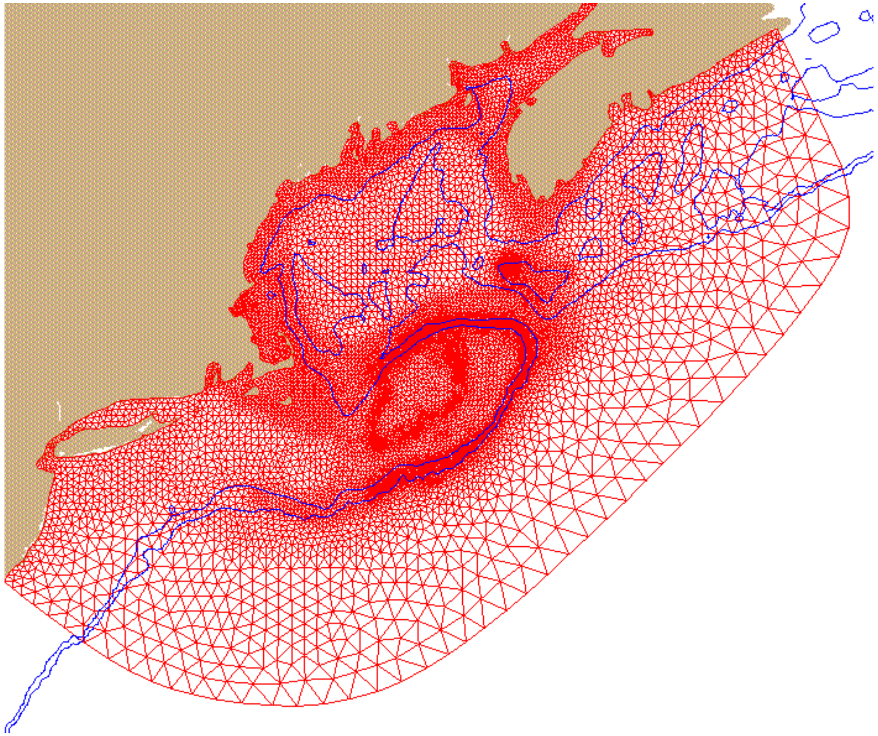
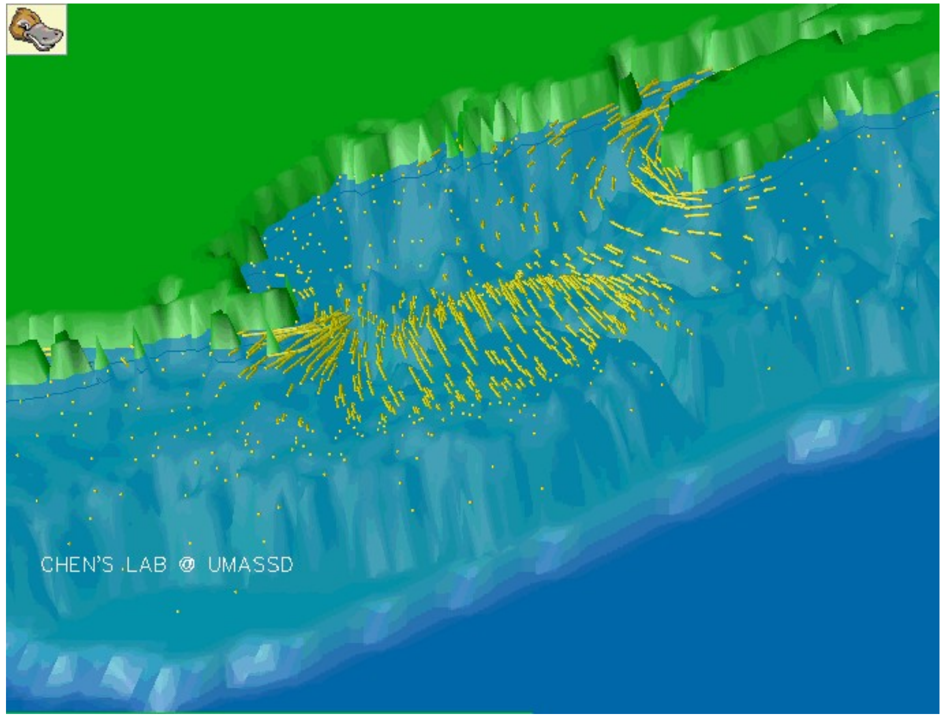
# Grid data

Can be adapted to local data





# 3D Data Space

How is the volume data organized?

- Cartesian, i.e., regular grids:
  1. CT/MR: often dx=dy<dz, e.g. 135 sclices (z) by $512^2$ values in x & y
  2. **Data enhancement**: iso-stack-computation = interpolation of additional slices, so that dx=dy=dz --> $512^3$ Voxel
  3. Data: **Cells** (Faces), Corners: **Voxel**
- Curvilinear grid i.e., unstructured:
  - Data organized as Tetrahedra or Hexahedra
  - Often: Conversion to Tetrahedra

**Terminology**

**Tetrahedron**. “A 3D primary cell that is a simplex with four triangular faces, six edges, and four vertices.” –the Visualization Toolkit (VTK)

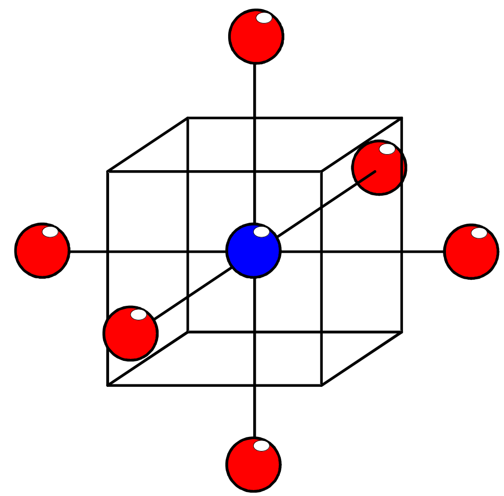
# Volume Visualization (VolVis) – Challenges

Challenges:

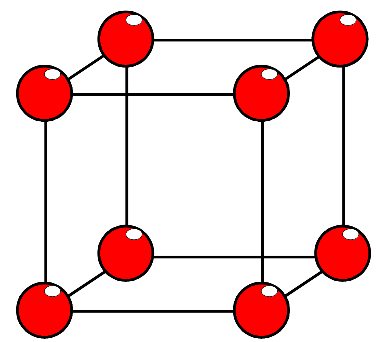
- rendering projection,
  so much information and so few pixels
- large data sets, e.g.,
  512x512x1024 voxels at 16 bit/voxel = 512 Mbytes
- Computational Speed,
  Interaction is very important, >10 frames per second (fps)

# Voxels vs. Cells

Two ways to view the volume data:



- Data as a set of voxels
  - **voxel** = short for volume element (recall: pixel = "picture element")
  - voxel = point sample in 3D
  - not always interpolated

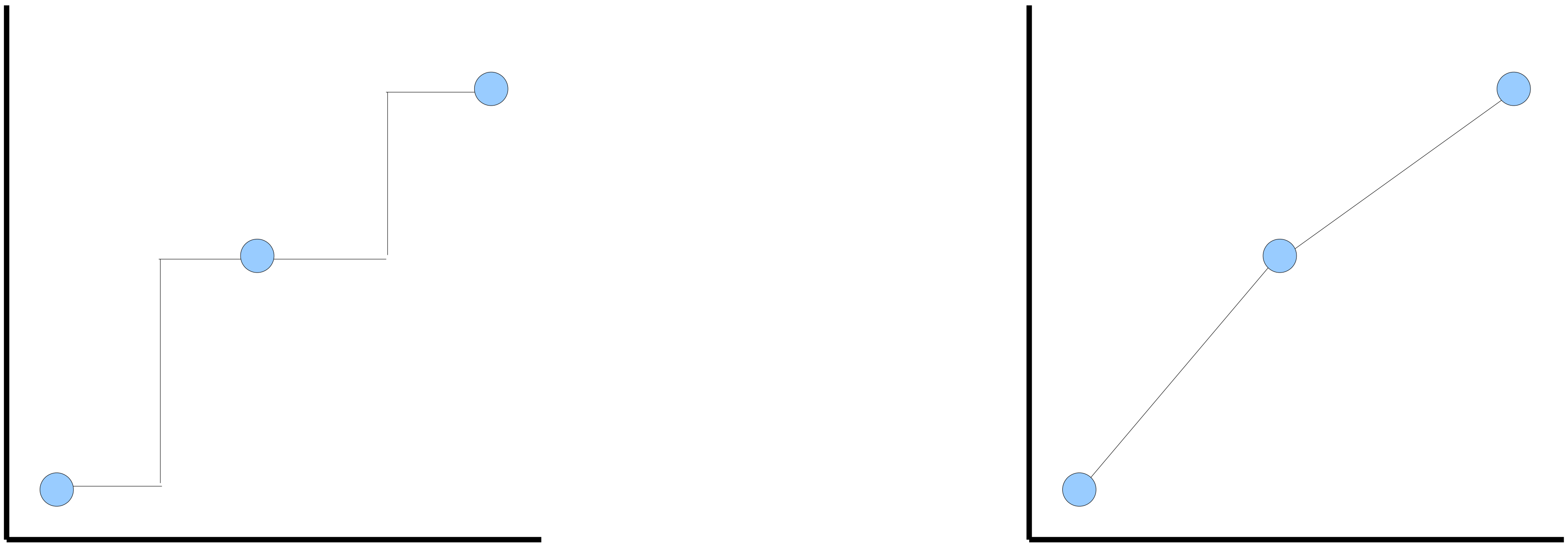


- Data as a set of cells
  - **cell** = Cubic Primitive (3D)
  - corners: 8 voxel
  - value(s) in cell: are always interpolated

# Interpolation

**(More) Terminology:**

**Interpolate**: ``Estimate a value of a function at a point, ***p***, given known function values and points that bracket ***p***."



Nearest neighbor | Linear

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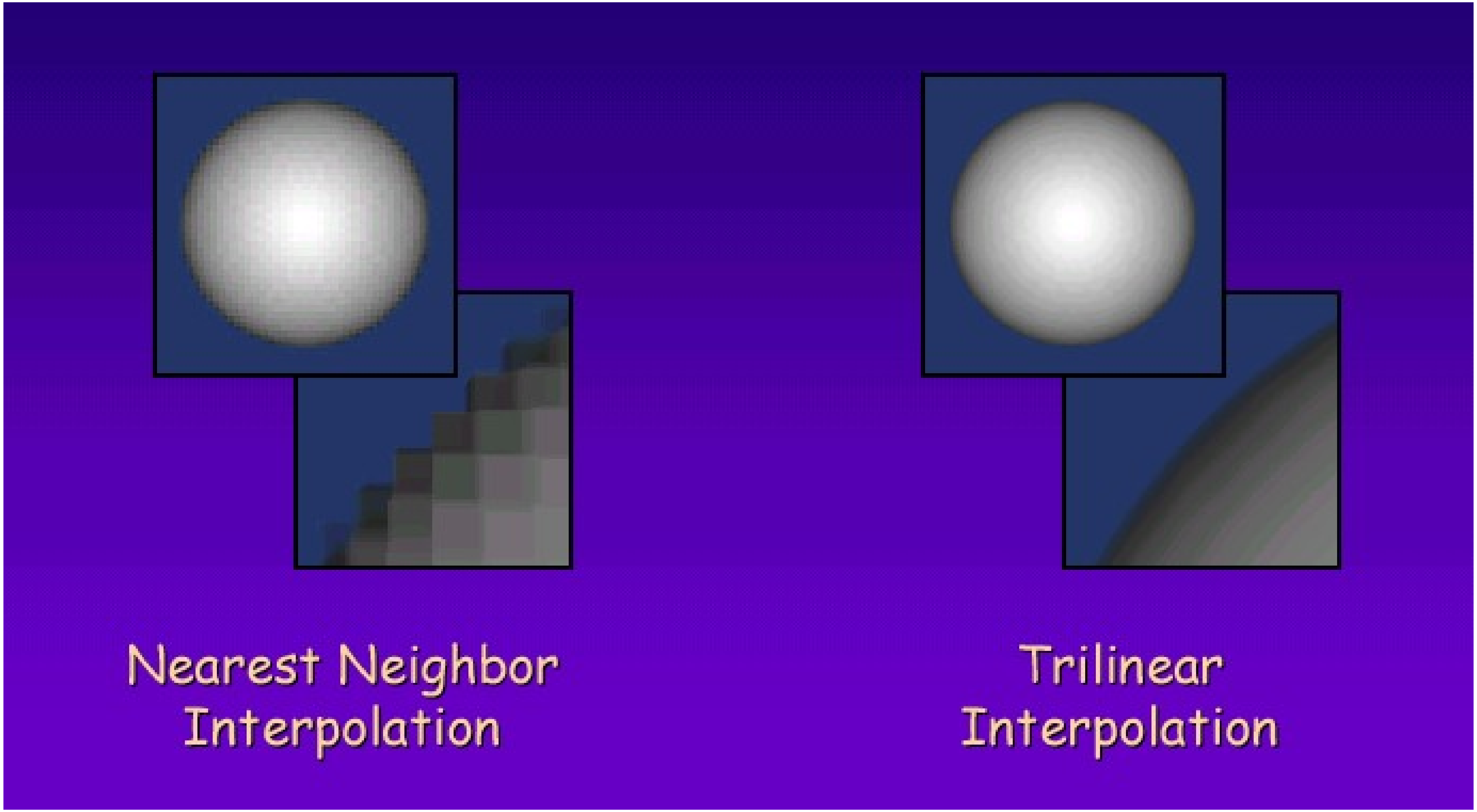
# Interpolation – Influence

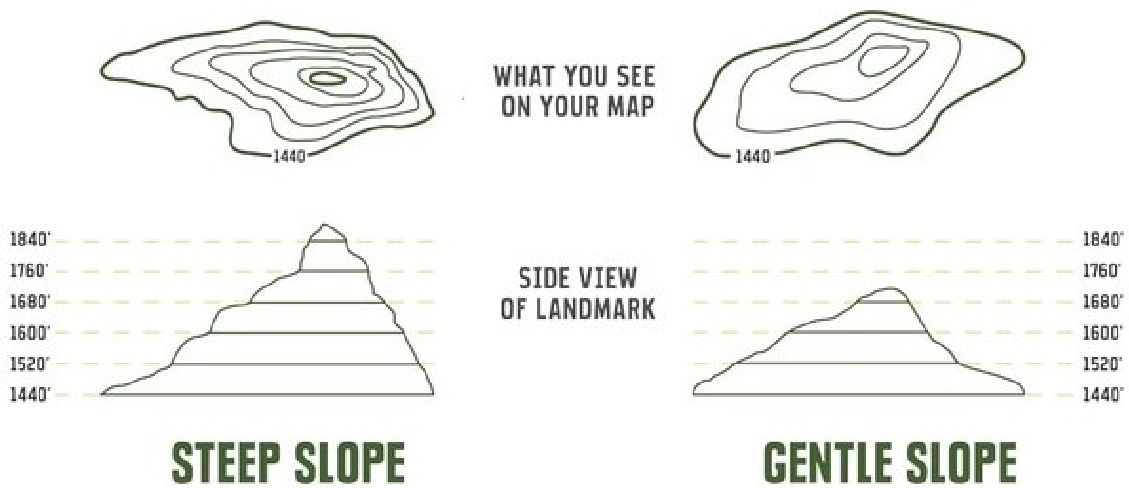


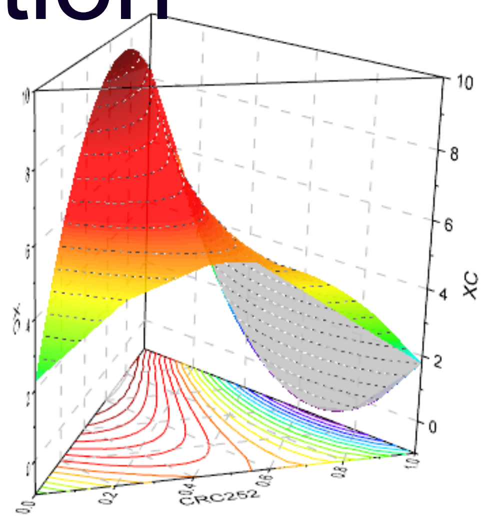
# Isosurfaces

**Level set :** {(**x**) | f(**x**) = a}

- The set of all points where the function equals some value

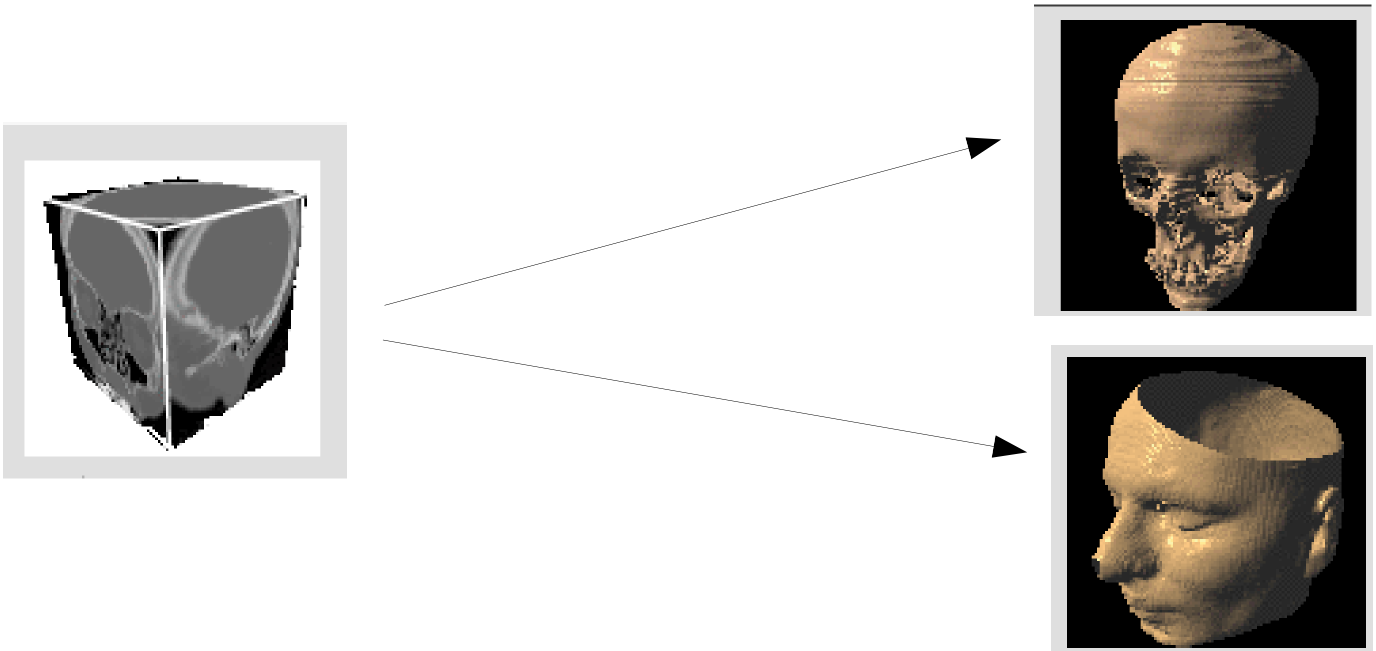
**Isocontour** surface made from the level set of a 2D scalar function



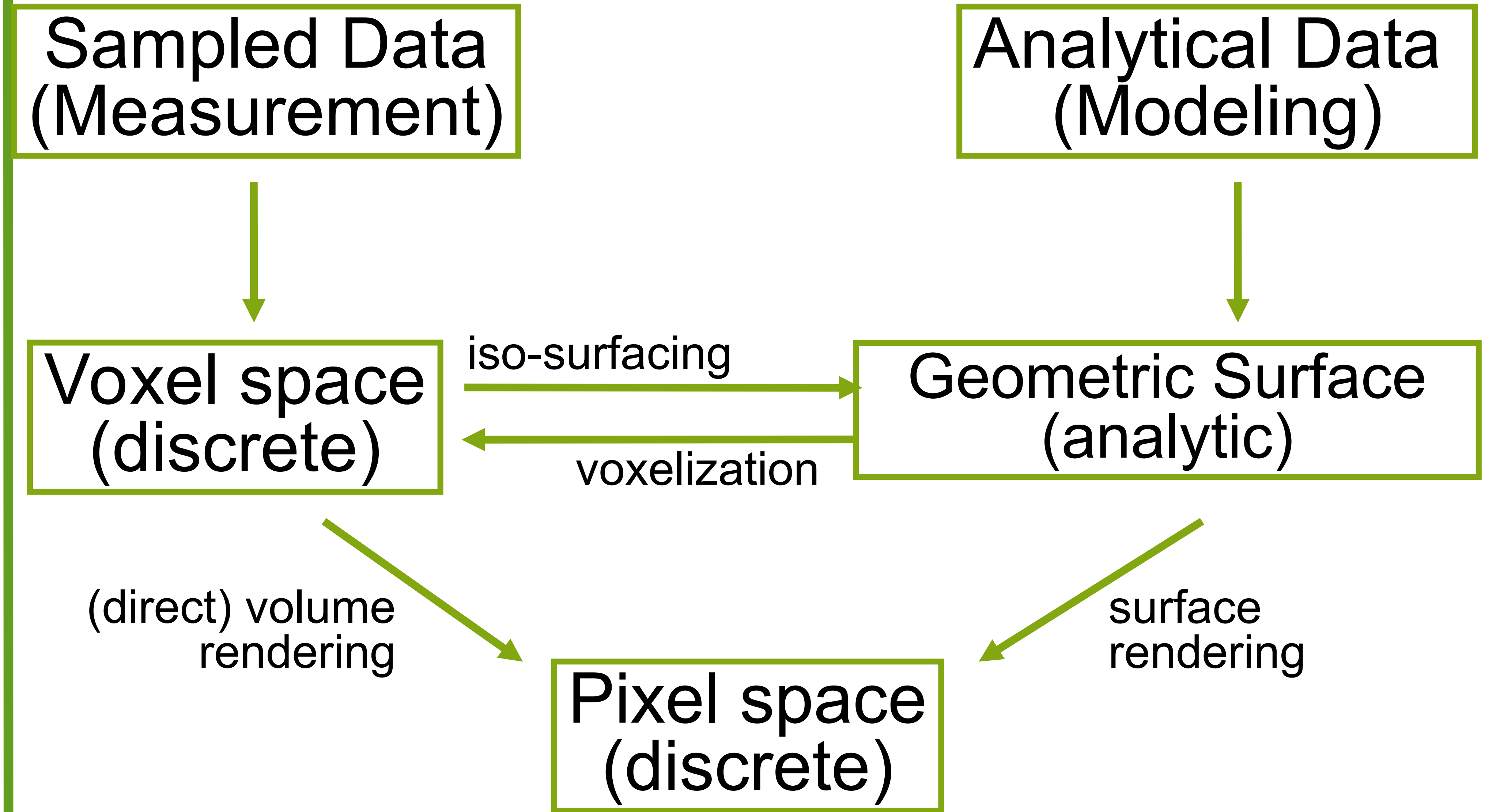



# Isosurfaces

**Isosurface** surface made from the level set of a 3D scalar function



# Conceptual VolVis Framework





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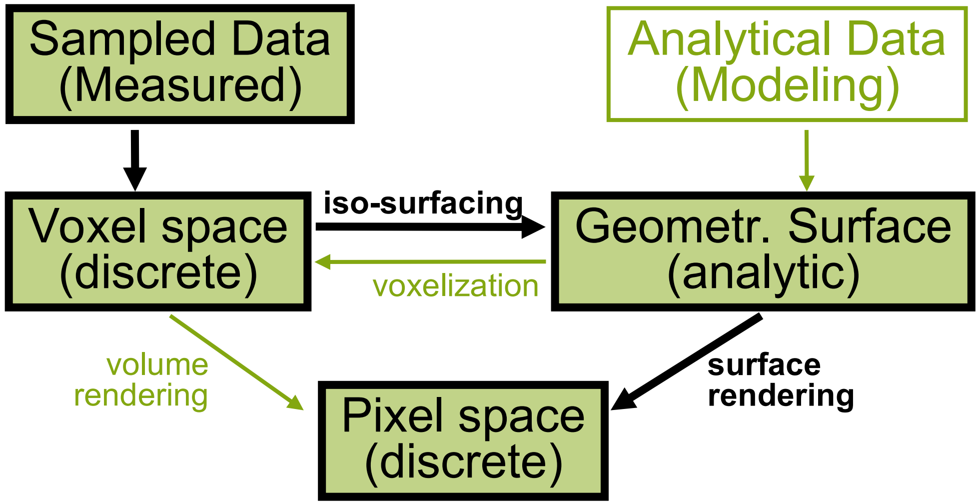
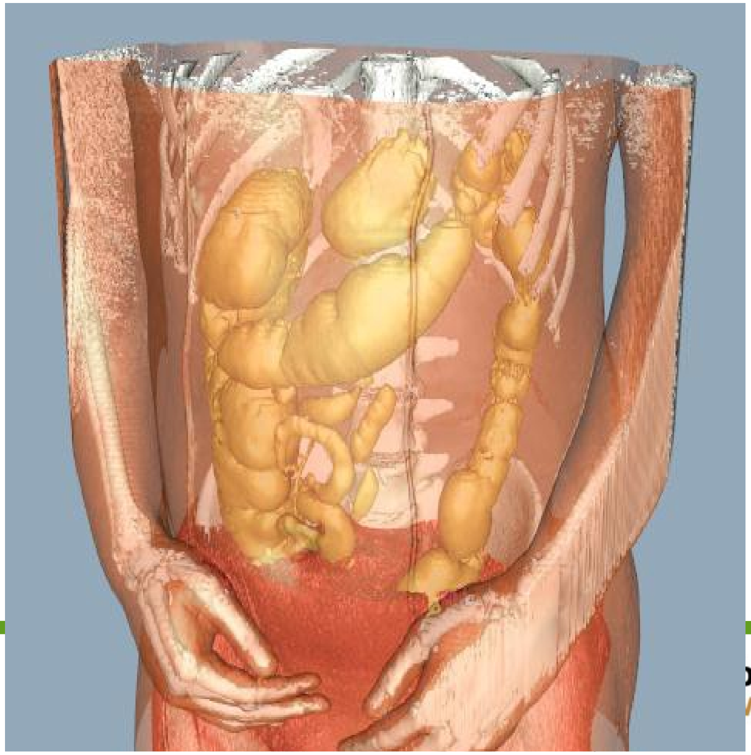
# Conceptual VolVis Framework

Example 1:

- CT measurement
- iso-stack compuation
- iso-surface computation (marching cubes)
- Surface rendering (OpenGL)



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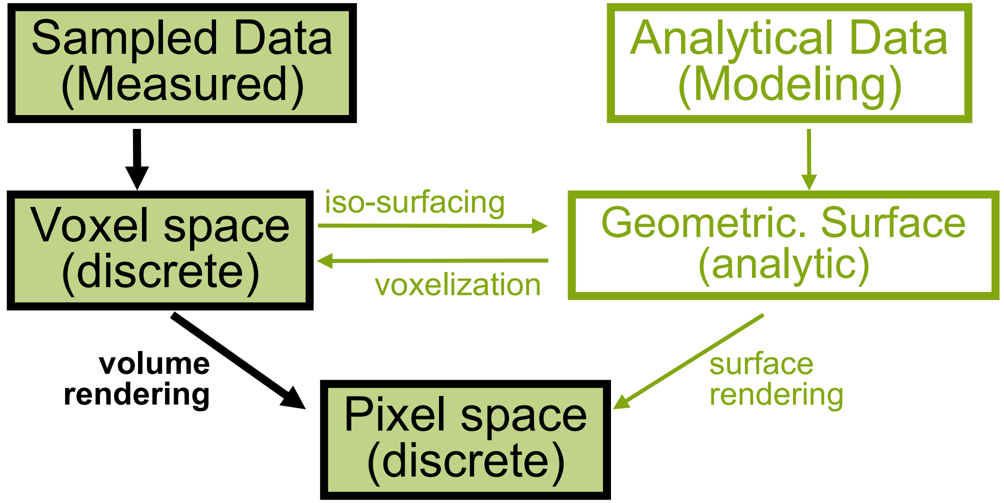
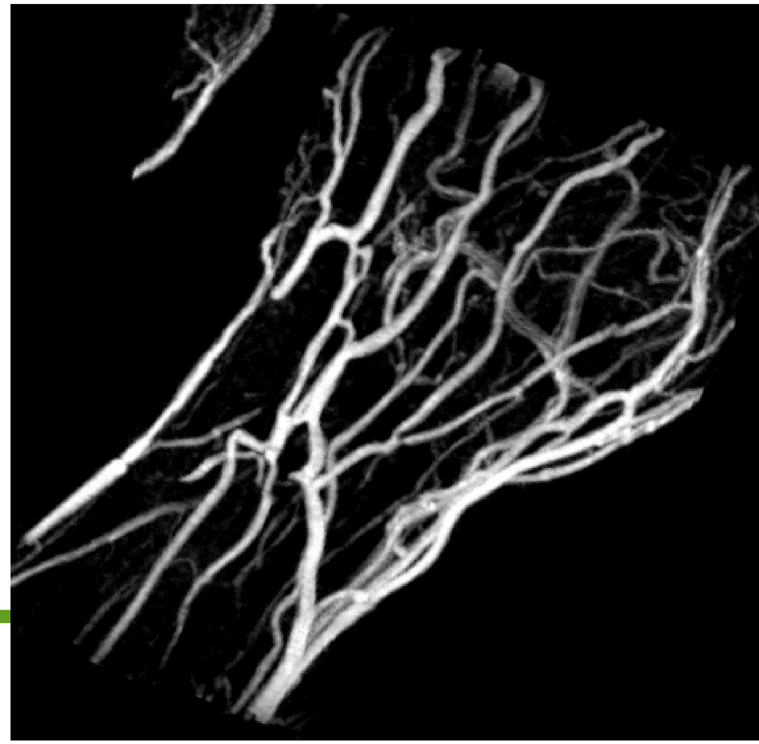
# Conceptual VolVis Framework

Example 2:

- MR Measurement
- iso-stack computation
- MIP (maximum intensity projection)
- Image: Vessels in Hand



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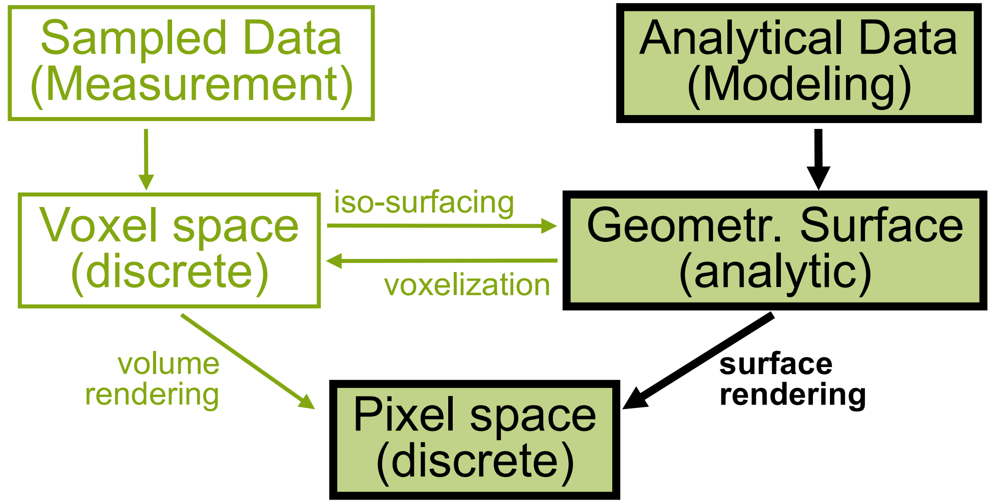
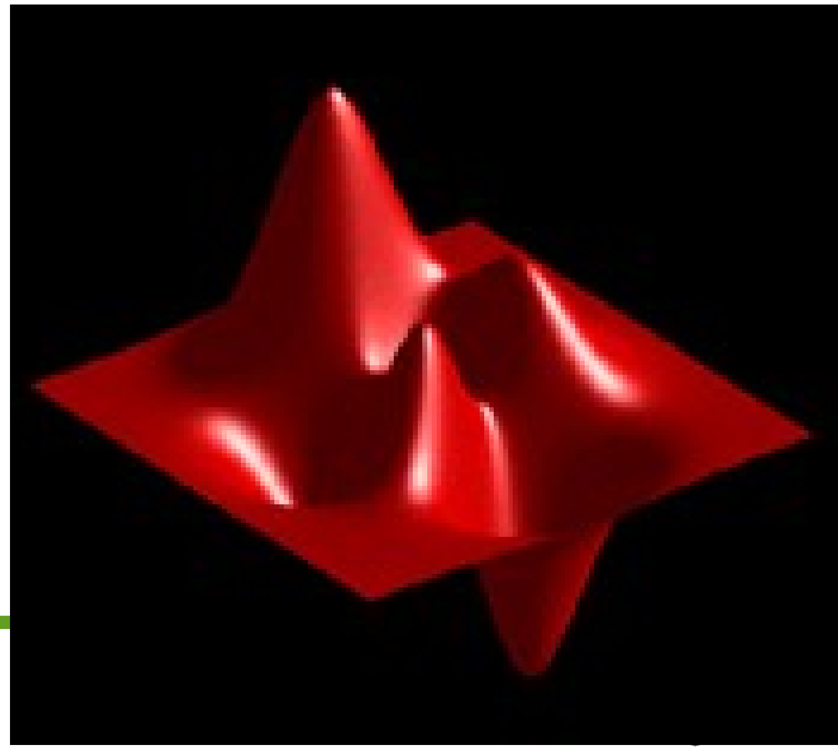
# Conceptual VolVis Framework

Example 3:

- potential function $\rho(x,y,z)$
- iso-surface $\rho(x,y,z)=\rho_0$
- surface ray tracing



# VolVis-Techniques – Overview

Indirect volume visualization:

- **Indirect**: Compute isosurfaces, then render
- slicing, MPR (multi-planar reconstruction)
- marching cubes (marching tetrahedra)

Direct volume visualization:

- **Direct**: project volume onto image plane
- ray casting
- shear-warp factorization
- Splatting
- 3D texture mapping

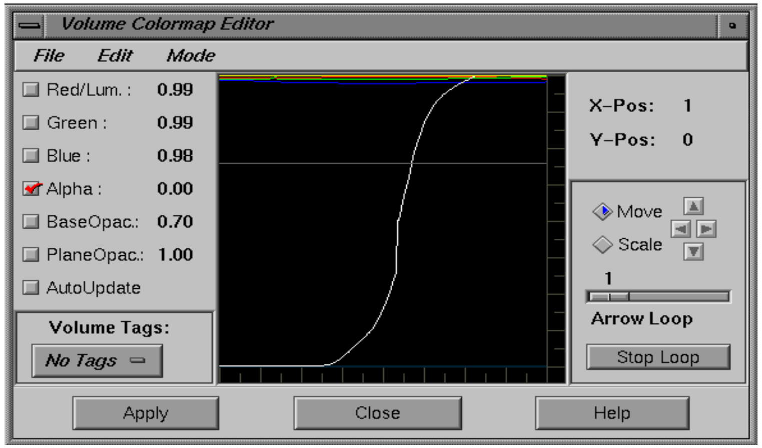
# Transfer functions

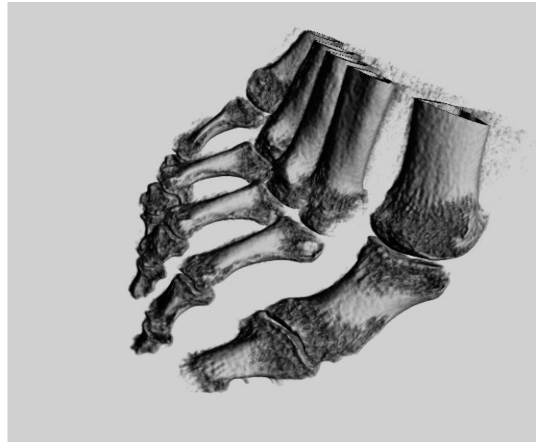
- Empowers user to select “structures”
- Extract important features of the data set
- Classification is non trivial
- Histogram can be a useful hint
- Often interactive manipulation of transfer functions needed
- Usually needed for volume visualization
- Color table for volume visualization
- Maps raw voxel value into presentable entities

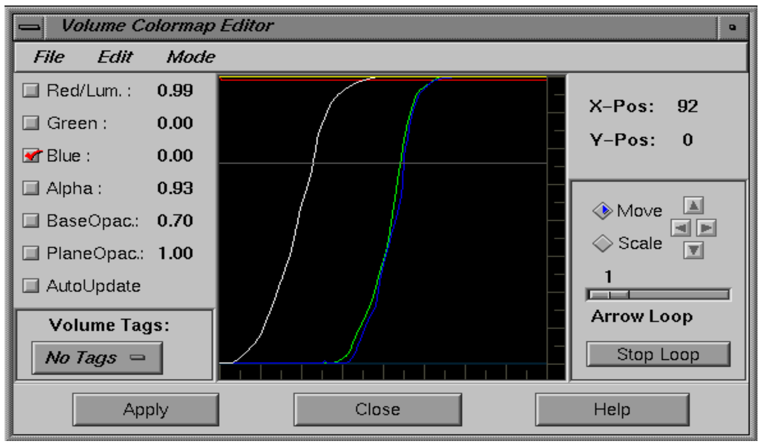
# Transfer functions

- Assign each scalar value a different color value
- Assignment via transfer function T
  T :: scalarvalue -> colorvalue
- Common choice for color representation: RGBA
- Alpha value is very important, describes opacity
- Code color values into a color lookup table
- On-the-fly update of color LUT

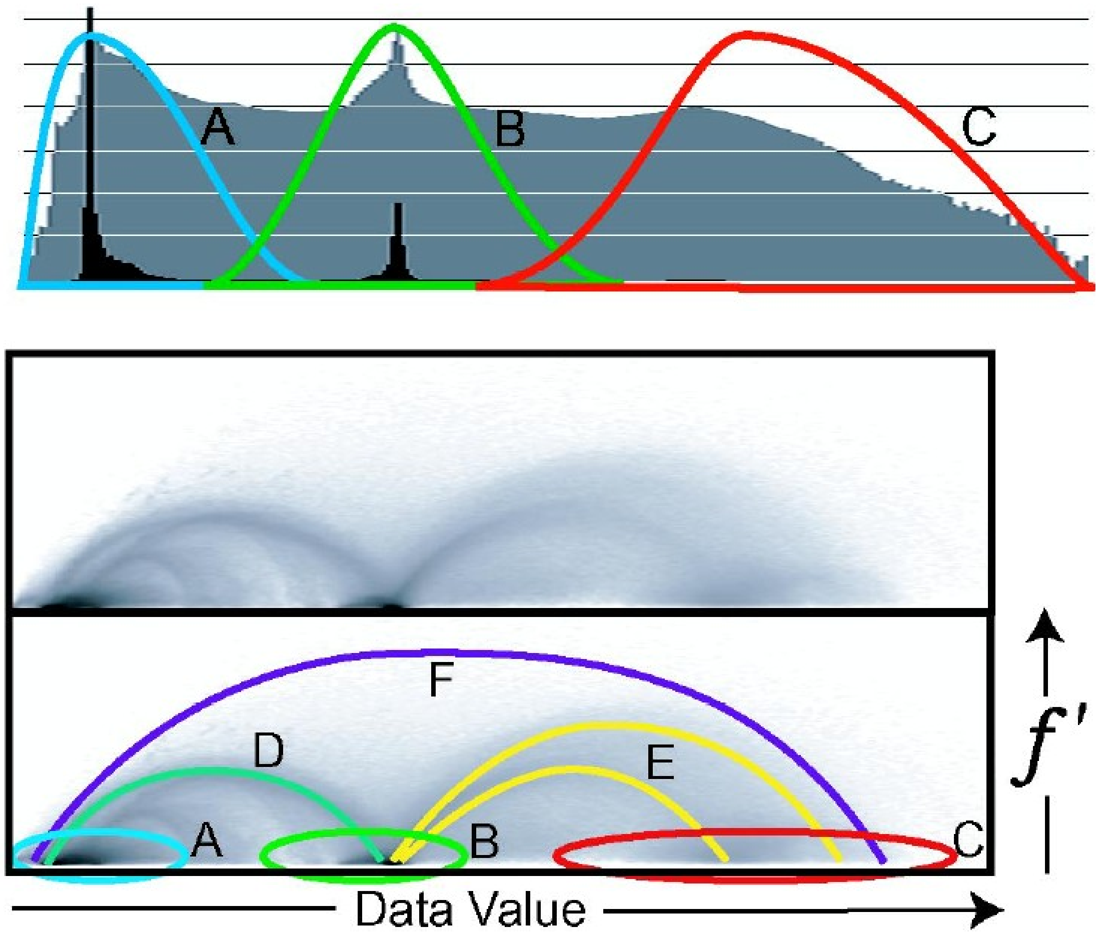
# Transfer functions

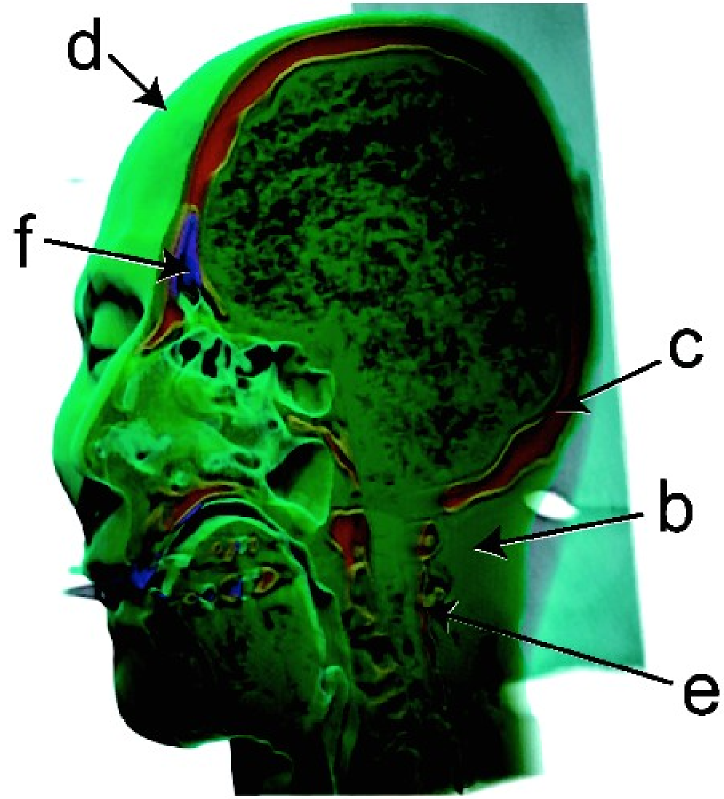





# Transfer functions



# Simple VolVis Methods

## Slicing

# Slicing

Slicing:

- Axis-aligned slices
- regular grids: simple
- no transfer function
  no color
- windowing:
  contrast adjustment/enhancement

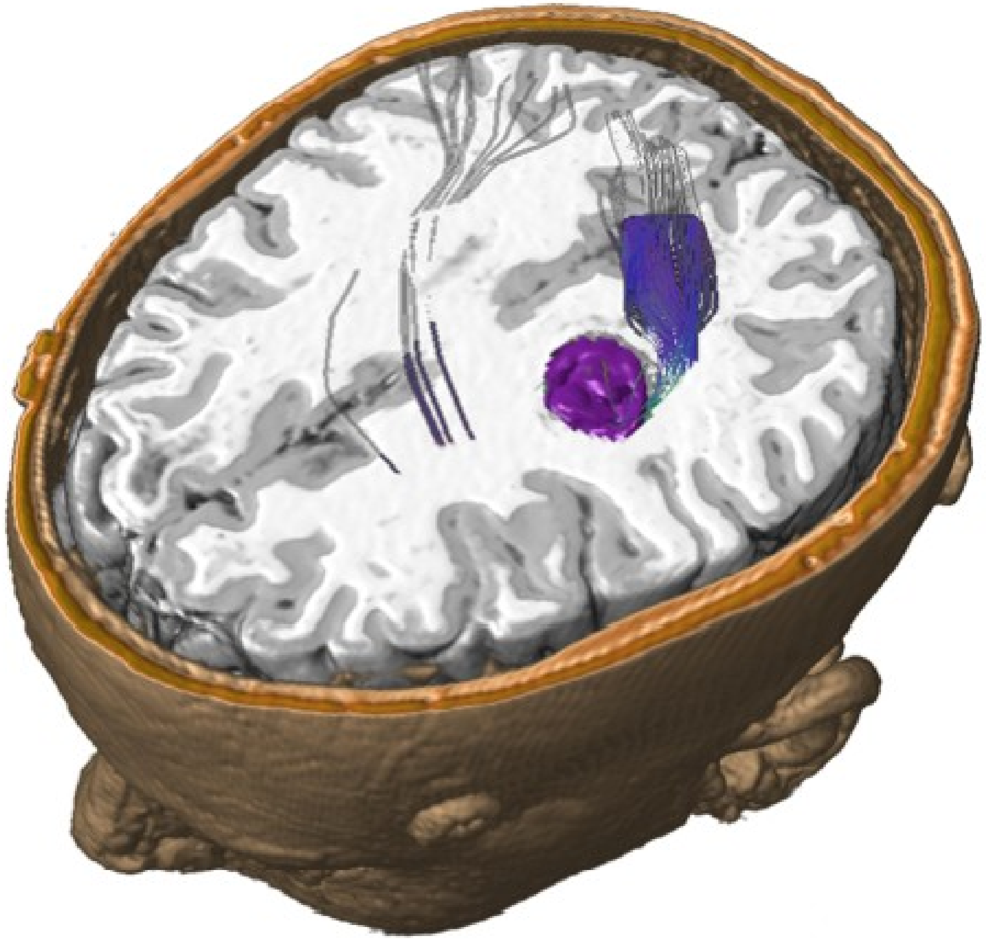
# Slicing

Not so simple:

- slicing through all grids
- interpolation necessary

Slicing:

- Combines well with 3D-Vis.



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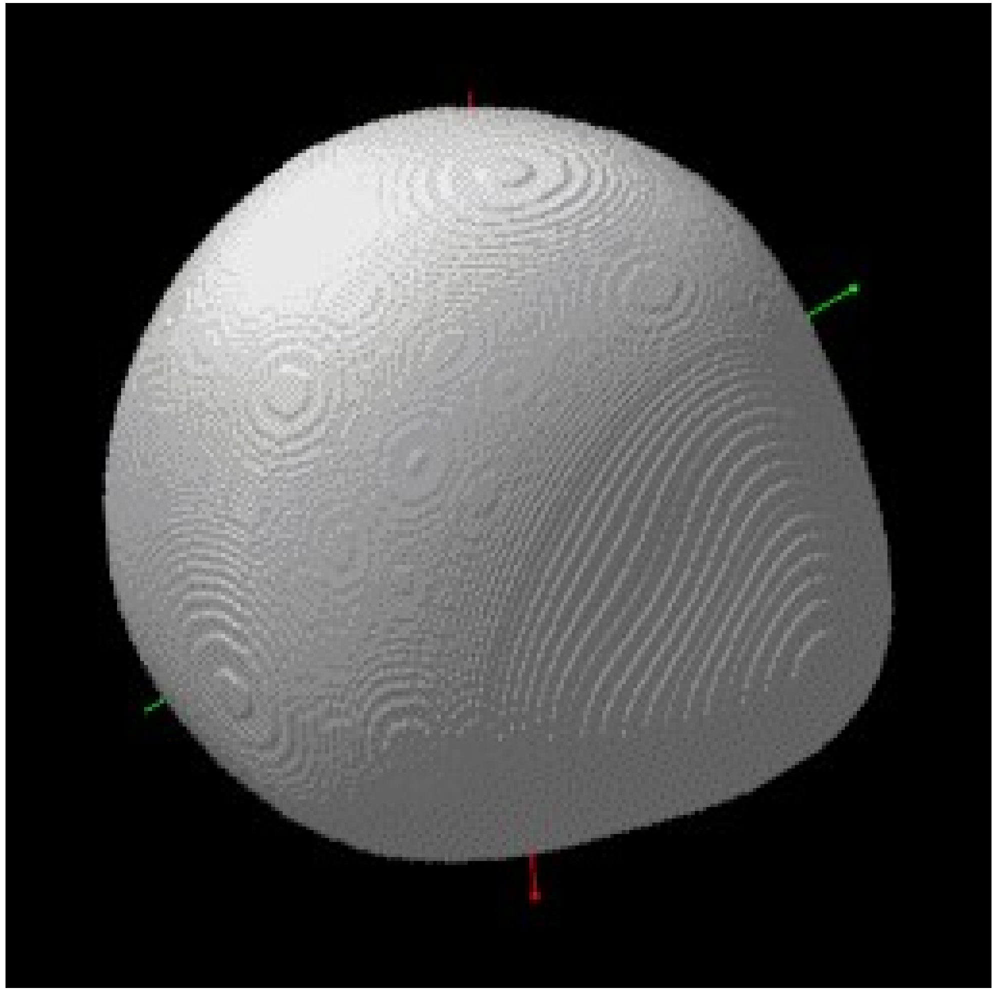
# Slicing

Example:
- Analytical Data set



# Summary

- Data is usually given on a grid
- Conceptual volvis framework is a pipeline from data to visualization
- Indirect vs direct visualization
- Transfer function maps data values to color

# Further Reading and Acknowledgements

For more information, please see, **Data Visualization: Principles and Practice, Chapter 10 Volume Visualization** by A.C. Telea, AK Peters, 2008

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