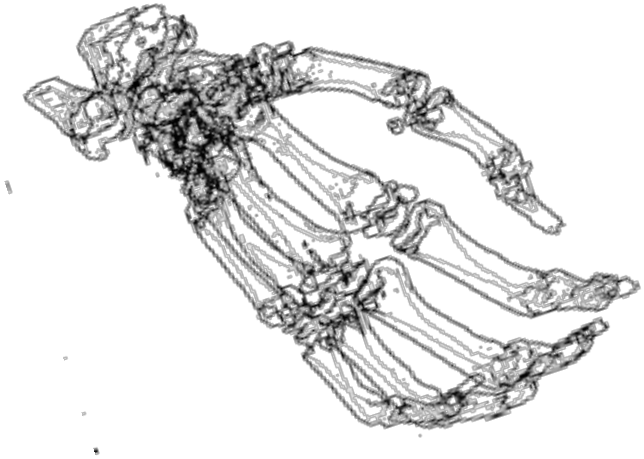
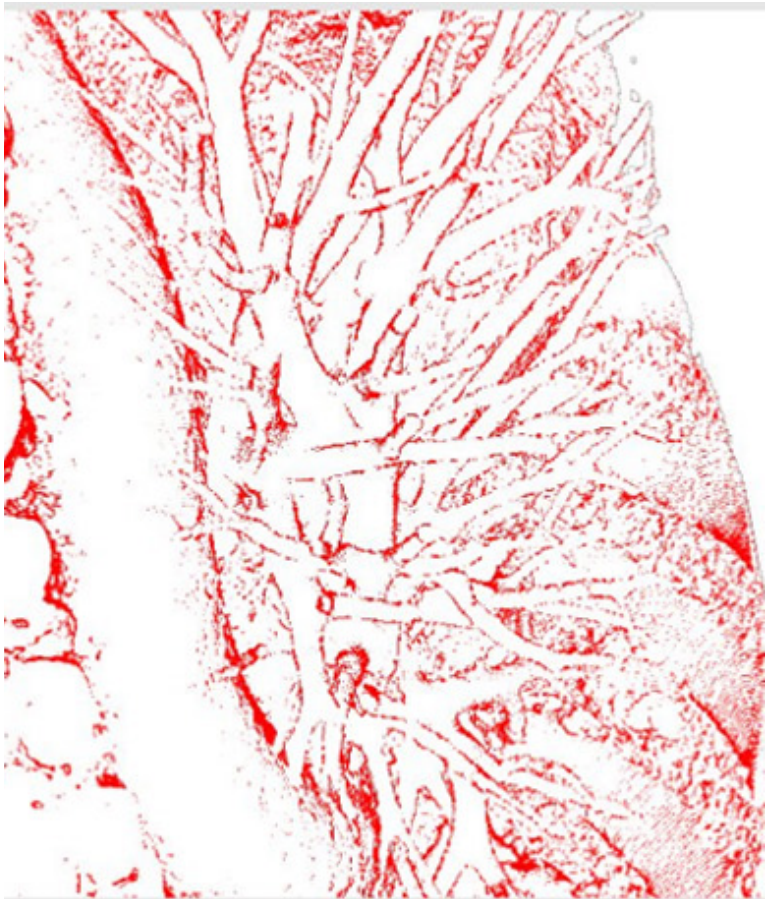
Module #13b:
Non-Photorealistic Rendering

Non-Photorealistic Rendering

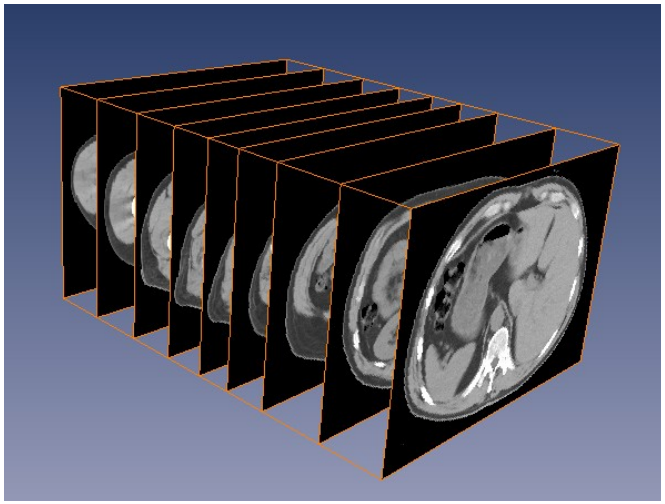
- The use of local image processing to produce artistic and illustrative effects
  - Pen-and-ink drawing
  - Silhouettes
  - Stippling
  - etc

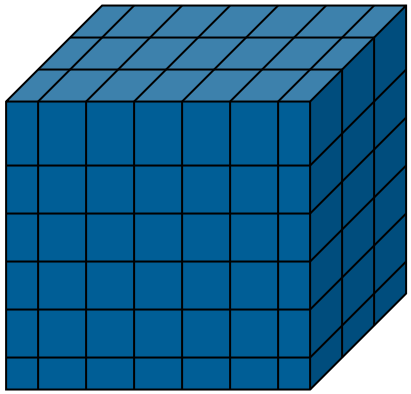




Volume Data Visualization

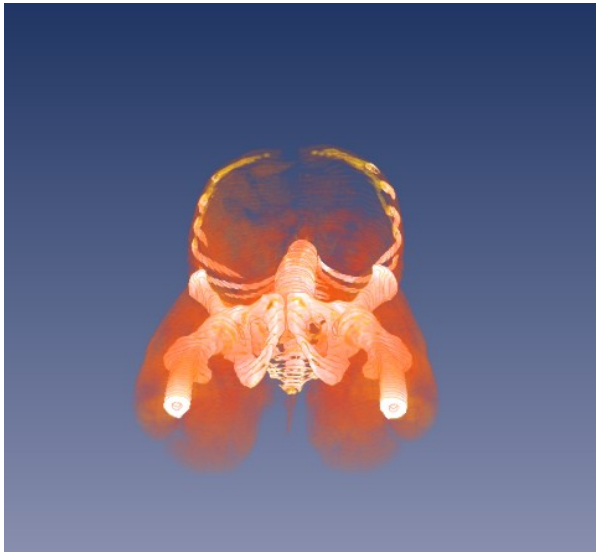
- 3D matrix of data value
- Suitable for densely sampled functions
- Traditionally expensive for storage and rendering



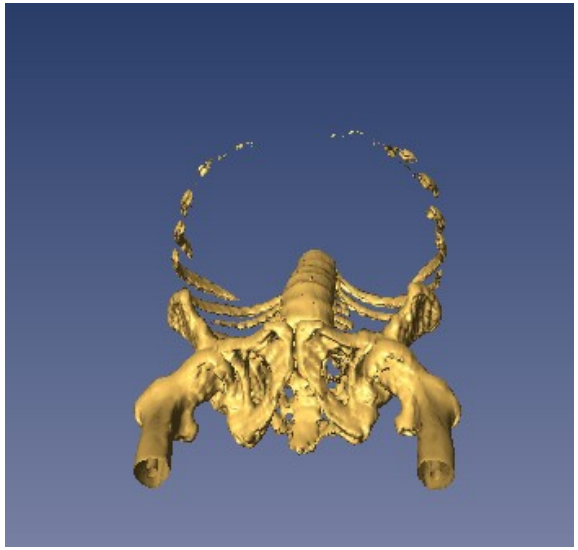


Volume Visualization

- Direct Volume Rendering
  - Transfer function (color and opacity)

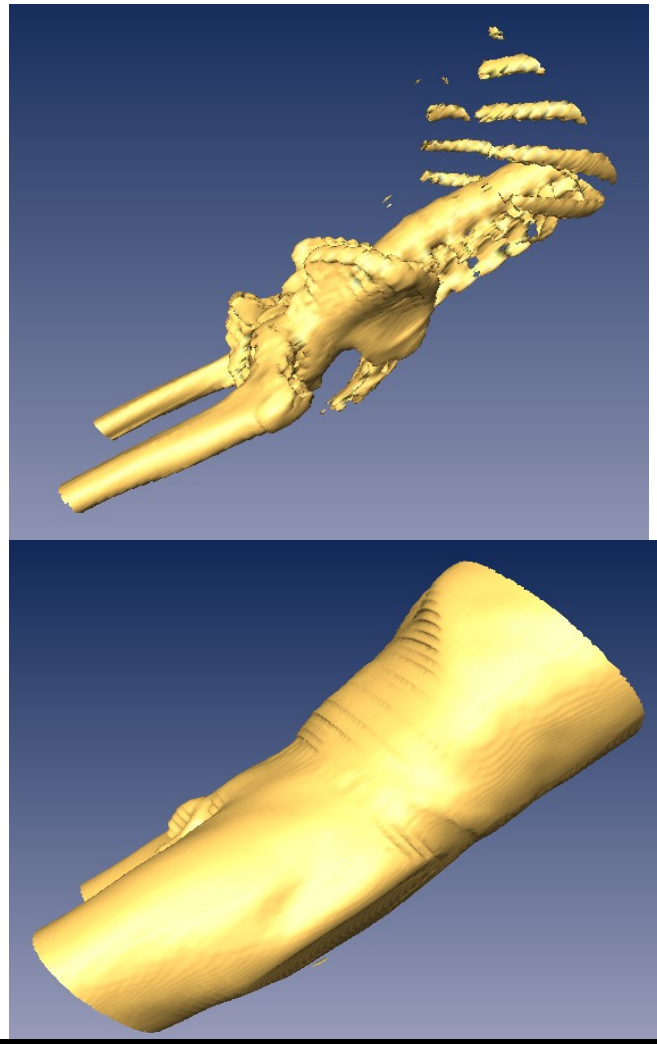


- Isosurface



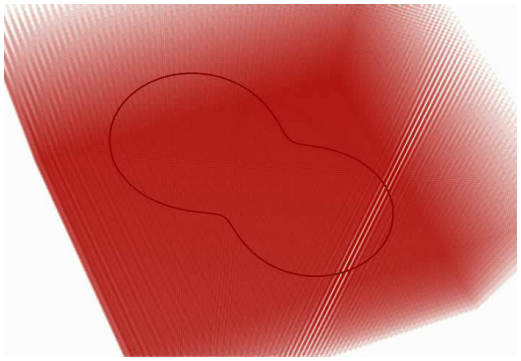
Isosurface Extraction

- Implicit surface that represents points of a constant value
  - Density
  - Pressure
  - Temperature
  - Velocity
- Given a threshold ***t***
  - Values “inside” greater than ***t***
  - Values “outside” less than ***t***



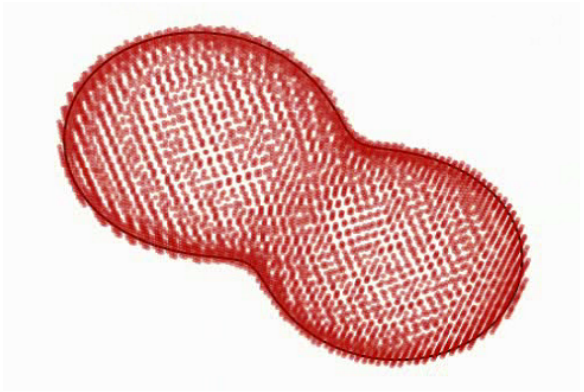
Key Idea: Lines are Sparse

Direct Volume Rendering



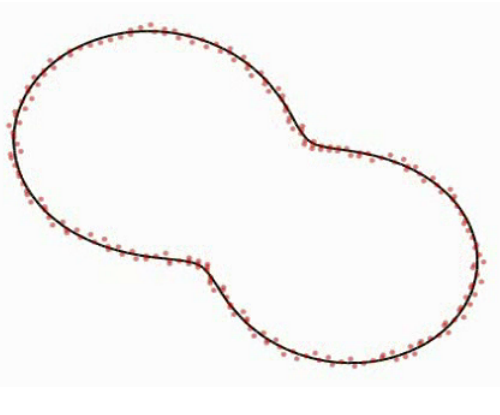
O(volume)

Optimized Isosurface Extraction



O(surface)

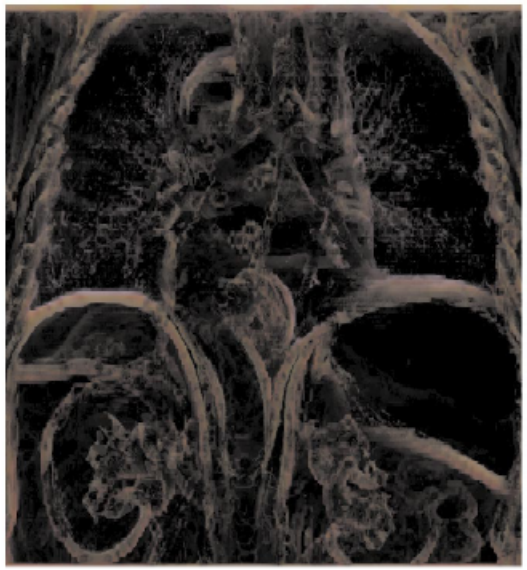
Line Extraction



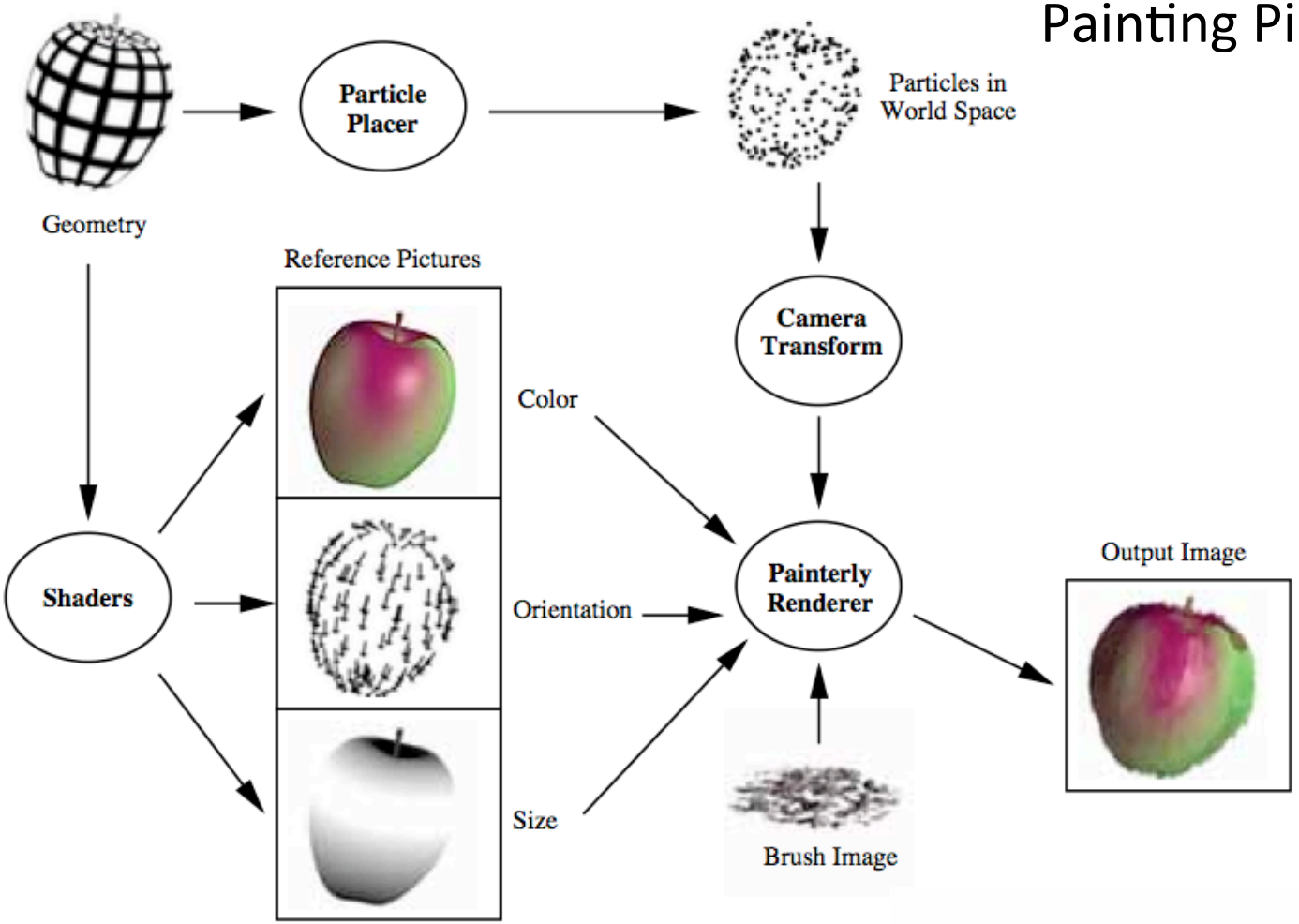
O(line)

Background

- Line Drawing from 3D Data

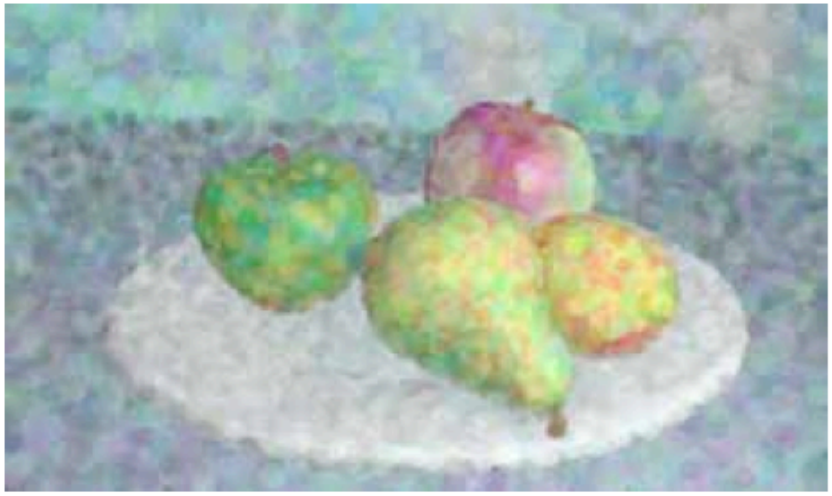


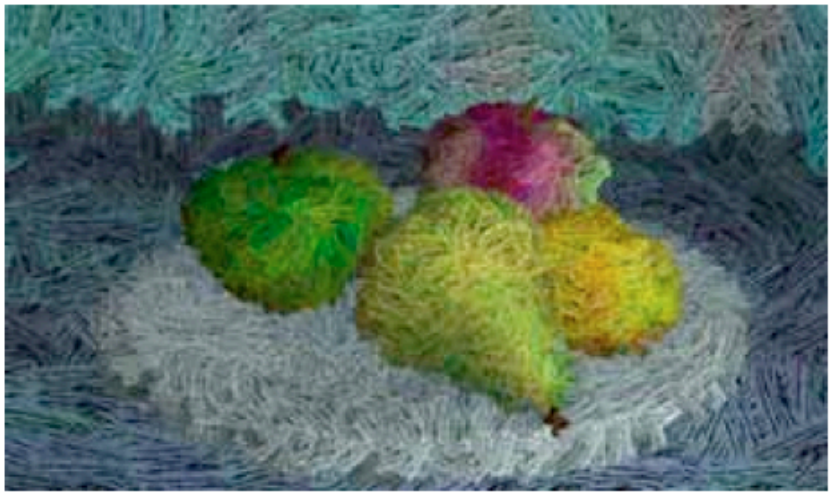
Painting Pipeline



Brushes (color & opacity):

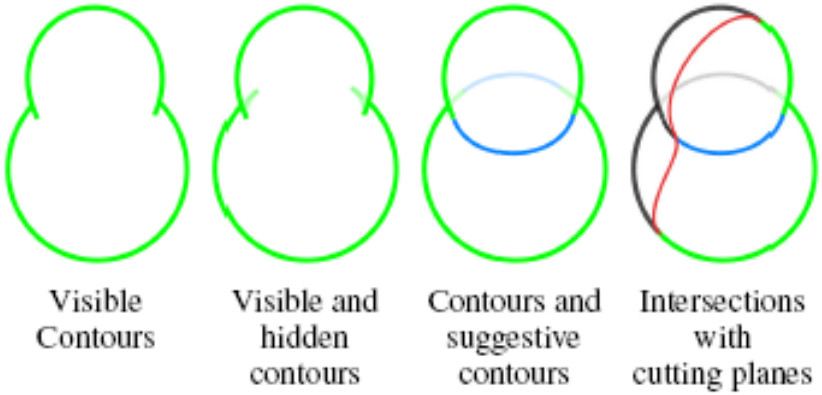
Different Brushes and Orientation Fields



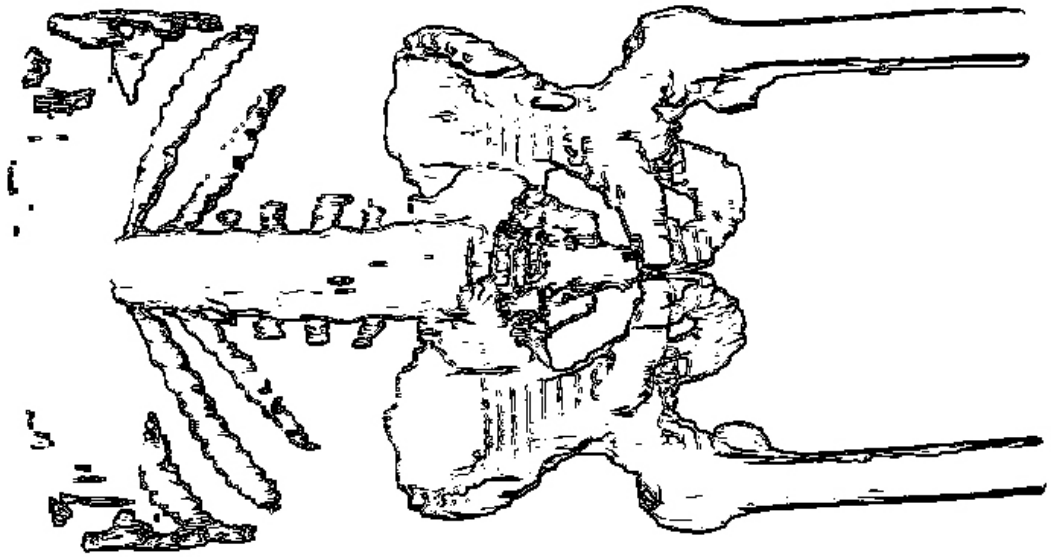
What kind of lines?

- Contours
- Suggestive Contours
- Cutting Planes



1. Contours

- Denote depth discontinuities
- Surface normal perpendicular to view direction
  - Definition: $n \circ v = 0$

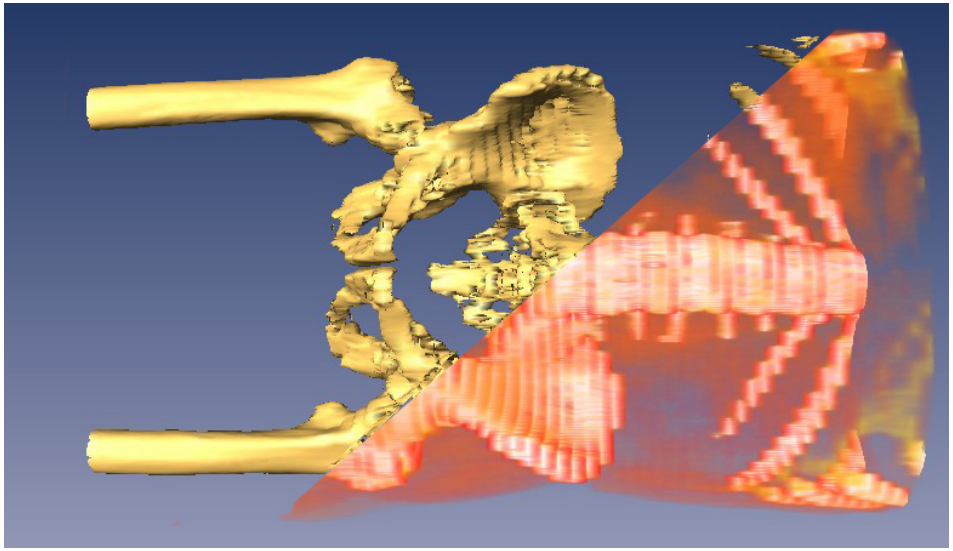


2. Suggestive Contours

- Complement contours in line drawings to produce more effective rendering of shape.
- Definition:
  - Radial curvature zero
  - Directional derivative to camera positive

3. Cutting Plane

- View independent
- Intersection of cutting planes with isosurface.

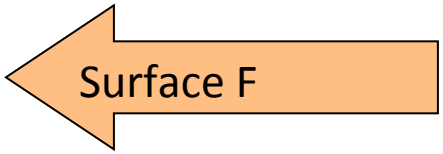


Outline

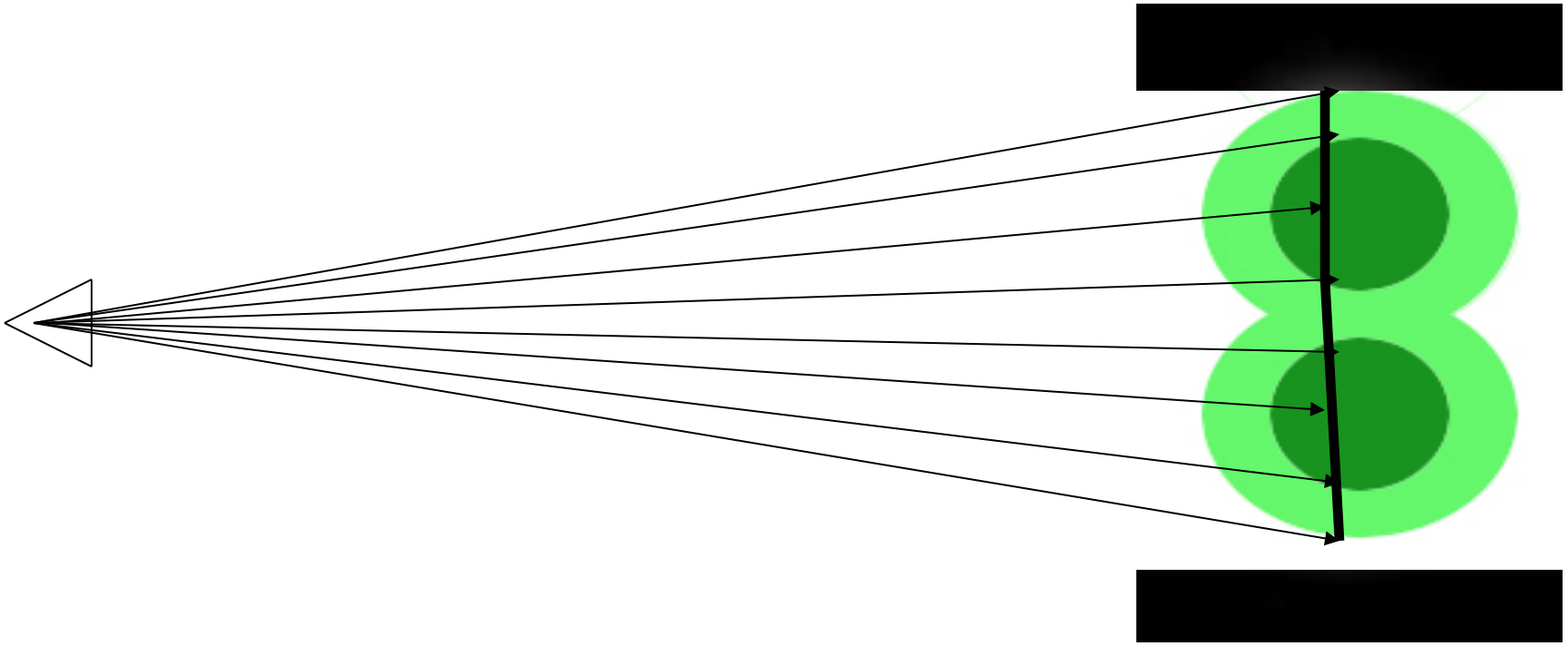
- Background
- **Line Extraction**
- Hidden-Line Removal
- Stylization
- Conclusion

Extracting Contours

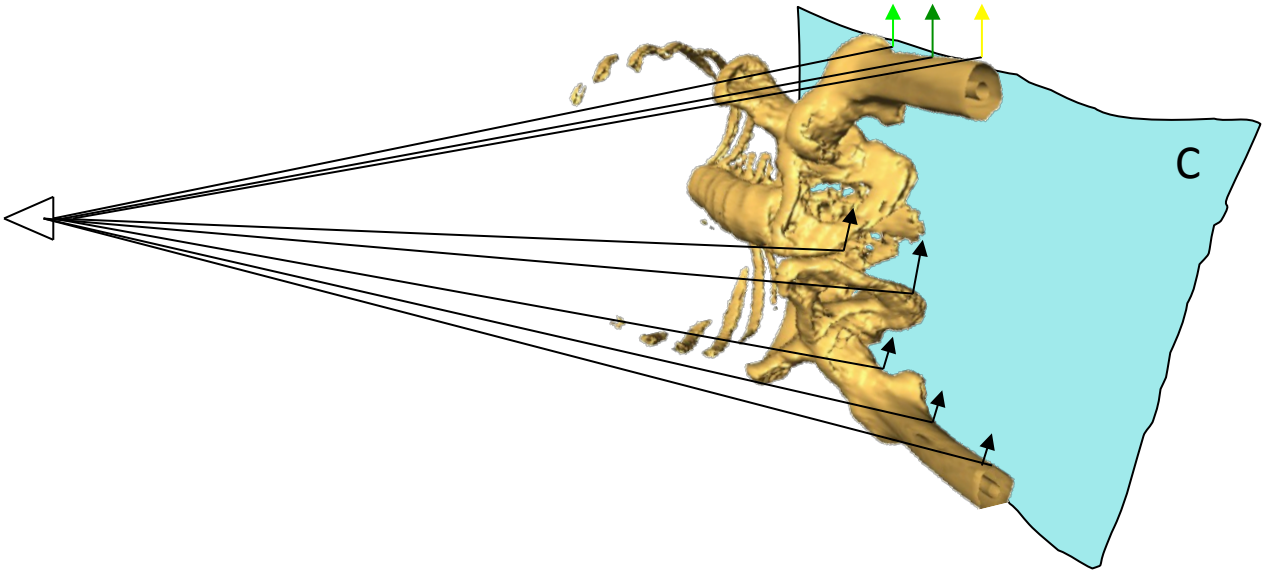
- At surface contours: n ◦ v = 0
- Let **α(i,j,k)** is a volume (3D matrix)
  - Isosurface at threshold ***t*** :
    - $f(i, j, k) = \alpha(i,j,k) - t$
  - Isosurface *normal* at point **p**:
    - $N(p) = \Delta f(p)$
  - Surface containing contours at all isovalues
    - $N(p) \circ v(p) = 0$



Extracting Contours



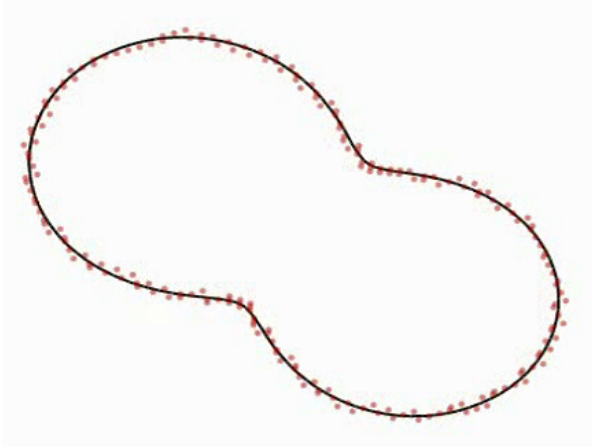
Extracting Contours

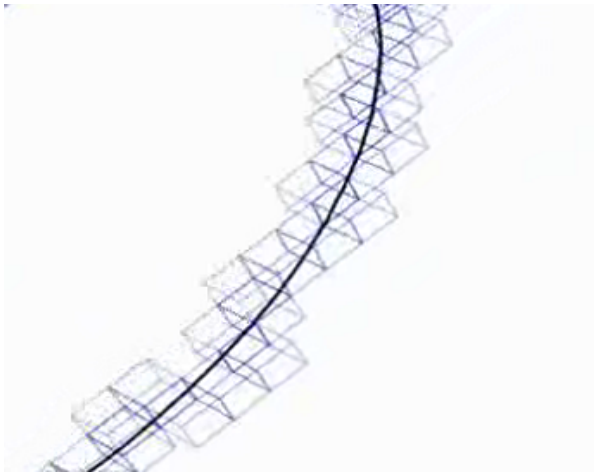


- Contours at intersection between **F** and **C**
- Lines
  - Surface intersection between this isosurface and contours surface.

Extra Lines

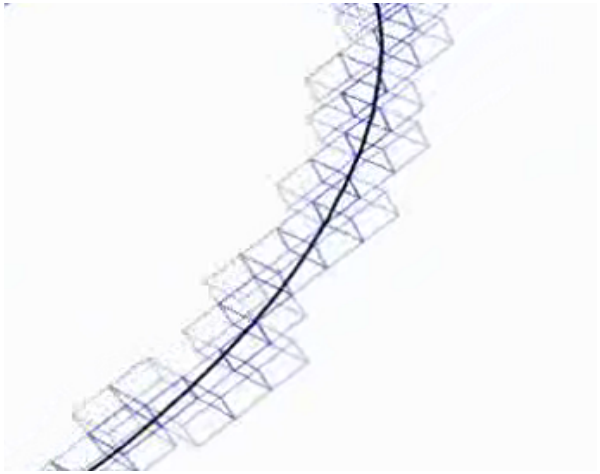
- Brute force $O(n^3)$
- Optimization
  - Locate seed cells
  - Proceeding to neighbor cells by extending end points of the line segment at seed cell.





Search for seeds

- Probe random cells
- Gradient Descent
  1. From voxel P, take steps proportional to the *negative* of the **gradient**
  2. From voxel P’, find descent using **n** ◦ **v**



Other Line Types

- Suggestive contours
  - Recall: Radial curvature zero
  - Intersect isosurface S with $K_r = 0$
- Cutting plane intersections
  - Intersect isosurface S with $Ax + By + Cz – D = 0$

Outline

- Background
- Lines Extraction
- **Hidden-Line Removal**
- **Stylization**
- Results
- Conclusion

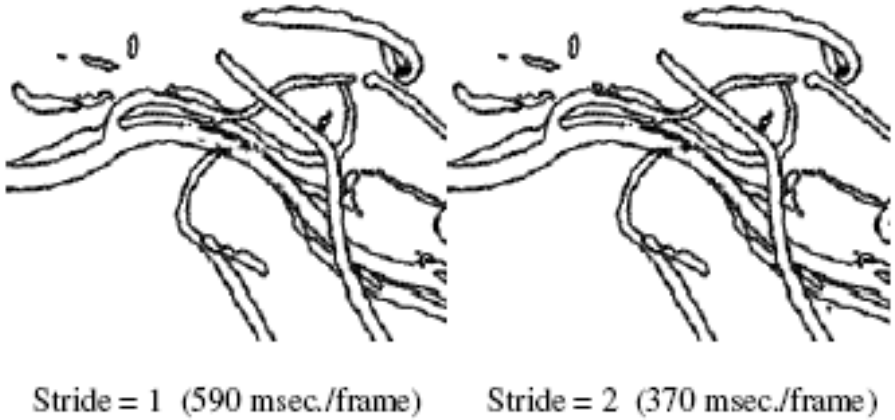
Hidden-Line Removal

- Large number of lines
  - Hard to distinguish which surfaces are closer to the camera
- Solution
  - Detecting surfaces occluded by isosurfaces closer to the camera
  - Remove them

Hidden-Line Removal

- Solution #1:
  - For each line segment:
    - Trace a ray through the cells towards the camera
    - Test for isosurface intersection
  - Complexity $O(n^2)$
- Solution #2:
  - Approximate visibility every k^{th} voxels

Approximate Visibility



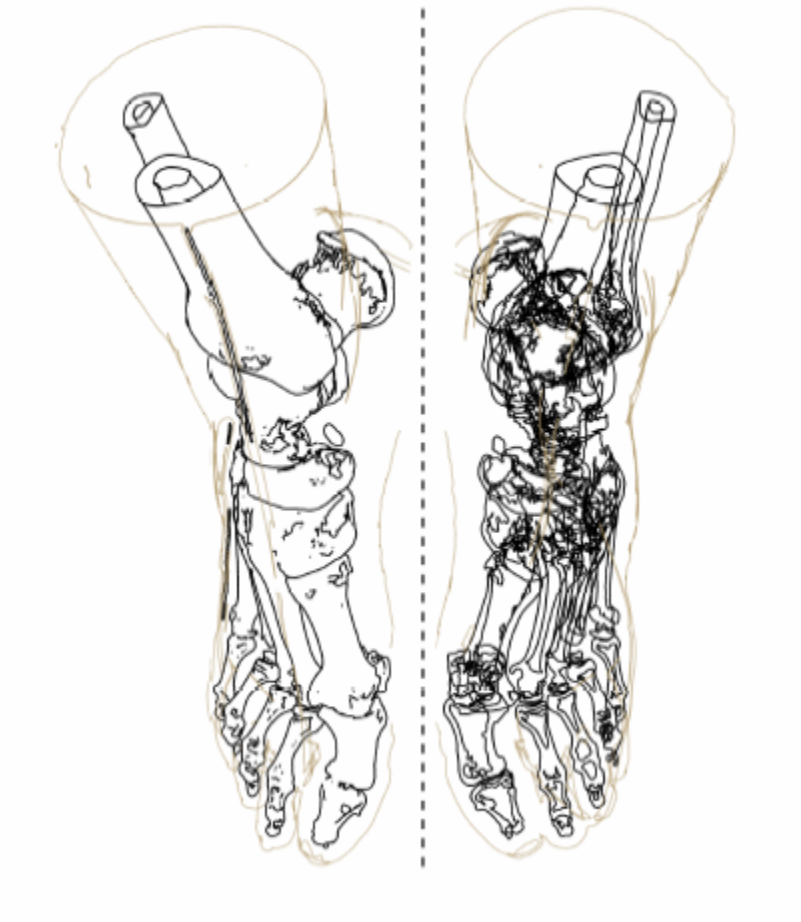
Stride = 1 (590 msec./frame) Stride = 2 (370 msec./frame)

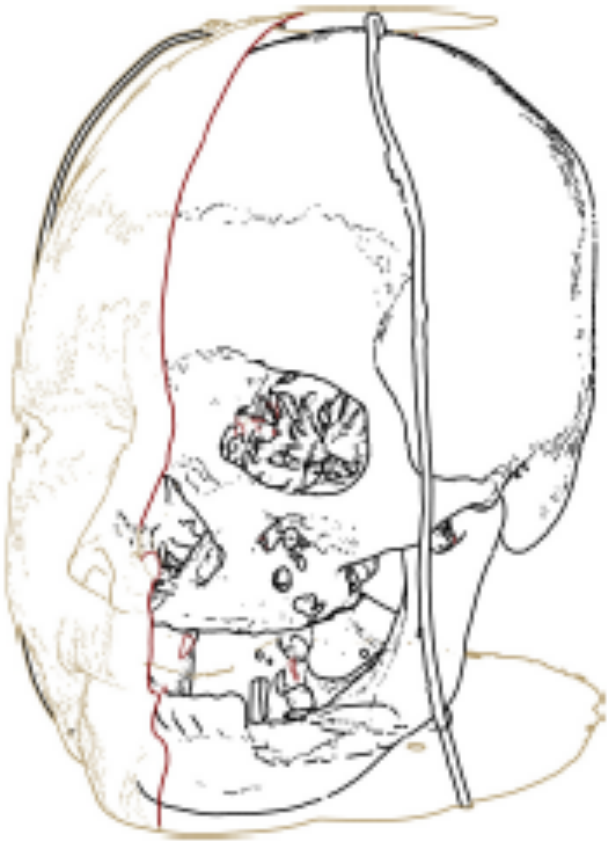
Stride = 4 (280 msec./frame) Stride = 8 (244 msec./frame)

Stylization

- Color, width, opacity, modulated by:
  - Line type
    - Contour
    - suggestive contours
    - cutting plane
  - Isovalue
  - Occlusion test
  - Cutting plane test
  - Back-facing test

Multiple Isovalues





Bonsai

Silhouettes

Suggestive Contours

Different isovalue

Video: Line Drawing from Volume Data

Michael Burns, Janek Klawe, Szymon Rusinkiewicz, Adam Finkelstein, Doug DeCarlo
ACM Transactions on Graphics (Proc. SIGGRAPH), August 2005

Non-photorealistic Volume Rendering