Introduction to visualization
(3 lectures)

⇒ 1. Philosophy and key issues
(T. Kuhn, The Structure of Scientific Revolutions)

2. The design of visualizations
(Tufte, Envisioning Information)

3. The scientific illustration tradition

4. Scientific visualization techniques

5. Visualization software and systems

Philosophy and key issues

- Why visualize?
- uses of visualization
- visual metaphors
- the role of realism
- handling complexity

Why visualize?

"The purpose of computing is insight, not numbers."
- Richard Hamming

- computers produce too much data
- bandwidth of human visual channel is high
- large portion of brain devoted to visual processing
- well developed languages for visual communication
- AI versus IA

Uses of visualization

- <u>data exploration</u>
- hypothesis testing
- steering of computations
- program / performance debugging
- presentation
- education

Steps in data exploration

- thinking about the data
- building a visualization
- searching a parameter space
- looking for patterns
- looking for associations
- finding errors
- discovering the unexpected

The Structure of Scientific Revolutions

- Thomas Kuhn, 1962

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1. normal science

- **gathering facts to support a paradigm**
- **mopping up operations**

"Normal science does not aim at novelties of fact or theory and, when successful, finds none. Discovery commences with the awareness of anomaly."

2. anomoly

- **accidental discoveries**
- **unexpected results**

"Novelty ordinarily emerges only for the man who, knowing with precision what he should expect, is able to recognize that something has gone wrong."

3. crisis

- **attempts to “fix” existing theory**
- **loosening of rules for research**
- **emergence of new theories**

“Almost always the men who achieve these fundamental inventions of a new paradigm have been either very young or very new to the field.”

4. revolution

- **transition to a new paradigm**
- **return to normal science**

“Textbooks...have to be rewritten in the aftermath of each scientific revolution, and, once rewritten, they inevitably disguise...the very existence of the revolutions that produced them.”

History of visualization

1972	Cray research founded
1974	first ACM Siggraph conference
1975	Evans and Sutherland frame buffer
1985	volume rendering [Drebin et al.]
1987	fast isosurfacing [Lorensen]
1987	NSF panel on Visualization in Scientific Computing (ViSC)
1990	first IEEE Visualization conference
1991	High-Performance Computing Act
1992	High-Performance Computing and Communications (HPCC) program
1995	first IEEE InfoVis conference

HPCC challenges

- “Grand challenges”
  - weather prediction
  - computation fluid dynamics
  - materials modeling
  - molecular dynamics
  - astrophysics

- “National challenges”
  - environmental monitoring
  - design and manufacturing
  - digital libraries
  - health care

Visual metaphors

data to be analyzed → *visual metaphor*

graphical primitives → *visual metaphor*

visual metaphor → visualization

- **Some obvious metaphors**
  - **memory hot spots = temperature map**
  - **World Wide Web = display of globe**
  - **code profiling = colored code display**

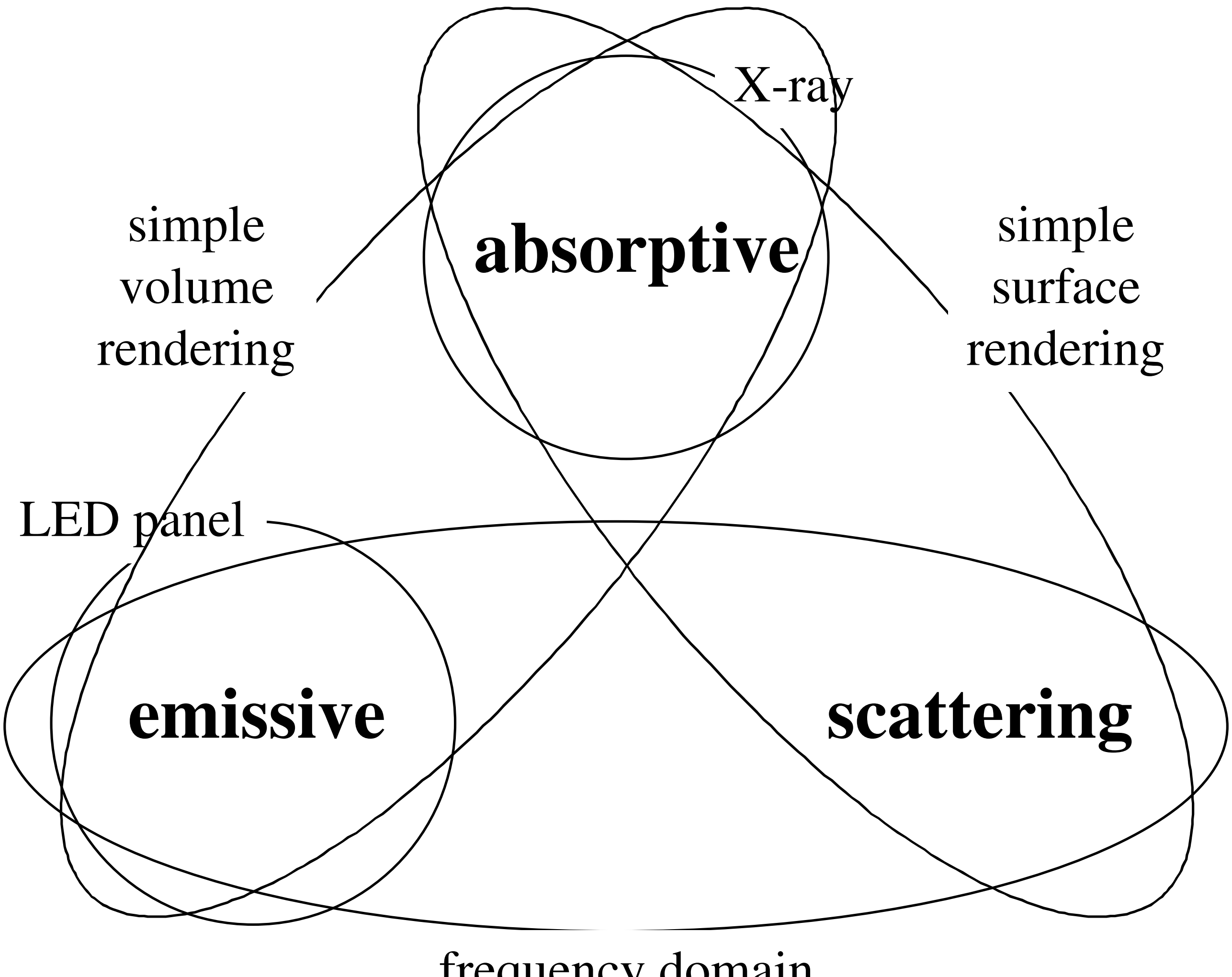
- **Some non-obvious metaphors**
  - **memory and time = 3D "strip surface"**
  - **cache size params = volume rendering**

The role of realism

- **viewing a 3D model on a 2D display**
    1. **3D -> 2D reduces information content.**
    2. **If it is a projection (not a slice), we need a mental model of the scene, lights, and projection method.**
    3. **When shown an ambiguous image, we choose the more plausible and familiar interpretation.**

- **successful realism**
    – **eliminates ambiguity / misinterpretation**
    – **improves perception of subtle features**
    – **allows more data to be displayed at once**

Common projection methods



others:

- **maximum intensity projection (MIP)**

Principal visual cues

- occlusion
- transparency
- perspective and foreshortening
- aerial perspective: desaturation, blurring
- shading
- shadows
- stereopsis
- kinetic depth effect
- head motion parallax

Realistic visualization

- **some successes**
  - photorealistic volume rendering
  - haptic displays
- **some failures**
  - volume renderings of nearly transparent data
  - purely absorptive, emissive, or scattering displays
- **a methodology...**
  - raiding the museum’s model shop

Non-realistic visualization

- **shorthand for realistic effect**
  - **hatching**
- **enhanced realism**
  - **outlining**
- **abstraction**
  - **cartoon**

Handling complexity

feedback path

- **During simulation**
  - **change the level of observation**
- **During visualization**
  - **change the visual metaphor**
- **During scene generation**
  - **change the level of detail**
- **During display**
  - **improve performance**

rendering pipeline

Level of detail

- **well-known strategies**
  1. **culling unseen geometry**
  2. **multiple geometric LODs**

- **some new strategies**
  3. **multiple layers & frame rates**
  4. **image-based-rendering**

Level of abstraction

- **the scientific method**
  - abstract the behavior to produce a model
  - approximate the model
  - evaluate the approximation
- **changing the scale**
  - changing the scale within a model
  - changing models
  - aliasing effects
- **modeling computer systems**
  - arbitrary complexity
  - context and navigation
  - transition and continuity