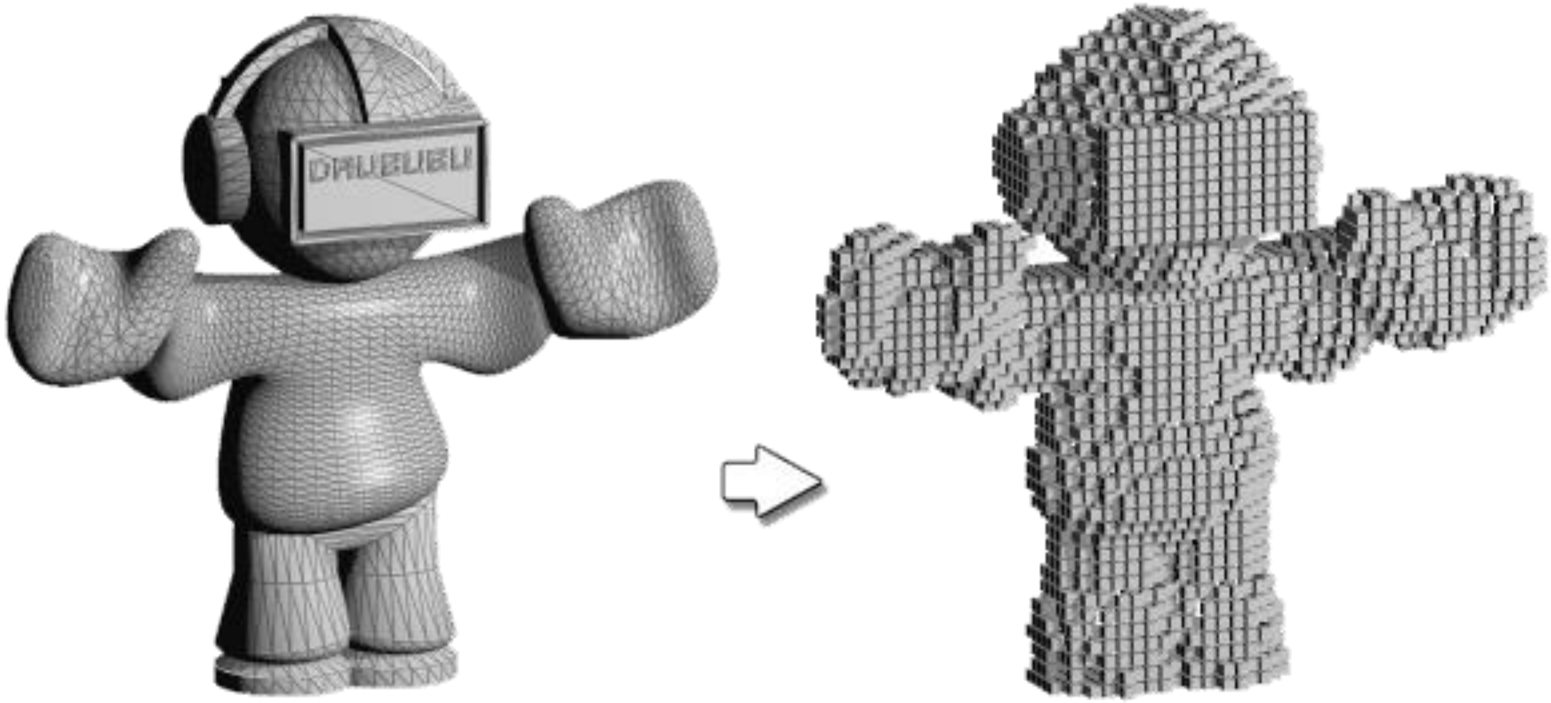
Volume Visualization. Introduction

Isabel Navazo & Pere-Pau Vázquez
Dept. Computer Science – UPC

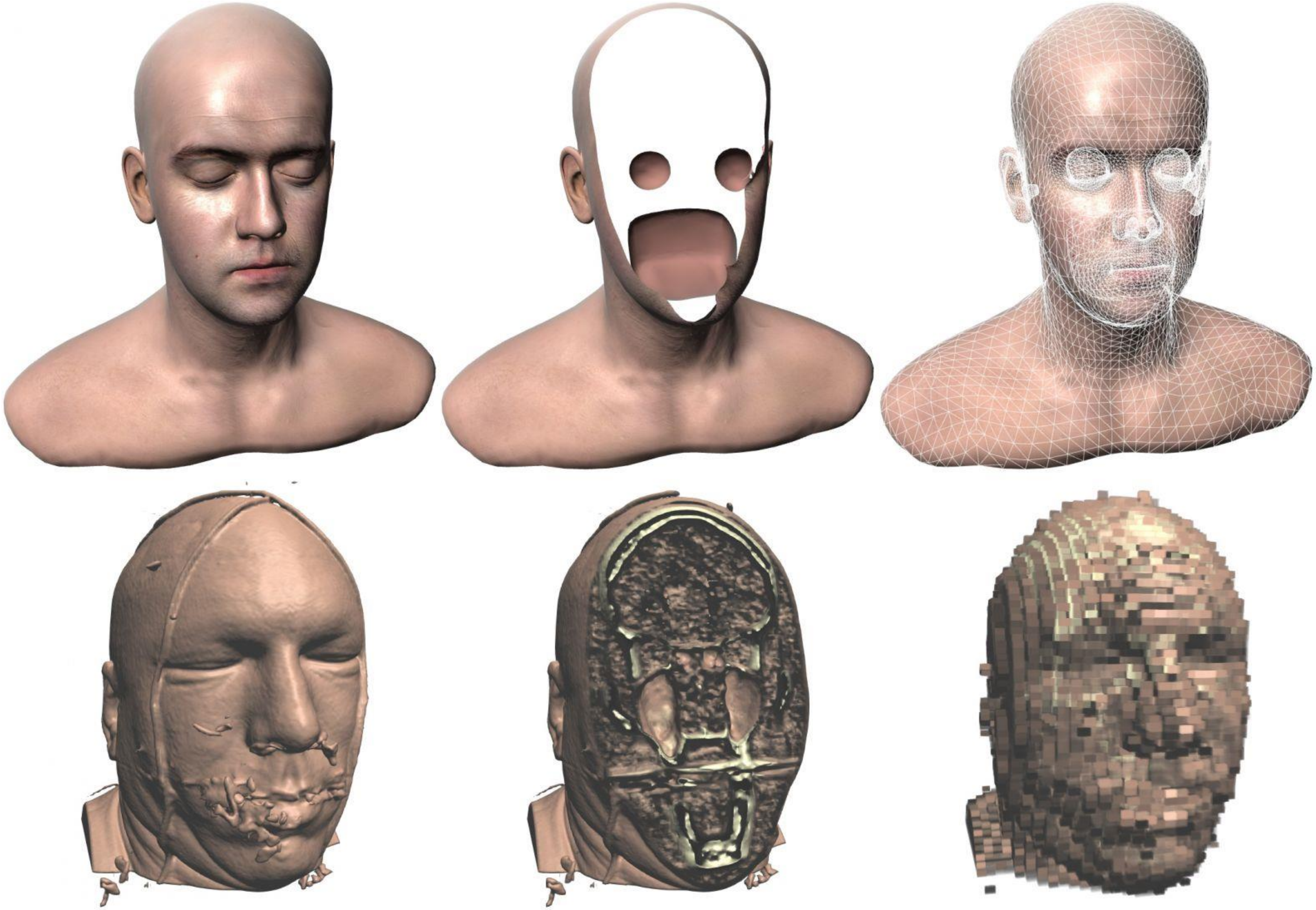
From polygons to voxels

- Polygons vs voxels



From polygons to voxels

- Is that all?
  - No, voxels have information from the model **inside**



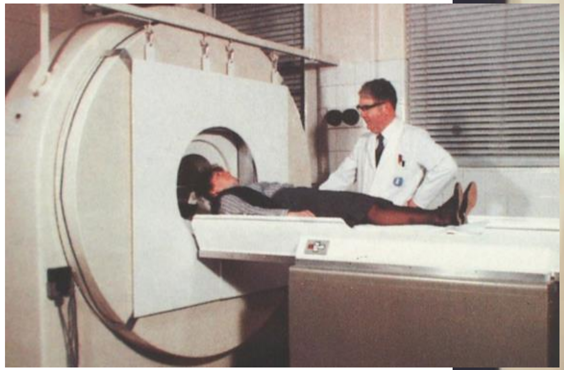
From polygons to voxels

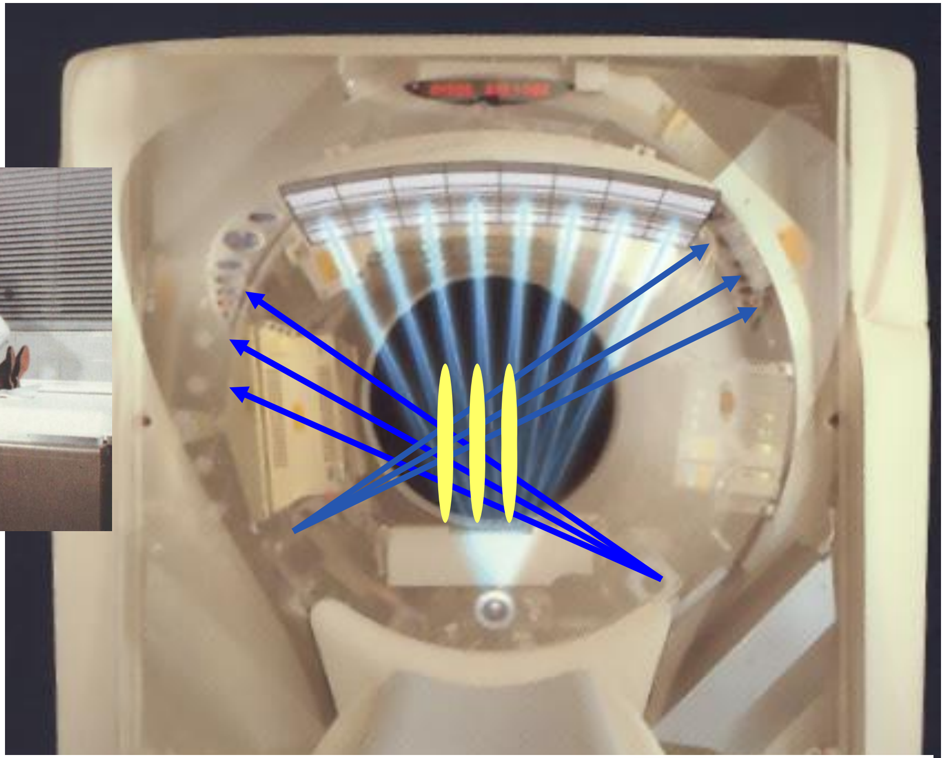
- Is that all?
  - No, voxels have information from the model **inside**
- We can not render with the usual pipeline

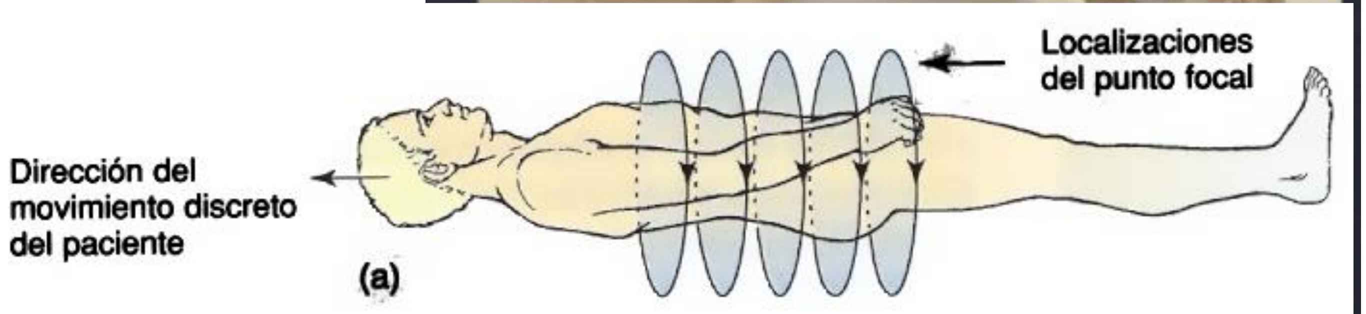
From polygons to voxels

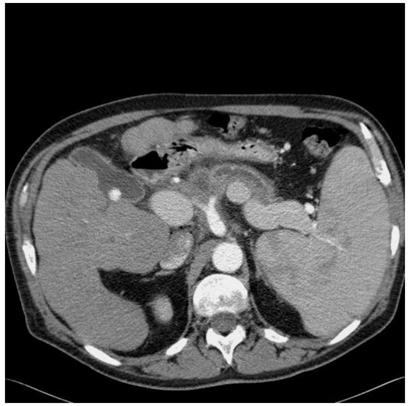
- Polygons:
  - Data: 3+ vertices
  - Rendering pipeline:
    - Upload data to GPU (through supported data structures & primitives)
    - Render (transform vertices + rasterize + shade)
- Voxels:
  - Data: set of 2D images
    - No polygons
    - Images do not carry volume (intermediate values) data

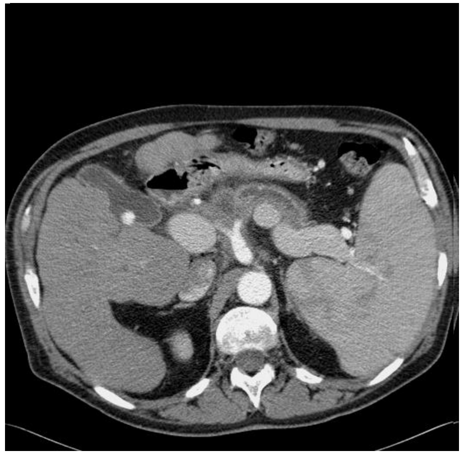
Applications: Medicine



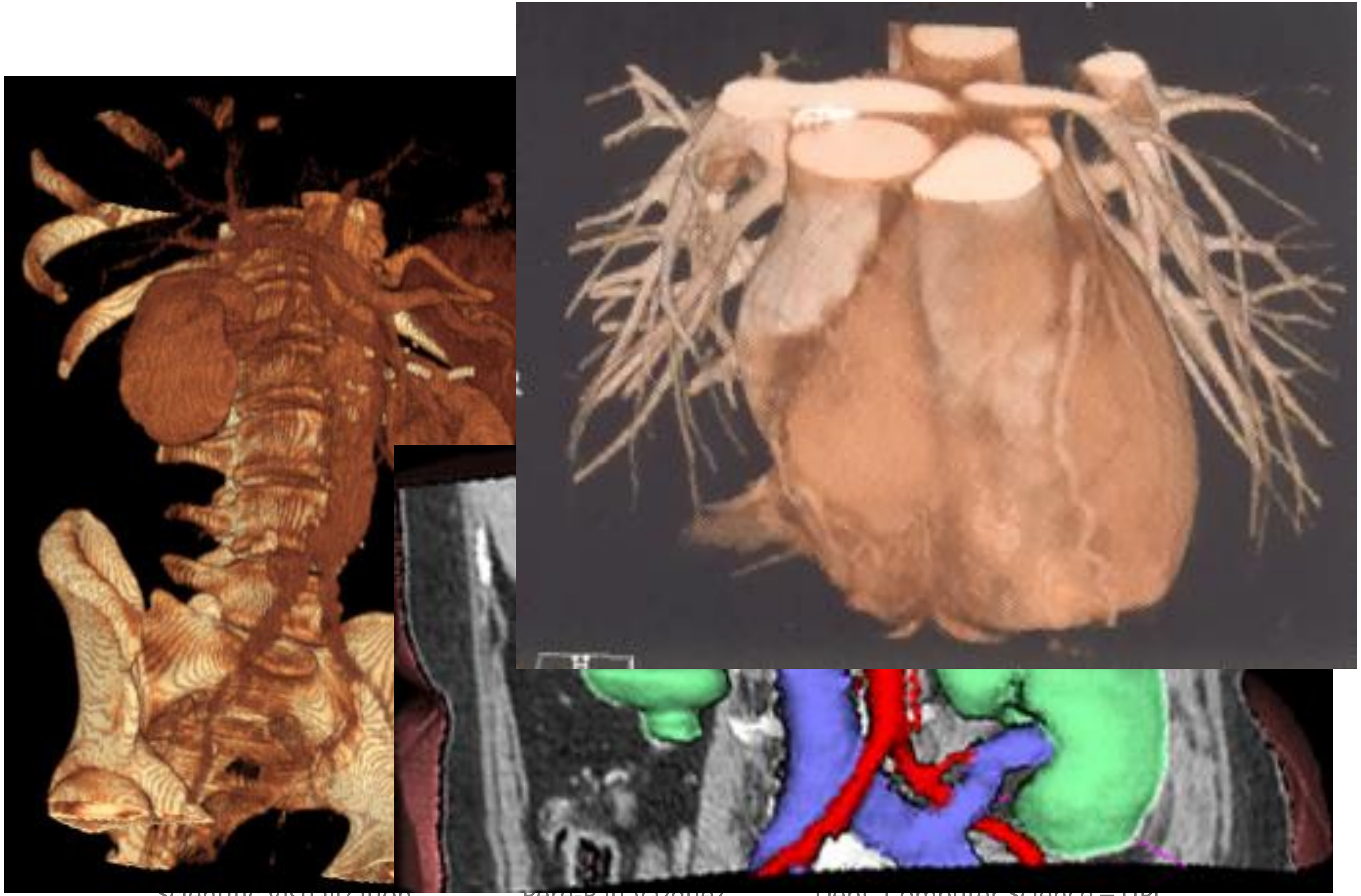




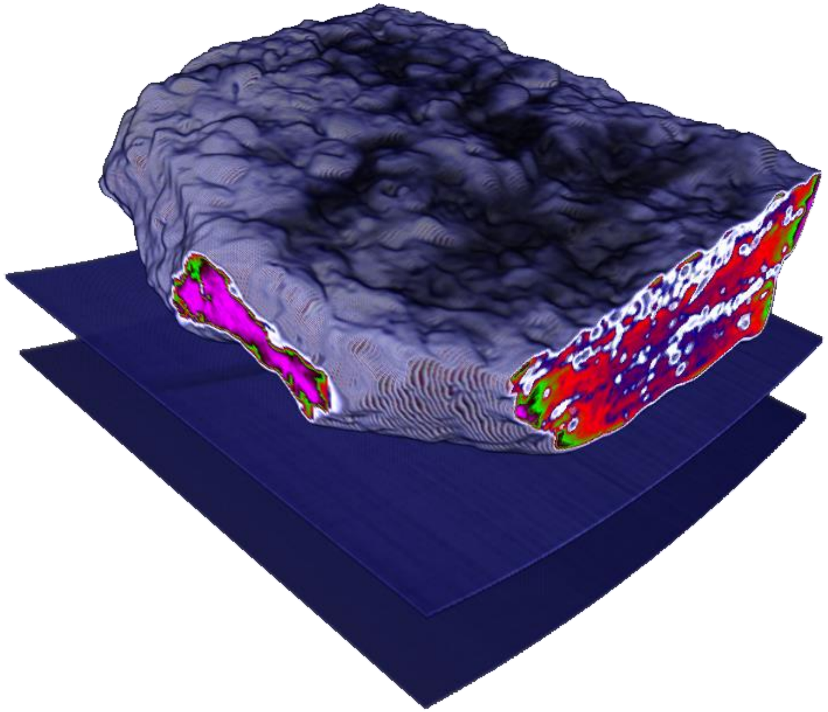




Applications: Medicine



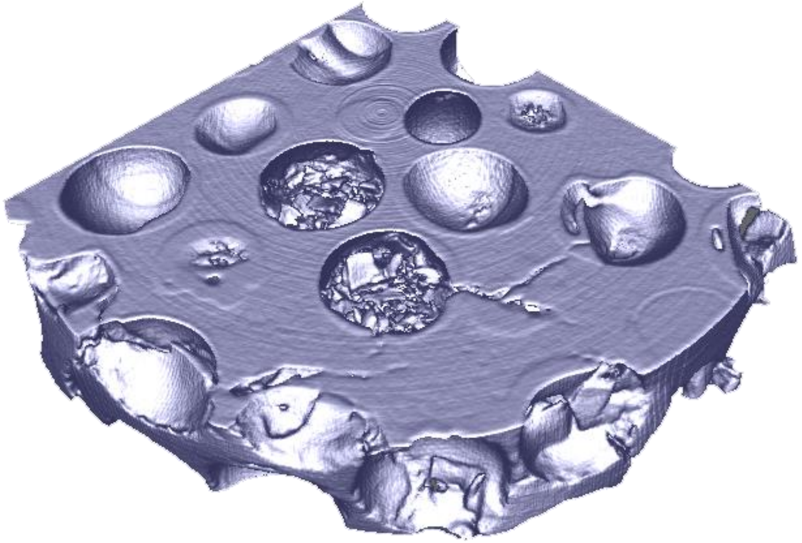
Applications: Geology



Muschelkalk
Virtual Reality Group,
University of Erlangen

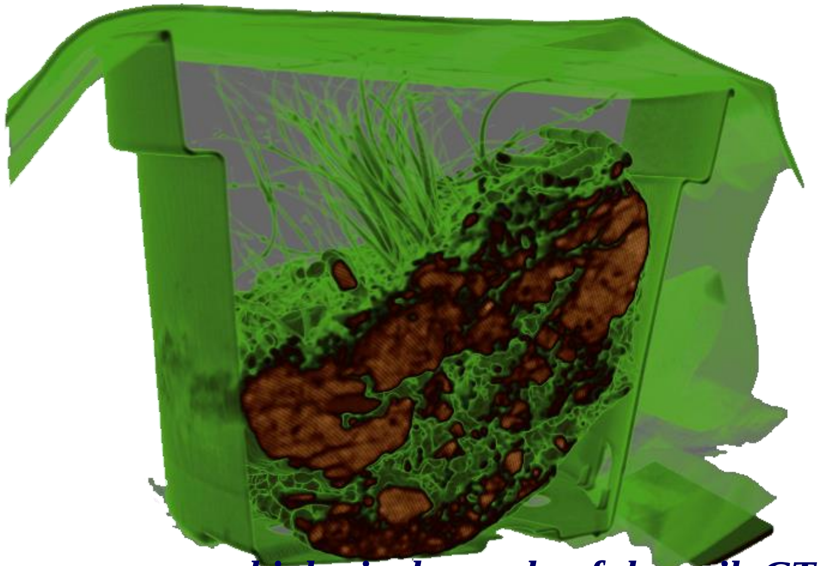
Applications: Sciences

Material Science,
Quality Control



Micro CT, Compound Material,
Material Science Department, University of Erlangen

Biology



biological sample of the soil, CT,
Virtual Reality Group,
University if Erlangen

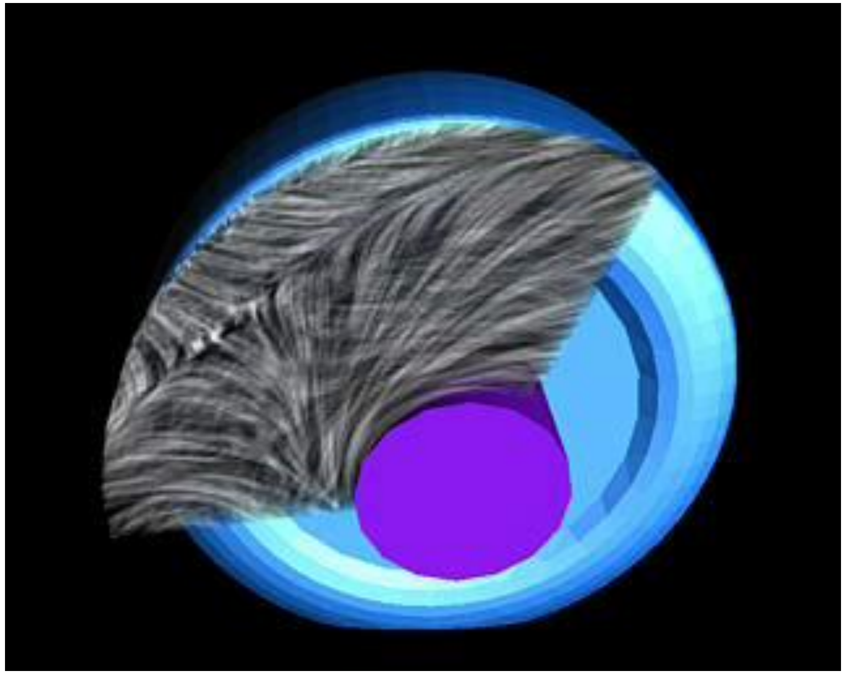
Applications: Archeology

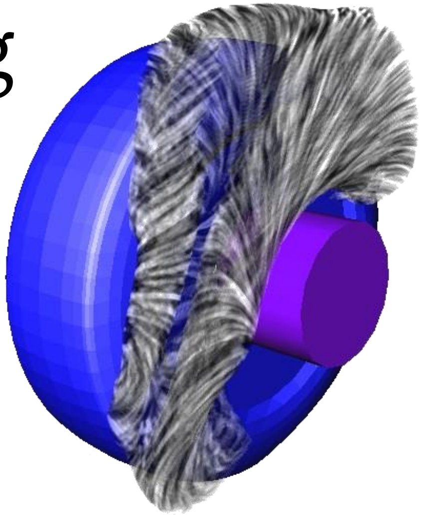
Hellenic Statue of Isis
3rd century B.C.
ARTIS, University of Erlangen-Nuremberg, Germany

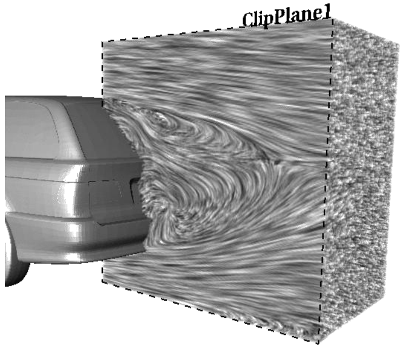
Sotades Pygmaios Statue,
5th century B.C
ARTIS, University of Erlangen-Nuremberg, Germany

Applications: vector visualization

- Computational Science and Engineering

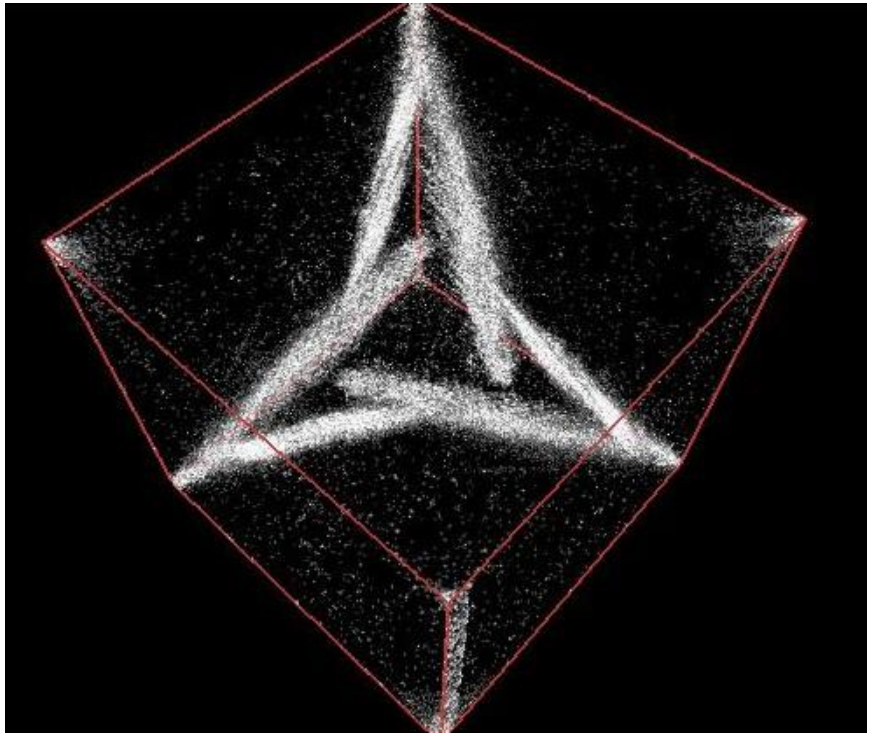


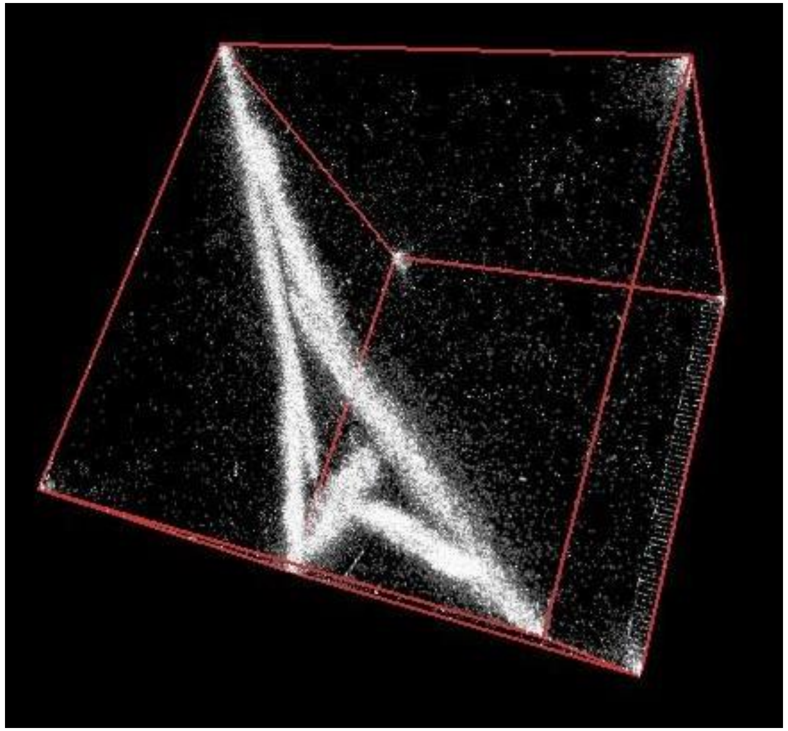




Applications: Computer Science

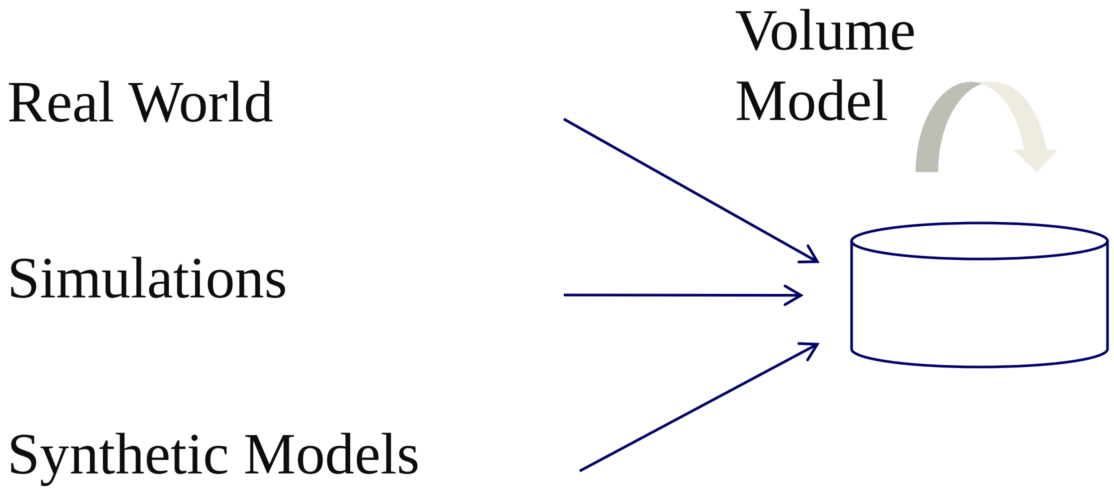
- Visualization of Pseudo Random Numbers





Entropy of Pseudo Random Numbers,
Dan Kaminsky, Doxpara Research, USA,
www.doxpara.com

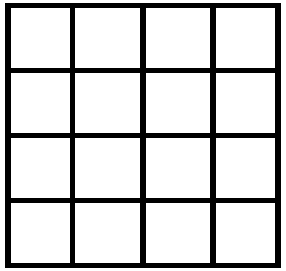
Volume Data

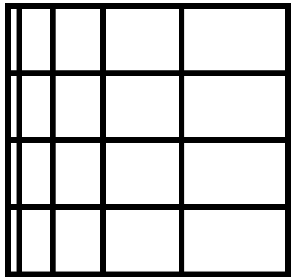


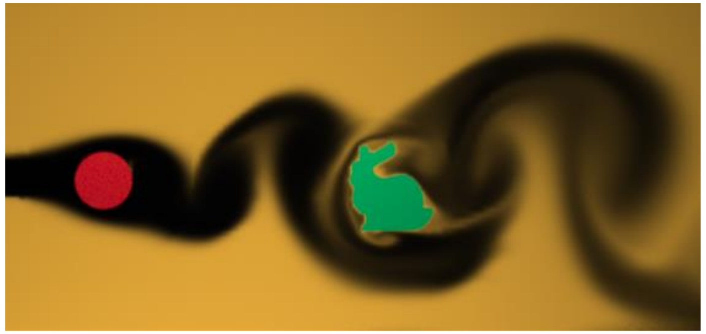
- Number and dimension of the sampled data
- Dimension and topology of the grid

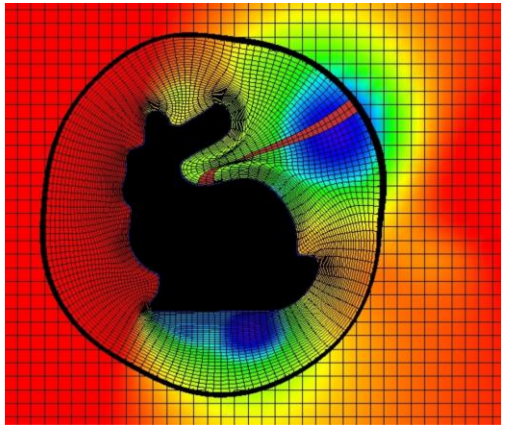
Volume Data: Grid types (1)

- Cartesian, uniform grids:
  - Spacing: regular
  - Geometry: regular
  - Topology: regular
  - Cell type: same
- Non-Uniform grids:
  - Spacing: irregular
  - Geometry: regular
  - Topology: regular
  - Cell type: same
- Curvilinear grids:
  - Spacing: irregular
  - Geometry: irregular
  - Topology: regular
  - Cell type: same



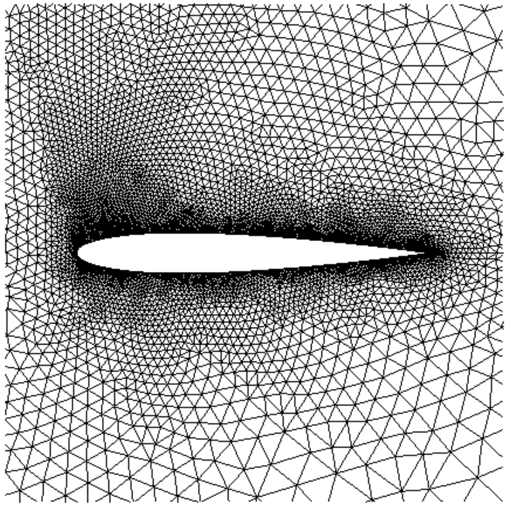


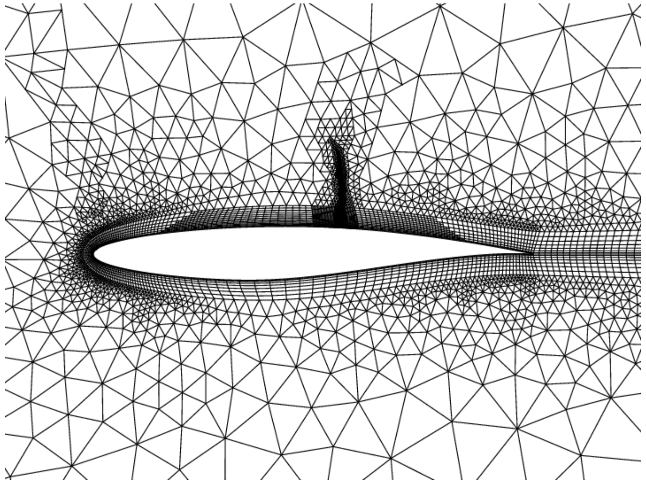




Volume Data: Grid types (2)

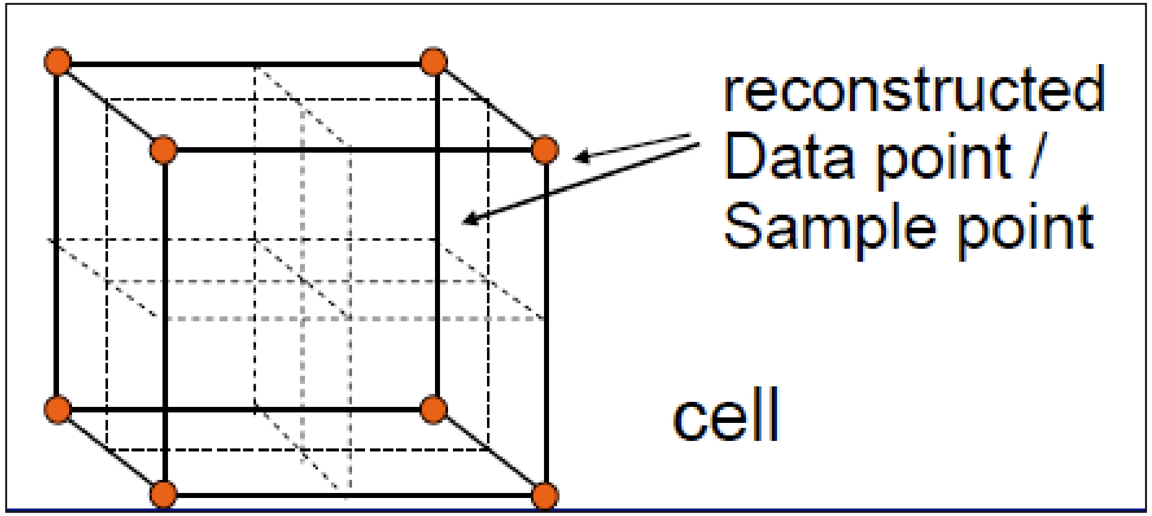
- Unstructured grids:
  - Spacing: irregular
  - Geometry: irregular
  - Topology: irregular
  - Cell type: same
- Hybrid grids:
  - Spacing: irregular
  - Geometry: irregular
  - Topology: irregular
  - Cell type: mixed





Volume Data: discrete data

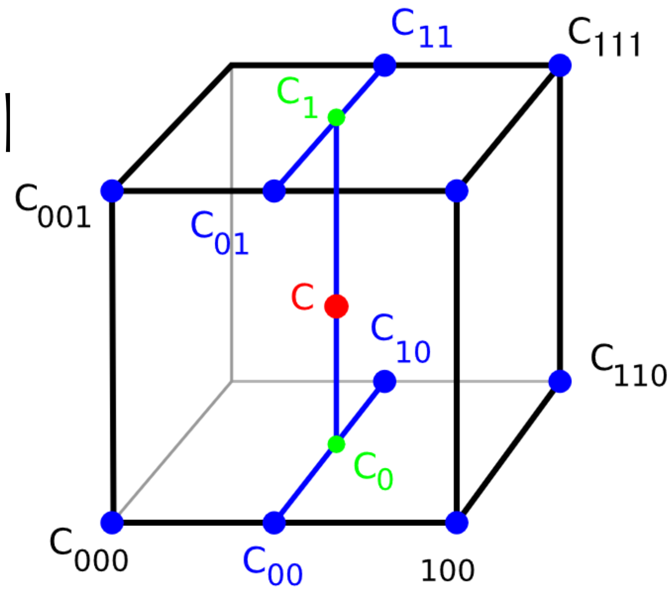
- Nearest neighbor (non-continuous)
- Data points has voxel value of voxel closest to him (clamping)
- Outdated concept



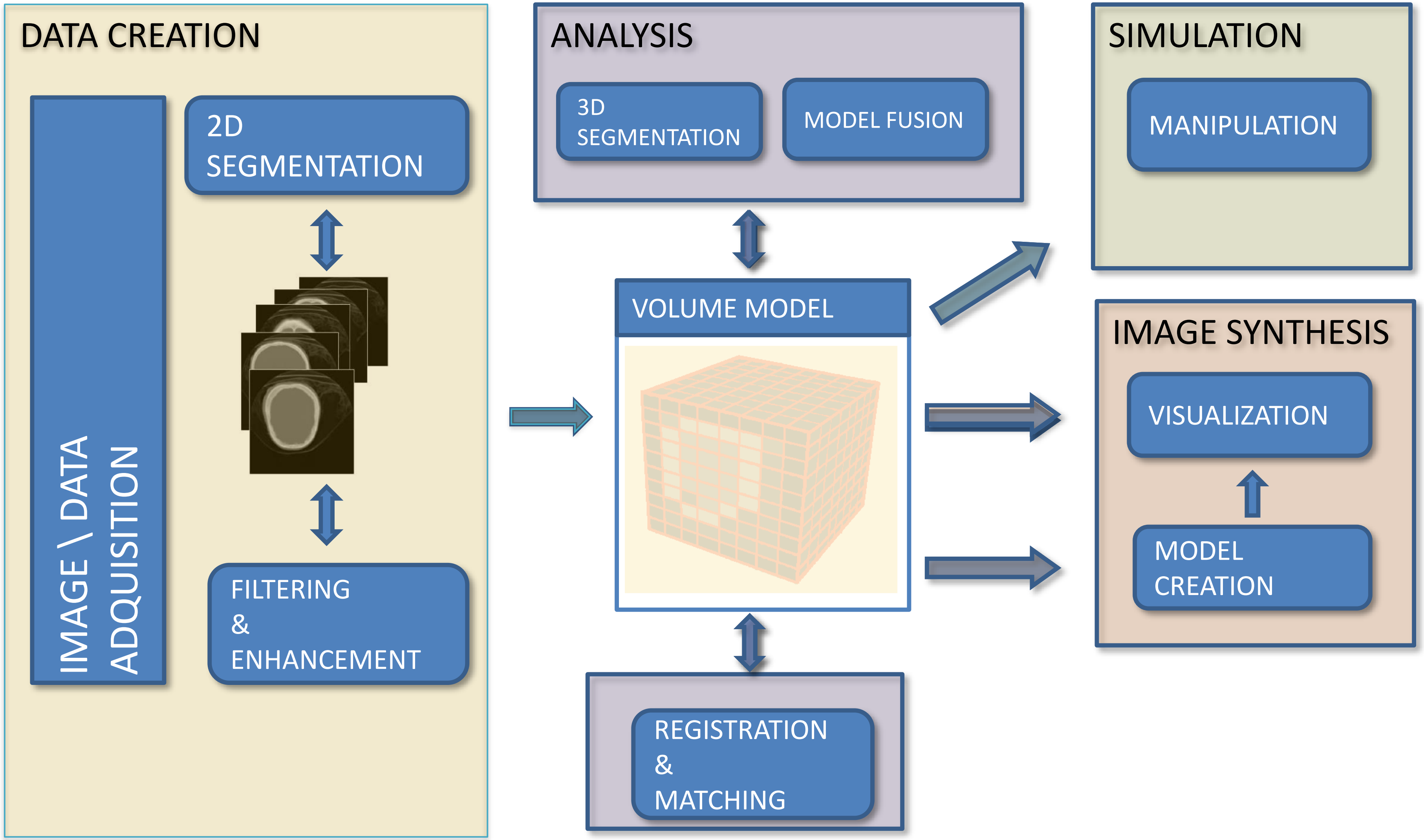
Volume Data: discrete data

Trilinear volume interpolation

- Four **linear interpolations** on edges
- On top of that, two **linear interpolations** (two bilinear interpolations)
- On top of that, one l



Volume Graphics Pipeline



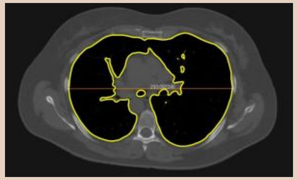
Volume Graphics Pipeline

VOLUME MODEL

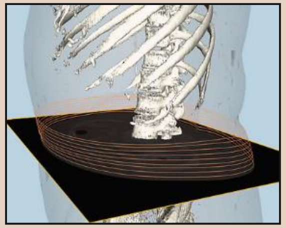
scalar **s**

IMAGE SYNTHESIS

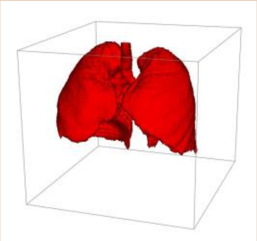
Indirect VOLUME VISUALIZATION



Countour Extraction



POLYGONAL MODEL CREATION



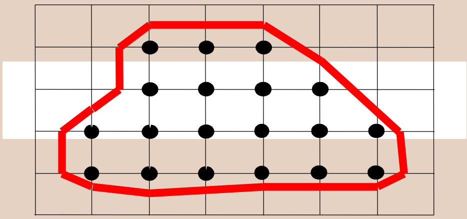
Volume Graphics Pipeline

VOLUME MODEL

scalar **s**

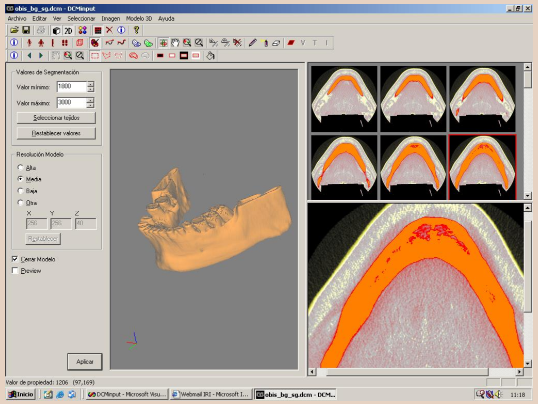
IMAGE SYNTHESIS

Indirect VOLUME VISUALIZATION

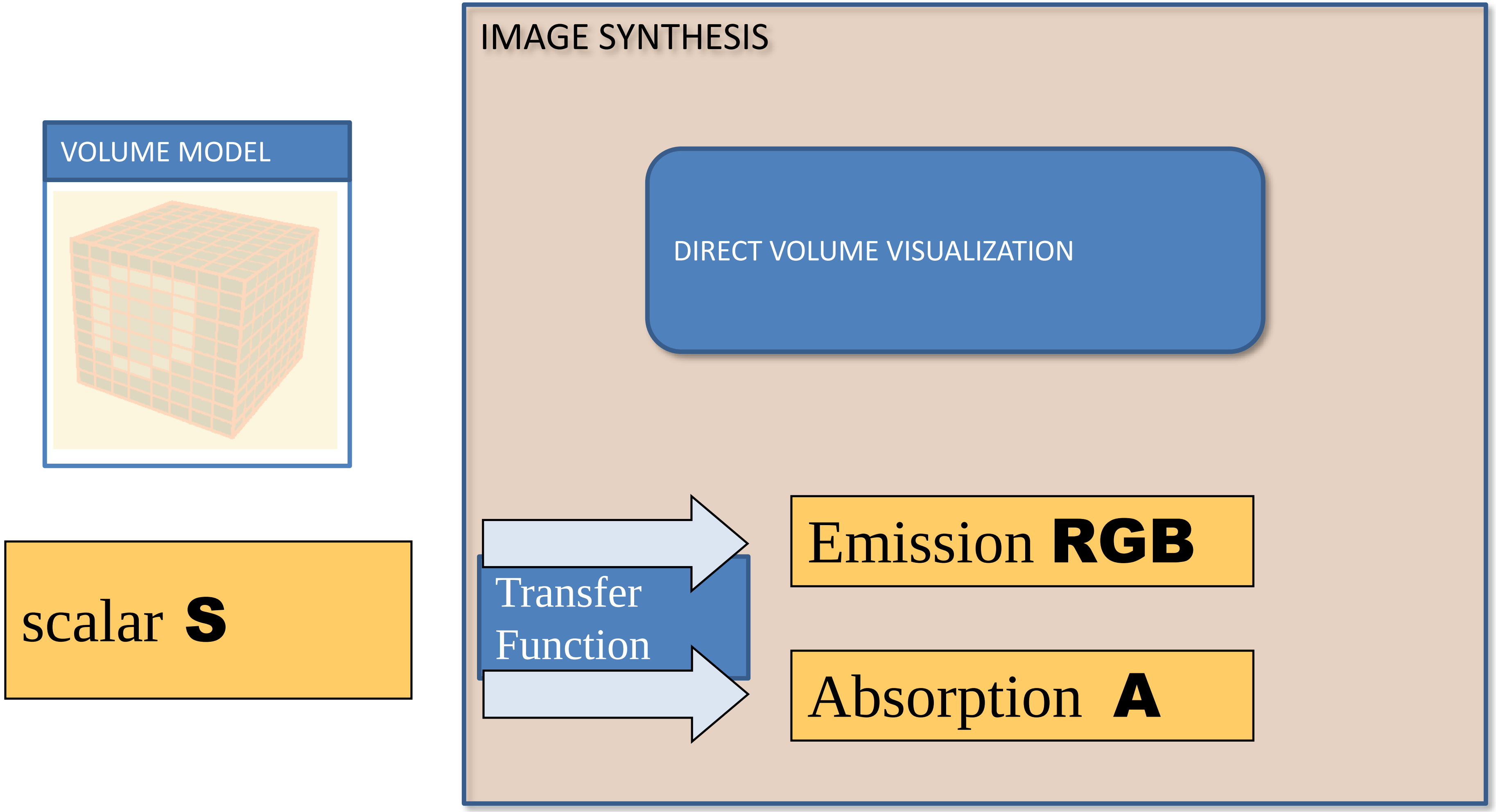


Isosurface Extraction

POLYGONAL MODEL CREATION

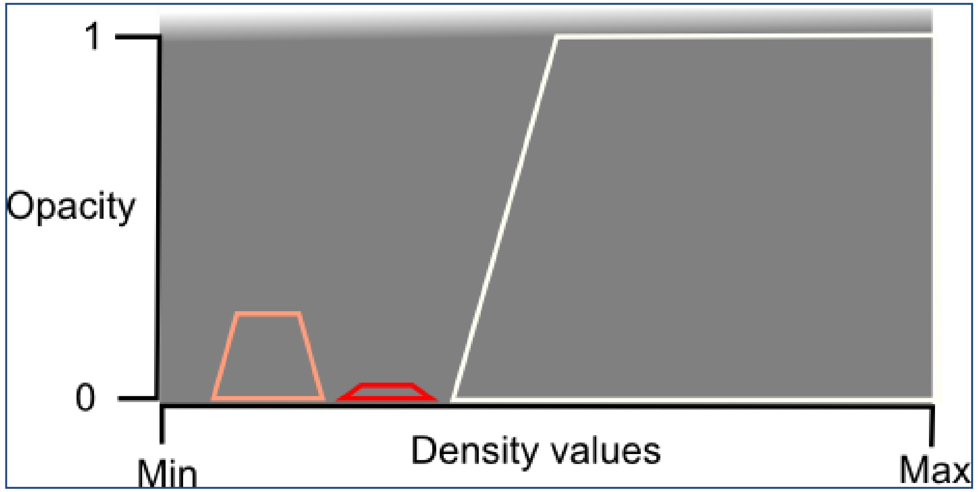


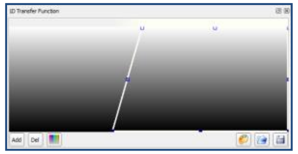
Volume Graphics Pipeline

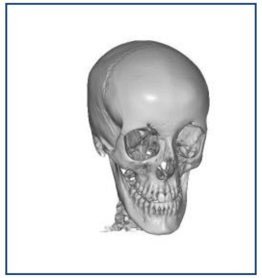


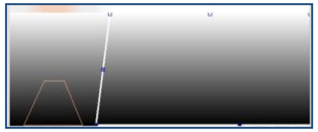
Classification

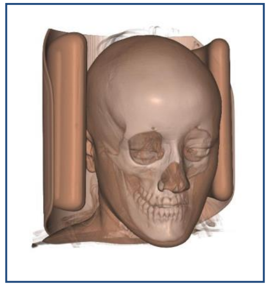
- Specifies the visual appearance of volume data: the **Transfer Function**

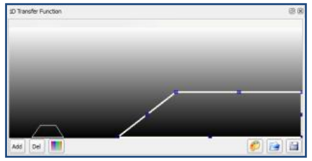


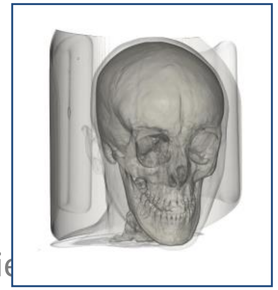




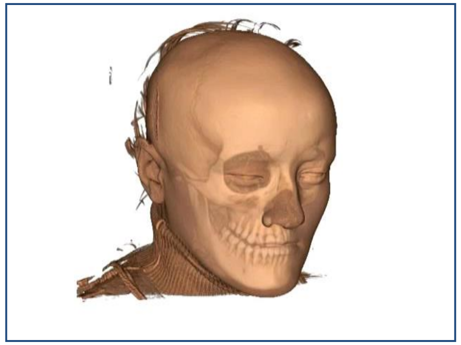




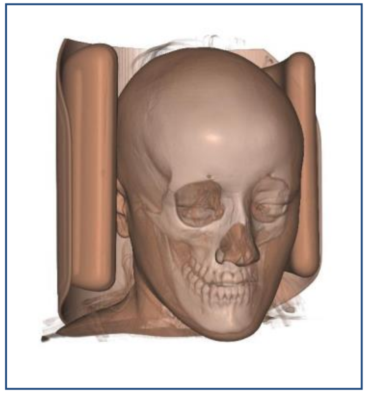


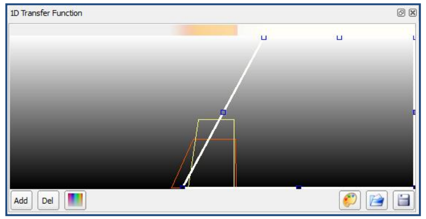


Classification



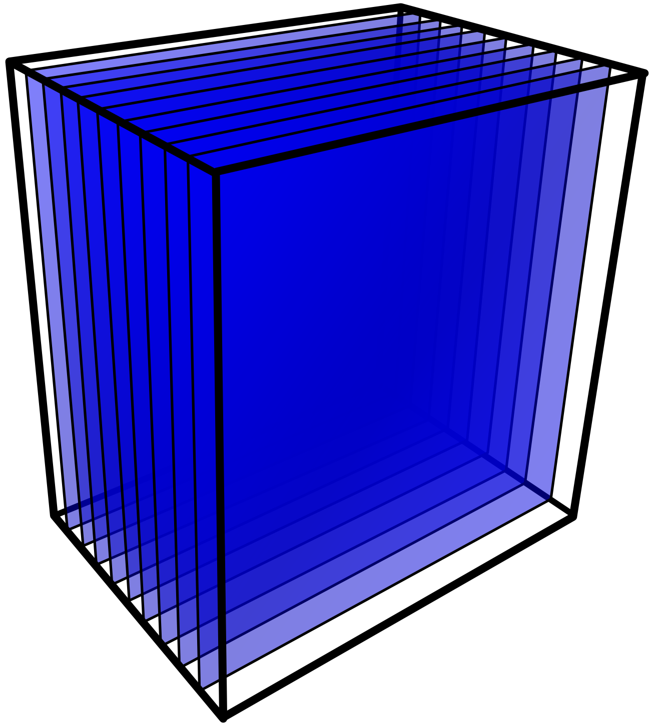
- Some considerations: pros & cons
- FT gives good results in many applications
- Focuses on “materials” not on anatomy structures
  - Some structures has the same “material” (due to acquisition devices limitations)
  - It is not possible “identify” all structures
  - Fuzzy boundaries (densities)
- Not semantic information only visual perception
- Some times is difficult to design the needed TF

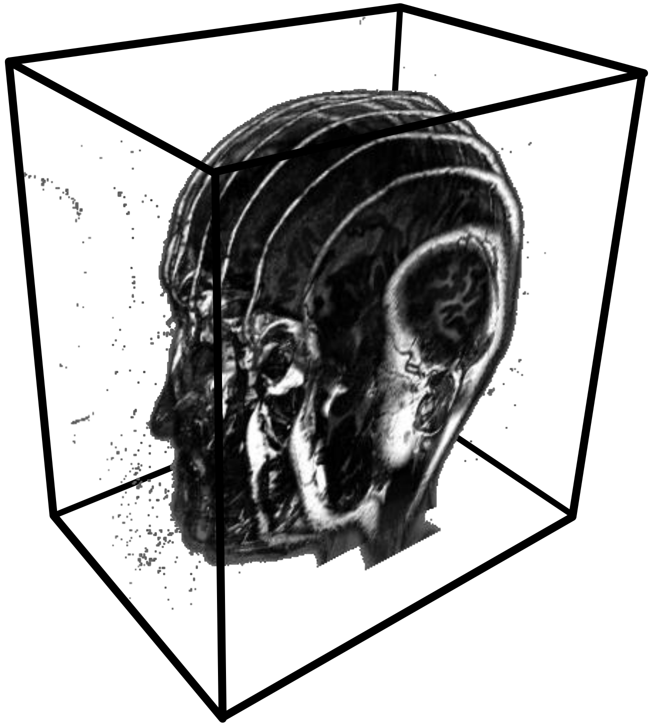




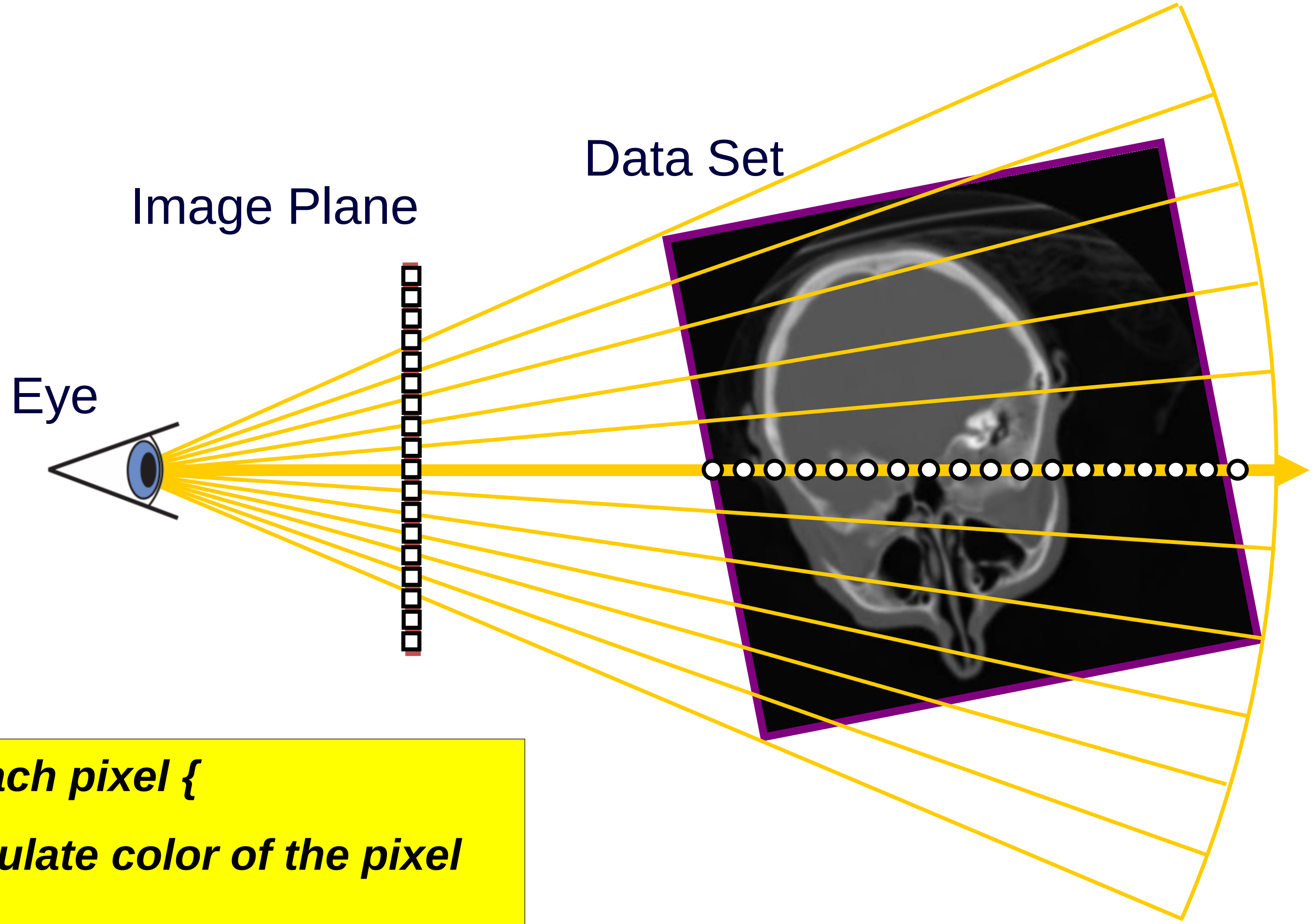
Texture-based Approaches

- No volumetric hardware-primitives!
- ➡ Proxy geometry (Polygonal Slices)





Ray-casting

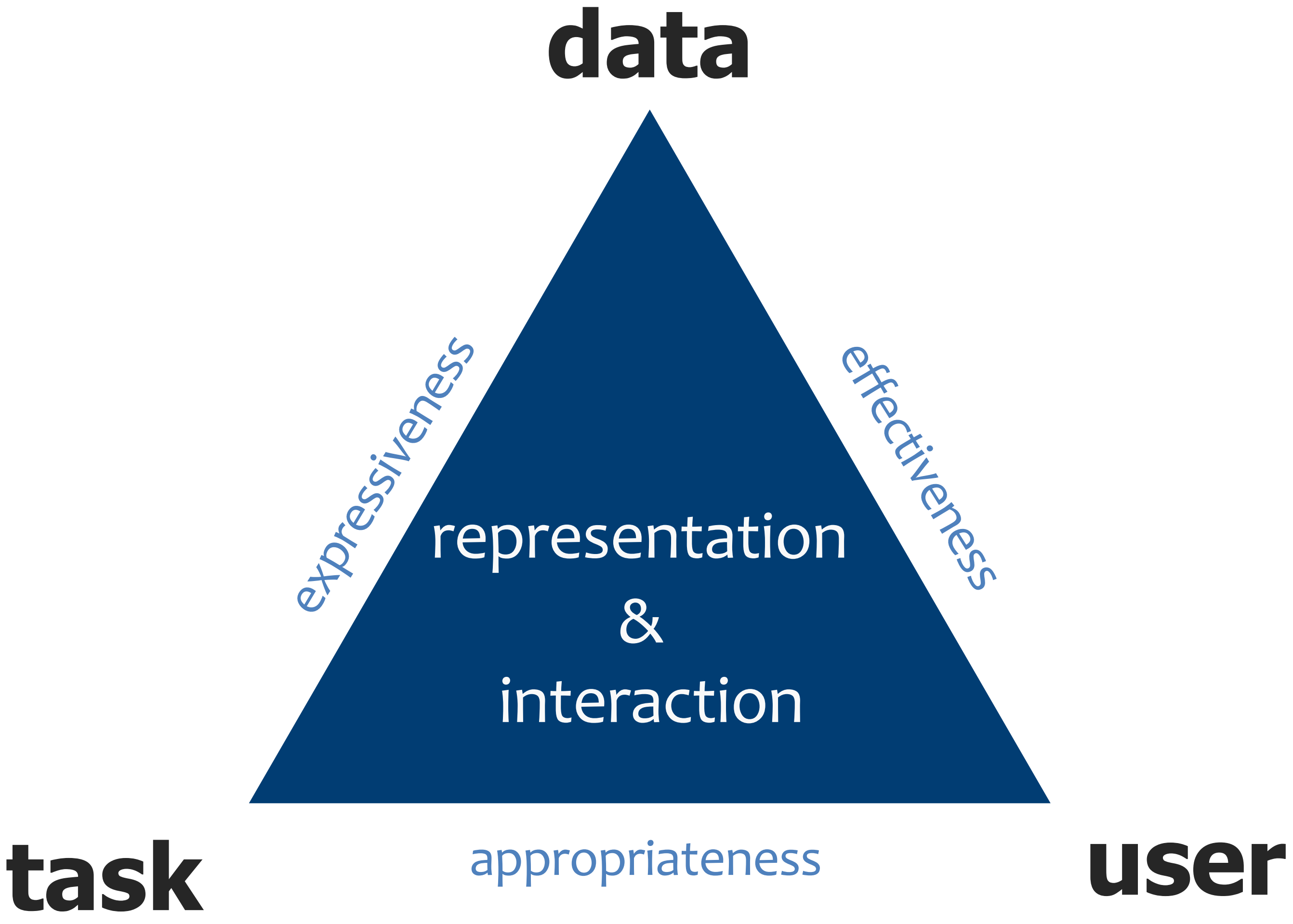


For each pixel {

calculate color of the pixel

}

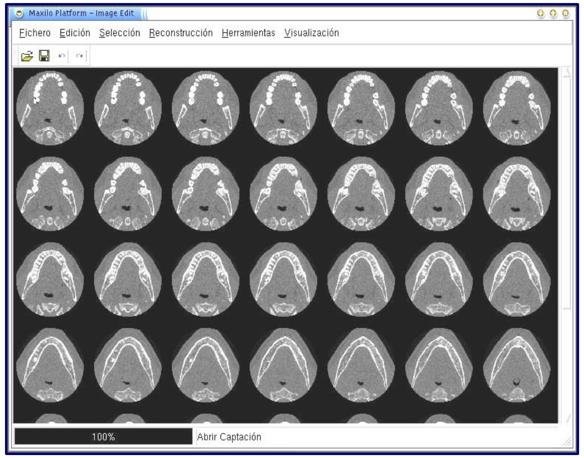
Volume Visualization. Introduction



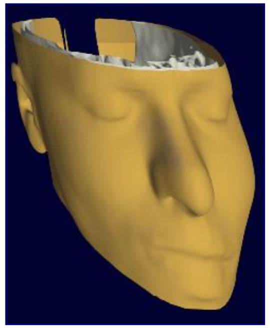
Volume Visualization. Introduction

- Data:
  - Volumetric models: CT, MRI, SPECT, simulation…
- Users:
  - Medical doctors, researchers
- Tasks:
  - Surgery planning, diagnostic, surgery, training (surgery simulation, diagnose), education…

Application overview (medicine)



Voxels

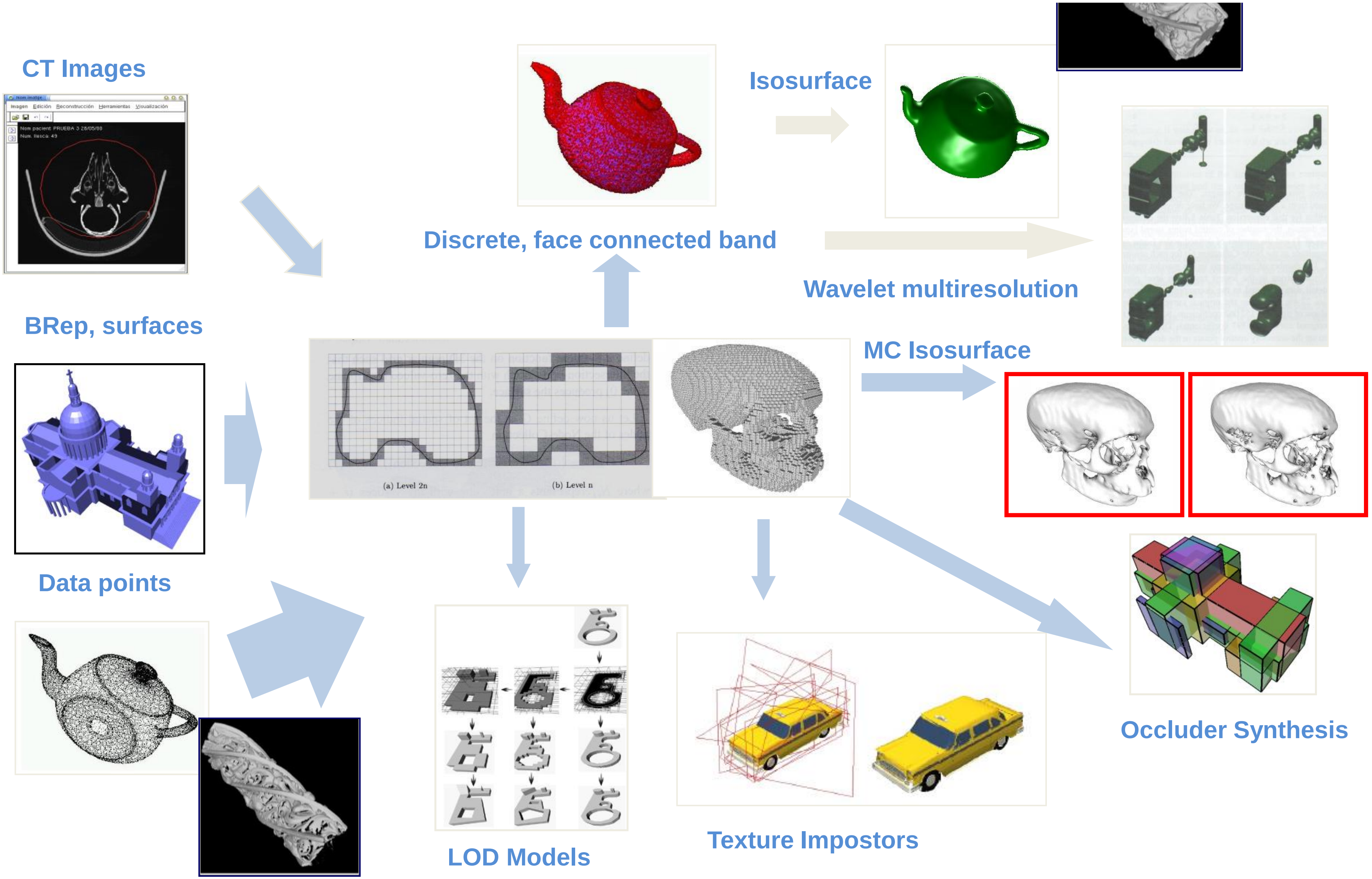


Diagnose

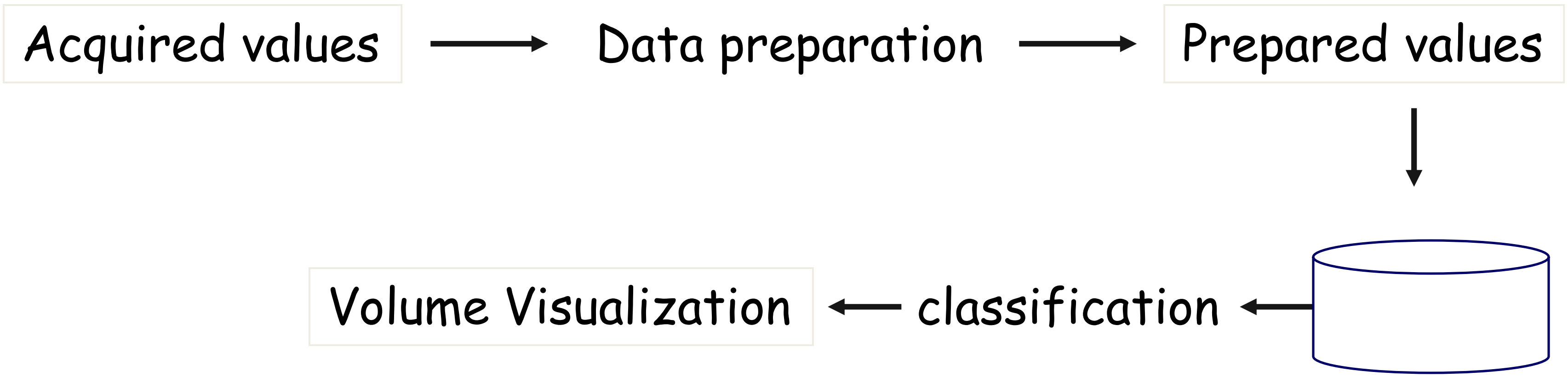
Training

Simulation and surgery planning

Other applications

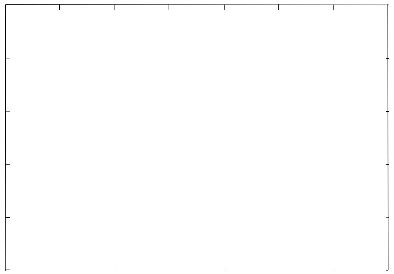


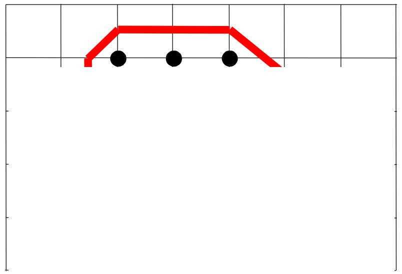
Volume Rendering Pipeline

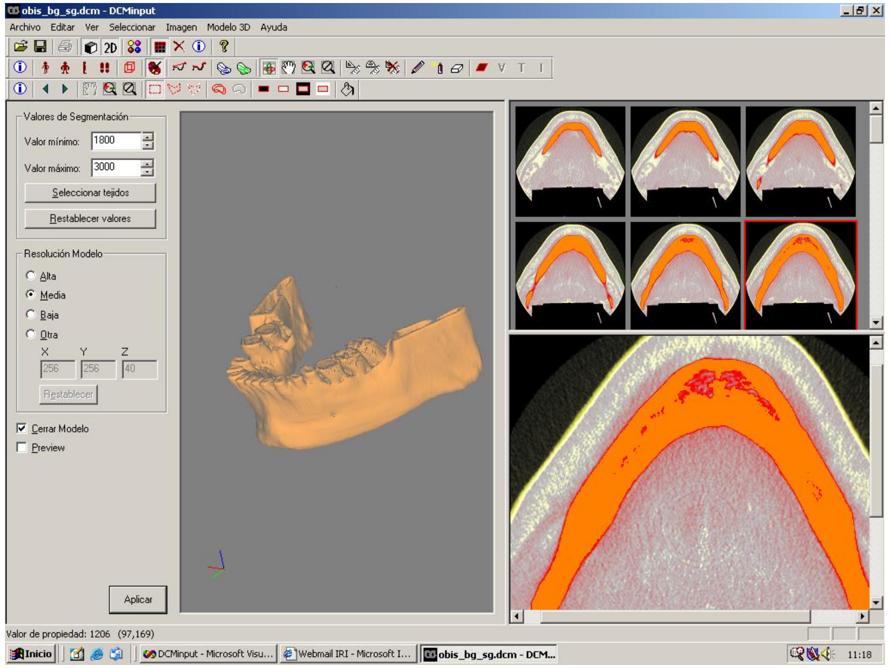


Used techniques

- Image processing
- Identification of structures (segmentation)
- Isosurface
- Visualization







Challenges

- Data acquisition
  - Limited resolution (size)
  - Limited information (what does it represent)
  - Speed (moving organs)

Challenges

- Data processing
  - Segmentation
  - Registration
  - Storage

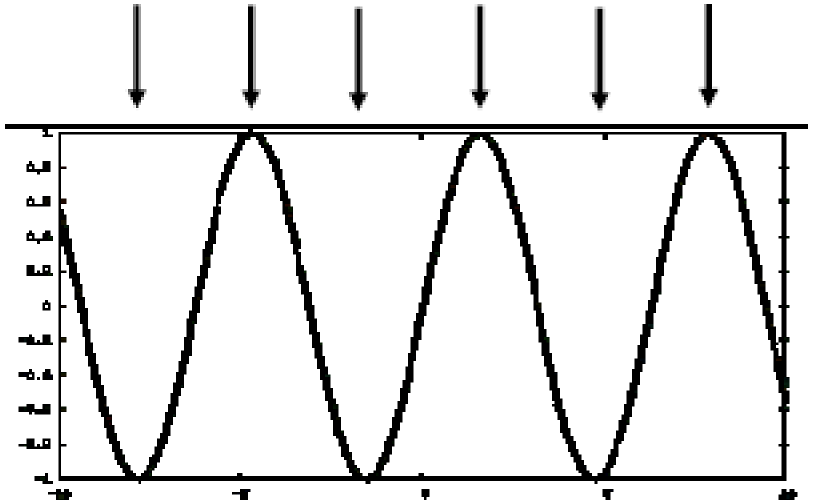
Challenges

- Rendering
  - Identification of structures (e.g. TF design)
  - Speed
    - VR
  - Interaction (pointing, selecting, measuring…)
  - Accuracy

Concepts: Volume Data Acquisition

Sampling Theorem (Nyquist, Shannon):

For a sufficient reconstruction of a signal, it must be sampled **at least twice as fast** (**Nyquist - Rate**)

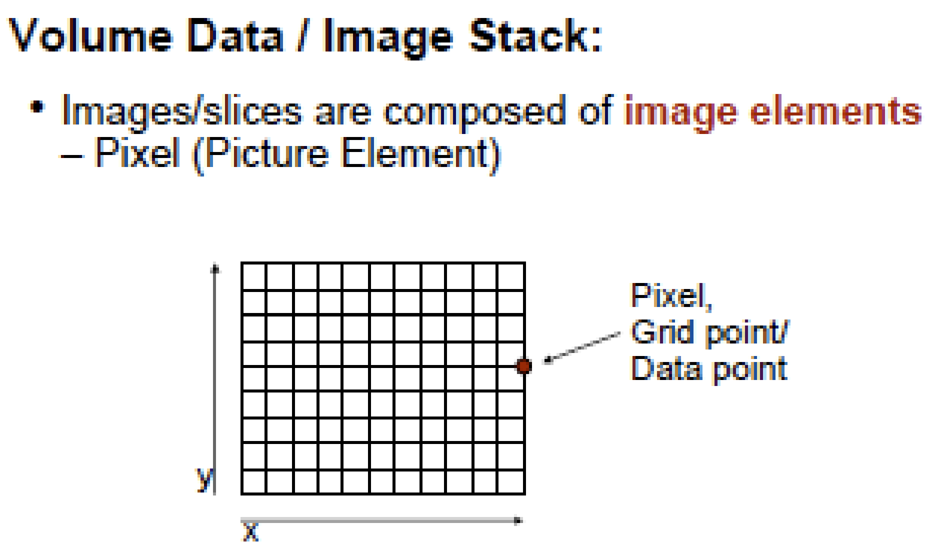


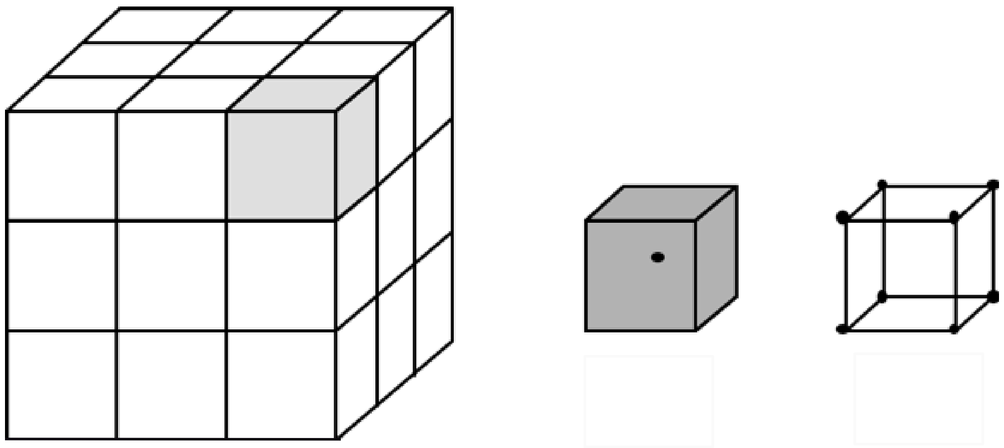
1x +1x => 2x

Concepts: Volume Data Artifacts

- Source of most artifacts can be traced back to the following phenomena:
  - Violations of the sampling theorem
  - Partial volume effects
  - Interpolation artifacts

Volume Models





- Array 2D, 3D (textures)
- Run-length
- Shell (fuzzy voxels)
- Octrees, wavelets,…

Fundamentals

- Introduction:
  - Definition of Volume Modeling and Visualization
  - Scientific Applications
  - Volume representation
  - The visualization pipeline
- Isosurface extraction

Volume Visualization. Introduction

Isabel Navazo & Pere-Pau Vázquez
Dept. Computer Science – UPC