CSE 564
Visualization & Visual Analytics

Medical & Scientific Visualization

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Medical Imaging: Overall Concept

human (in pain) → imaging device → data → imaging algorithm → reconstructed cross-sectional image
Imaging Modalities Overview

CT

MRI / fMRI

Nuclear

PET

SPECT

Ultrasound

X-ray

magnetic spin

metabolic tracer X-ray emission

sound waves
Anatomic vs Functional Imaging

Person alive | Person dead
---|---
MRI scan | anatomical information

PET scan | functional information

bright spots = high brain activity

An MRI scan shows you that you have a brain
A PET scan shows that you use it
History: X-Rays

Wilhelm Conrad Röntgen

- 8 November 1895: discovers X-rays.
- 22 November 1895: X-rays Mrs. Röntgen’s hand.
- 1901: receives first Nobel Prize in physics

An early X-ray imaging system:

Note: so far all we can see is a projection across the patient:
The breakthrough:

- acquiring many projections around the object enables the reconstruction of the 3D object (or a cross-sectional 2D slice)

CT reconstruction pioneers:

- 1917: Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.
- 1963: Allan Cormack publishes mathematical analysis of tomographic image reconstruction, unaware of Radon’s work.
- 1972: Godfrey Hounsfield develops first CT system, unaware of either Radon or Cormack’s work, develops his own reconstruction method.
- 1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.
Computed Tomography: Concept
Reviewing Radiographs

Would 3D visualization help?
Would 3D visualization help?
3D Visualization via Volume Rendering

Reconstructed object enables:

- Enhanced X-ray visualization from novel views:

- Maximum Intensity (MIP) visualization:

- Shaded object display:
Cartotid Stenosis
Virtual Colonoscopy

Virtual endoscopy, arthroscopy, etc.
Dataset
Renderings
- Data scanned with medical scanners (MRI, CT, PET, SPECT, etc.)

- Data photographed from histological slices (NIH-NLM Visible Human)

head

thorax

feet

atlas created from ~1700 1/3 mm slices
Comes Back to Life…

ROCKY 3000
Scientific Visualization

- shock wave
- virtual frog
- nerve cell
- spiral flow
- transparent MRI head
- wind flow
- semi-transparent tomato
- MRI head
Relativistic simulation of laser particle acceleration in an under-dense hydrogen plasma (800M particles)
Navier-Stokes equations for viscous, incompressible liquids.

\[ \nabla \cdot u = 0 \quad \text{Conversation of mass} \]

\[ u_t = -(u \cdot \nabla)u + \nu \nabla^2 u - \frac{1}{\rho} \nabla p + f \quad \text{Advection} \quad \text{Diffusion} \quad \text{Pressure} \]
Navier-Stokes Solution

Via finite differencing
It all boils down to $Ax=b$. 

$$
\begin{bmatrix}
? & ? & \cdots & ? \\
? & ? & \cdots & \vdots \\
\vdots & \vdots & \ddots & \vdots \\
? & \cdots & \cdots & ?
\end{bmatrix}
\begin{bmatrix}
x_1 \\
x_2 \\
\vdots \\
x_{n^d}
\end{bmatrix}
=
\begin{bmatrix}
b_1 \\
b_2 \\
\vdots \\
x_{n^d}
\end{bmatrix}
$$

Divergence Operator

$$
\begin{bmatrix}
1 & 0 & 1 \\
-1 & 0 & 1 \\
-1 & 0 & 1
\end{bmatrix}
$$

Laplacian Operator

$$
\begin{bmatrix}
1 & -4 & 1 \\
-4 & 12 & -4 \\
1 & -4 & 1
\end{bmatrix}
$$
Visualize via Volume Rendering