Volume rendering

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SIG ’88 vol 22

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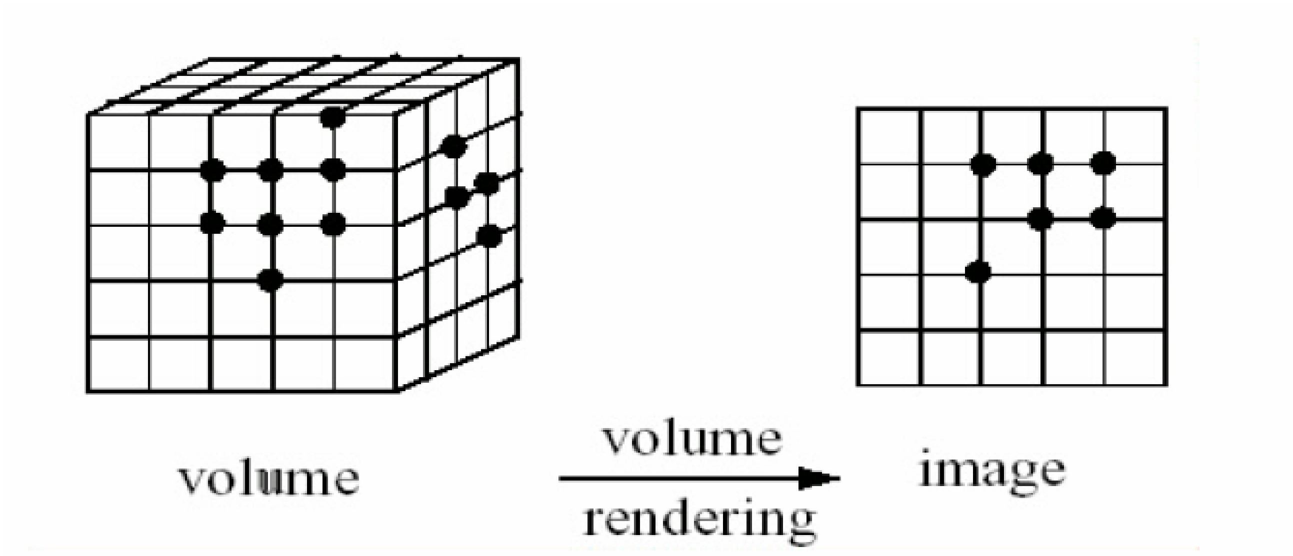
The Goal

- Given a volume (3D Image), render a 2D image as output. The process is called "Volume Rendering".



Definitions

- Slice – 2D image
- Volume – series of slices
- Value – number associated with each point
- Level /Iso Surface – the set of points having the same value.

Applications

- Medical imaging
- Paleontology and Archaeology
- Oil and Gas Exploration
- Security applications

Related Work

- Scene-based
  - Maximum Intensity Projection
  - Additive reprojection
  - Surface Rendering (Iso Surface)

- Object-based
  - Octree representation
  - Polygonal Models

The algorithm

- render volumes containing a mixture of materials.
- both the interior of the materials and the boundary between materials are colored.
- artifacts caused by aliasing and quantization are avoided.

Steps

Input raw data

Classification

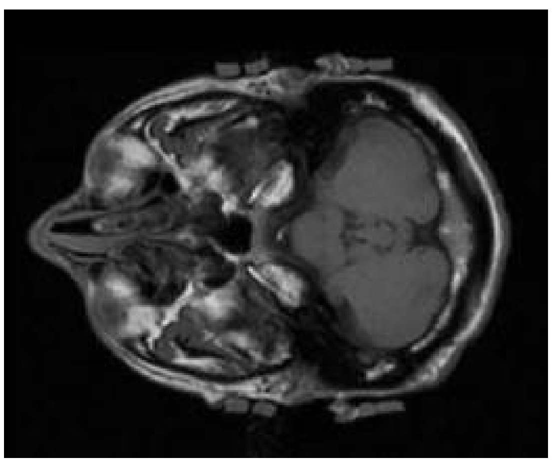
Material Percentage Volumes

Surface Extraction

Lighting Model

Viewing & Projection

Input Raw Data



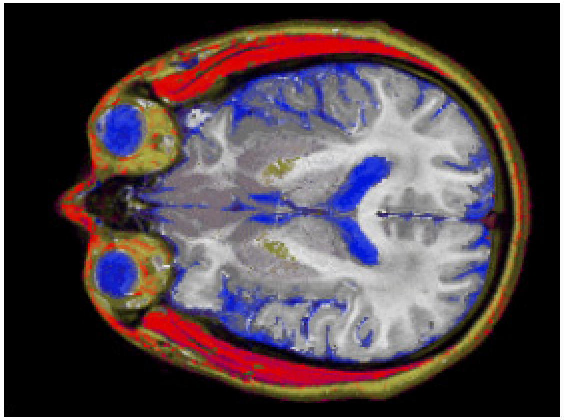
Type	Spatial Resolution	Intensity Resolution
CT	512x512	12 Bits
MRI	256x256	12 Bits

Classification 1/3

- "Label" each voxel. – give meaning to it.
  Probabilistic classifier: each voxel is a mixture of materials.

Pr(I) – probability that voxel has value I.
p_i – percentage of material i in voxel
P_i – Probability that material i has value I
n – number of material

$$\Pr(I) = \sum_{i=1}^{n} p_i P_i(I)$$



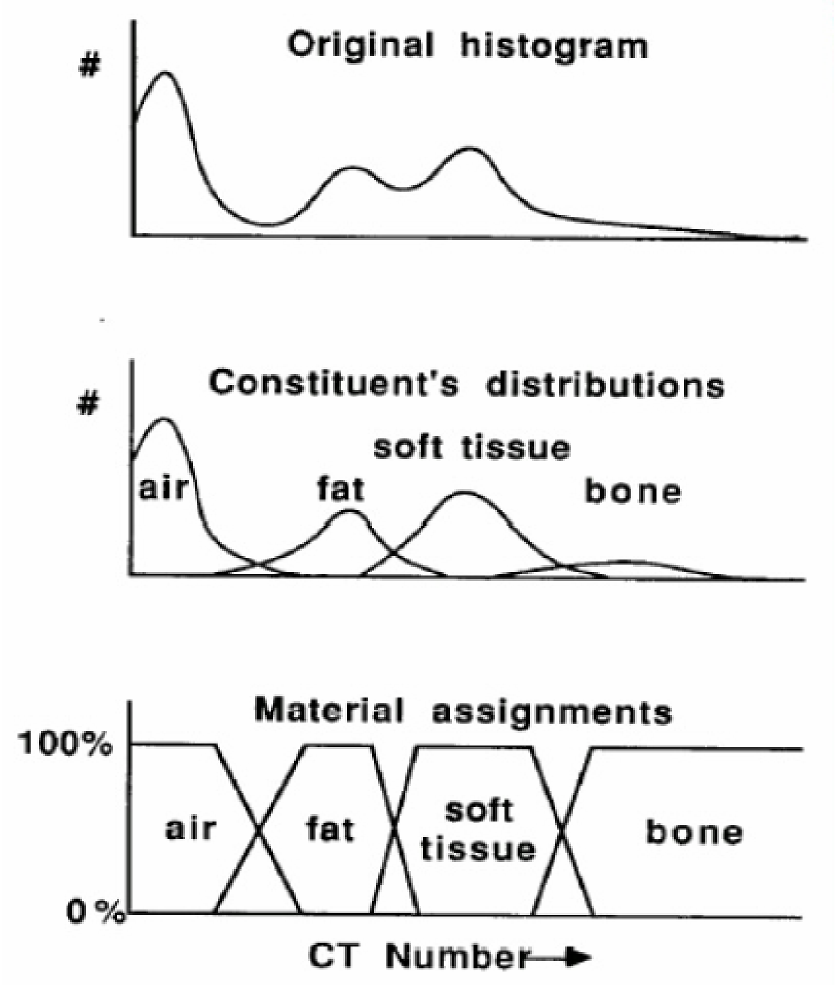
Classification 2/3

- When using CT, the distribution $P_j(I)$ are known in advanced.
- The bayesian estimate of the percentage of each material within a voxel of intensity I is given by:

$$p_i(I) = \frac{P_i(I)}{\sum_{j=1}^{n} P_j(I)}$$

Classification 3/3

- Determine the classification function from slide histogram.
- Assume that no more than two materials overlap.
- Assume linearity between peaks.



Material Percentage Volumes

- We have the material percentage in each voxel
  → we can create a material property volume.
  (we color the volume)
- Associate each material i with a color $C_{i.}$
- Calculate the color of each voxel.

$$C = \sum_{i=1}^{n} p_i C_i$$

$$C_i = (\alpha_i R_i, \alpha_i G_i, \alpha_i B_i, \alpha_i)$$

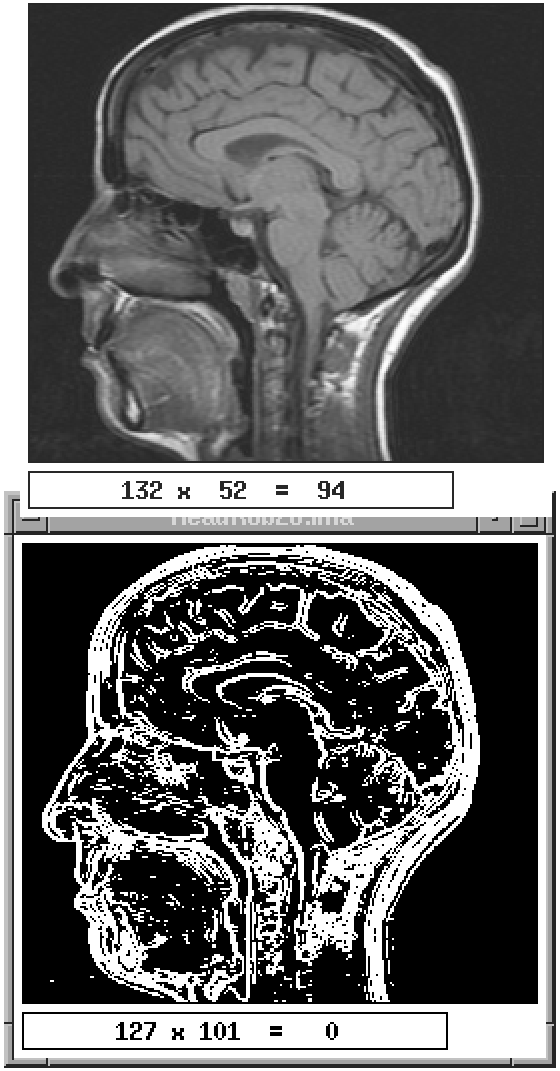
Surface Extraction

- For each voxel compute:
  - "strength"
  - normal
- Calculate density volume: $D = \sum_{i=1}^{n} p_i \rho_i$

  D – total ρ of a voxel

  ρ_i – material assigned density
- Combine two materials by assigning the same density.
- Compute normal to surface from ρ volume gradient:

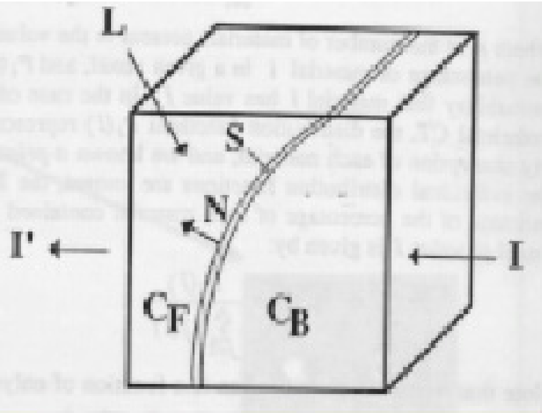
$$N_x = D_{x-1} - D_x$$
$$N_y = D_{y-1} - D_y$$
$$N_z = D_{z-1} - D_z$$



Voxel Light Model

A ray of light is travelling in the voxel.
It enters in the back, crosses the surface and exits from the front.

- assume light rays are not atenuated as they travel through the volume.



resulting color:

$$I' = C + (1-\alpha_c)I = C \textit{ over } I$$

voxel contains a surface:

$$I' = (C_F \textit{ over } (C_S \textit{ over } (C_B \textit{ over } I)))$$

surface reflected color:

$$C_S = f(N, L)C_{Diffuse} + g(E, N, L)C_{Light\text{-}source}$$

Viewing & Projection 1/3

- Use parallel merge projection
- To compute the final image, we project the image through Z plane.

  $I_z = C_z$ *over* I_z
- The images are merged to the final image from back to front (I_0 is the final image).
- The initial image I_n is set to background.

Viewing & Projection 2/3

- What we want to view the scene from another angle?
- To preserve the simplicity of the parallel merge projection, consider the viewing coordinate system fixed and transform the scene (the volume).
- Transform each individual slice and put it back in the volume.

Viewing & Projection 3/3

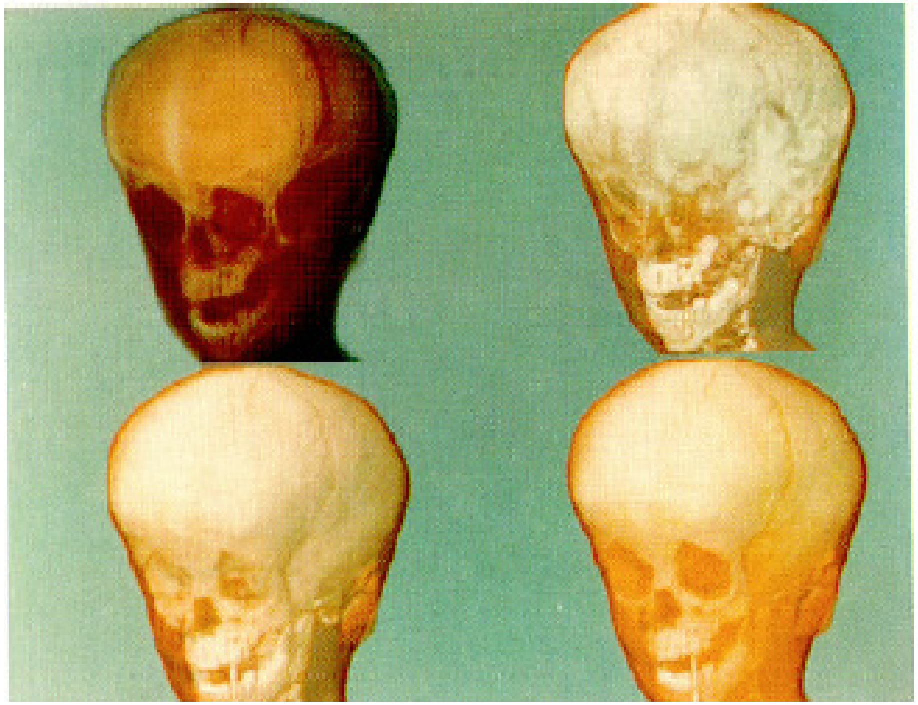
- Transform volume to lie in the viewing coordinate system.

$$T = P_z(z_e)\, R_z(\psi)\, R_y(\Phi)\, R_z(\theta)$$

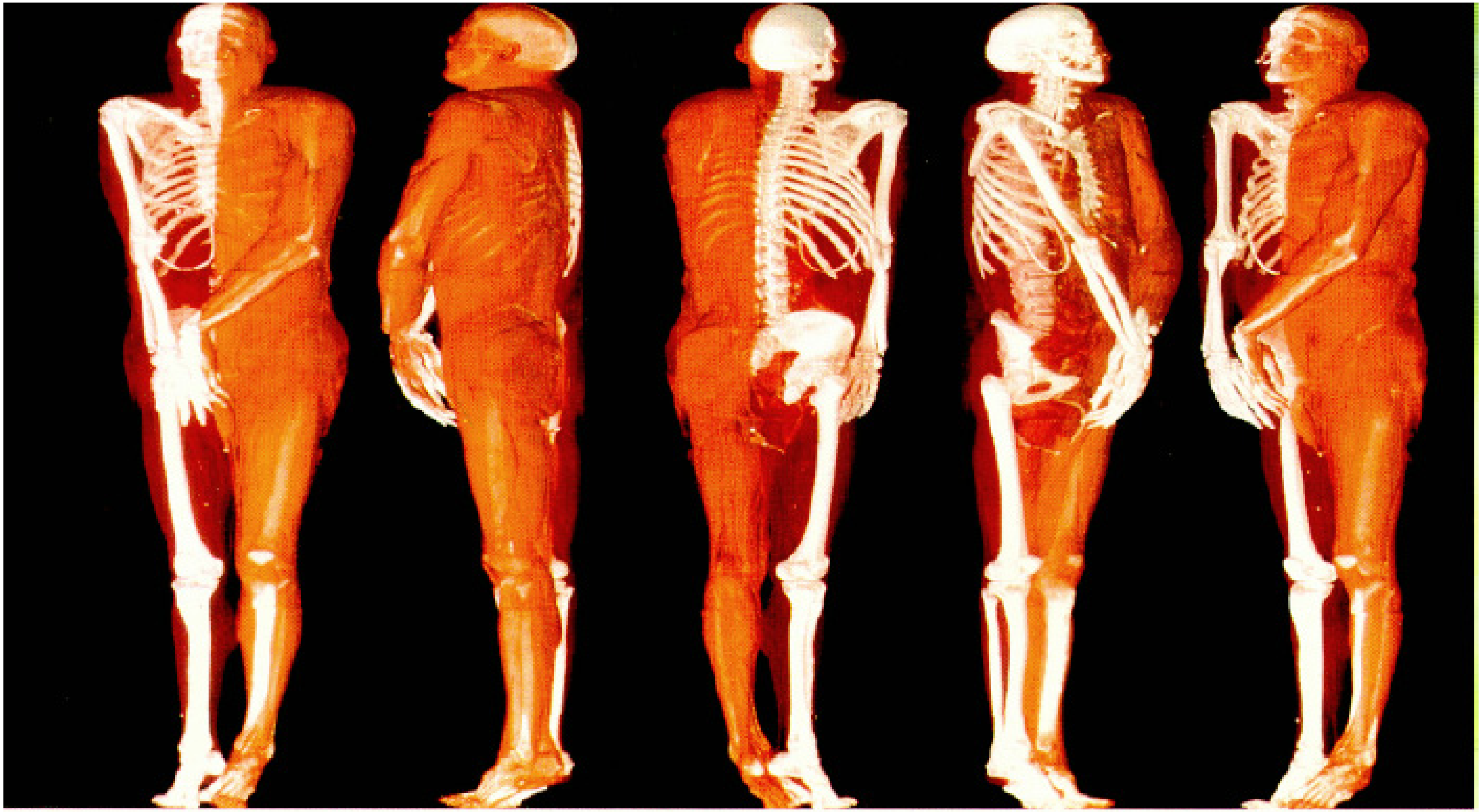
P_z – perspective transform

R_z, R_y – rotations about y and z axis

Results 1/2



Results 2/2



Thank you.