CSE 564
Visualization & Visual Analytics

Medical & Scientific Visualization

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<table>
<thead>
<tr>
<th>Lecture</th>
<th>Topic</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intro, schedule, and logistics</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Applications of visual analytics, basic tasks, data types</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Introduction to D3, basic vis techniques for non-spatial data</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Data assimilation and preparation</td>
<td>Project #1 out</td>
</tr>
<tr>
<td>5</td>
<td>Data assimilation and preparation</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bias in visualization</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Data reduction and dimension reduction</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Visual perception</td>
<td>Project #2(a) out</td>
</tr>
<tr>
<td>9</td>
<td>Visual cognition</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Visual design and aesthetics</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Cluster analysis: numerical data</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Cluster analysis: categorical data</td>
<td>Project #2(b) out</td>
</tr>
<tr>
<td>13</td>
<td>High-dimensional data visualization</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Dimensionality reduction and embedding methods</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Principles of interaction</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Midterm #1</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Visual analytics</td>
<td>Final project proposal call out</td>
</tr>
<tr>
<td>18</td>
<td>The visual sense making process</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Maps</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Visualization of hierarchies</td>
<td>Final project proposal due</td>
</tr>
<tr>
<td>21</td>
<td>Visualization of time-varying and time-series data</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Foundations of scientific and medical visualization</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Volume rendering</td>
<td>Project 3 out</td>
</tr>
<tr>
<td>24</td>
<td>Scientific and medical visualization</td>
<td>Final Project preliminary report due</td>
</tr>
<tr>
<td>25</td>
<td>Visual analytics system design and evaluation</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Memorable visualization and embellishments</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Infographics design</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Midterm #2</td>
<td></td>
</tr>
</tbody>
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Medical Imaging: Overall Concept

- Object
- Imaging device
- Data
- Imaging algorithm
- Reconstructed cross-sectional image
Imaging Modalities Overview

CT
MRI / fMRI
Nuclear
Ultrasound

X-ray
magnetic spin
metabolic tracer X-ray emission
sound waves
### Anatomic vs Functional Imaging

<table>
<thead>
<tr>
<th>Person alive</th>
<th>Person dead</th>
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</thead>
<tbody>
<tr>
<td>MRI scan</td>
<td>anatomical information</td>
</tr>
<tr>
<td>PET scan</td>
<td>functional information</td>
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<tr>
<td>bright spots = high brain activity</td>
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</tbody>
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An MRI scan shows you that you have a brain
A PET scan shows that you use it
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:
History: Computed Tomography

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?
VR?
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.
• 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…
Relativistic simulation of laser particle acceleration in an under-dense hydrogen plasma (800M particles)
Navier-Stokes equations for viscous, incompressible liquids.

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

\[ u_t = -(\mathbf{u} \cdot \nabla)\mathbf{u} + \nu \nabla^2 \mathbf{u} - \frac{1}{\rho} \nabla p + \mathbf{f} \]

Advection  Diffusion  Pressure
Navier-Stokes Solution

Via finite differencing

It all boils down to \( Ax = b \).

\[
\begin{bmatrix}
? & ? & \cdots & \cdots & ? \\
? & ? & \cdots & \cdots & ? \\
\vdots & \ddots & \ddots & \ddots & \vdots \\
? & \cdots & \cdots & ? & ?
\end{bmatrix} \begin{bmatrix}
x_1 \\
x_2 \\
\vdots \\
x_n^d
\end{bmatrix} = \begin{bmatrix}
\begin{bmatrix}
b_1 \\
b_2 \\
\vdots \\
b_n^d
\end{bmatrix}
\end{bmatrix}
\]

Divergence Operator

\[
\begin{bmatrix}
1 & 0 & 1 \\
-1 & 0 & -1 \\
-1 & 0 & -1
\end{bmatrix}
\]

Laplacian Operator

\[
\begin{bmatrix}
1 & -4 & 1 \\
-4 & 16 & -4 \\
1 & -4 & 1
\end{bmatrix}
\]
Visualize via Volume Rendering