HPC Bootcamp 2010: Visual Computing

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VT Advanced Research Computing
A Definition

• Generally:
  – The use of computer-supported, interactive, visual representations of data to amplify cognition
  Card, McKinlay and Schneiderman
  – Scientific Visualization
  – Information Visualization
  – Virtual Environments
Viewers, Browsers, Players

• Web3D Anywhere!
Rewind- to first principles

• The human mind is still the best analyst; how do we:
  – discover trends and relationships
  – communicate concept and results graphically
• How can perception inform design?
Principles of Perception
Of course, statistical graphics, just like statistical calculations, are only as good as what goes into them. An ill-specified or prepos­terous model or a puny data set cannot be rescued by a graphic (or by calculation), no matter how clever or fancy. A silly theory means a silly graphic:

**Solar Radiation and Stock Prices**

What is HCI?

• A multidisciplinary science of the interface: *psychology, design & media, human factors, sociology, computer science*

• Experimental methods to rationalize UI features, design, and software architecture
Norman’s Gulfs
Communication Across the Gulfs

User-centered design:

• **Evaluation**: Information Design
  – What do I see?
  – What does it mean?

• **Execution**: Interaction Design
  – What is my next goal?
  – How do I achieve it?
  – Make it happen!
Information Design

Goal: identify methods for representing and arranging the objects and actions possible in a system in a way that facilitates perception and understanding
Information Design

• Define and arrange the visual (and other modality) elements of a user interface
  – Screen layout, icon design, vocabulary selection
  – But also the “big picture” or overall info model
  – Models of perception, psychology guide this

• Engineering an information design
  – Make sure what people see (hear, etc.) makes sense, and helps them to pursue meaningful goals
  – Depends on what they are doing, hence the important role of user interaction scenarios
Good Graphics

- Precision
- Clarity
- Maximize Data-to-ink ratio
  - Data Ink Ratio = (data ink) / (total ink in the plot)
- Minimize Lie factor
  - Lie factor = (size of graphic) / (size of data)
Information Visualization Mantra

(Shneiderman)

• Overview first, zoom and filter, then details on demand
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Making Sense of an Information Display

**Perception**
color, shading, lines
characters, squares, spatial organization

**Interpretation**
Excel worksheet, a cell is selected, formula is displayed at top

**Making Sense**
Income worksheet, Total tax income is being calculated, the wrong multiplier is being used

Last month’s budget...?
In this aggregation of individual deaths into six areas, the greatest number is concentrated at the Broad Street pump.

Using different geographic subdivisions, the cholera numbers are nearly the same in four of the five areas.

In this aggregation of the deaths, the two areas with the most deaths do not even include the infected pump!

Visual Analysis Overview

![Diagram showing the processing in a typical visualization pipeline](image)

*Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)*
First Steps

Extract data and Map

• Data transformation
  – Raw data -> attributes of interest
  – File formats or scripts are usually employed

• Visual attributes
  – Assign attributes -> visual representation
  – Typically use some tool (e.g. Paraview, Excel, Gnuplot)
Second Steps

Publish and Deliver

• View transformation
  – ‘Camera’ location and properties

• Rendering assignment
  – Print vs. interactive
  – Resolution, size
  – Stereo, immersion
Fundamental Data Types

- Spatial / perceptual data:
  - geometry, colors, textures, lighting

- Abstract data / world & object attributes:
  - nominal, ordinal, quantitative

- Temporal data / behaviors:
  - states, dynamics
Data Transformations

• Data table operations:
  • Selection
  • Projection
  • Aggregation
    – \( r = f(\text{rows}) \)
    – \( c = f(\text{cols}) \)
  • Join
  • Transpose
  • Sort
  • ...

Visual Mapping: Step 1

1. Map: data items \(\rightarrow\) visual marks

**Visual marks:**
- Points
- Lines
- Areas
- Volumes
- Glyphs
Perception for Design

• Using our understanding of the human perceptual systems to guide design
  – Visual system
  – Auditory system
  – Vestibular system
• Leverage pre-attentive facilities
• Reduce cognitive overhead
Perception

• Organize and **encode** sensory data in the mind
  – Lines, shapes, colors are “extracted”
  – Very fast, generally with no conscious thought
  – May be influenced by expectations, “top-down”

• Low-level units then grouped and organized
  – Perceived as rows, columns, grids, figures
  – Seeing the relationships among different elements

• Design goal: make this perceptual process rapid and accurate
Background: Information Psychophysics

- Donald Norman, *Cognitive Engineering* (1986)
Pre-attentive Processing

- Involuntary, do not require conscious attention
- Parallel
- Efficient
- Resistant to instruction
Attention

• Pop out effects ‘stand out’ in some simple dimension (conjunctions don’t):
  – Rapid visual search
  – Form, color, simple motion/blinkling, spatial stereo depth, shading, position

12987621909023748594329
08706548394056024859543
7289009890509874632234
Frame Rate

• Threshold for perceiving continuity:
  – flicker < 50 Hz
  – > 24 fps looks smooth & plenty interactive

• Flicker & Attention can lead to change blindness (Simmons, 2000)

• Browser.getCurrentFrameRate()
• Implementing X3DPerFrameObserverScript
  - public void prepareEvents ()
Attention and blindness

- [http://viscog.beckman.uiuc.edu/djs_lab/demos.html](http://viscog.beckman.uiuc.edu/djs_lab/demos.html)
Animation Guidelines

• The higher the frame-rate the better
• Beware data assumptions:
  *Interpolation versus Sequencing*
• Provide user control over time? (e.g. DVDTimeController)
Representing multiple properties

- Flow of air around a car
  - Vectors and particle paths illustrate flow
  - Coloured slice indicates pressure
Features: Color

• Luminance channel
  (3x spatial accuracy)
• Red / Green channel
• Yellow / Blue channel

The spectrum is not a perceptually linear sequence
(not pre-attentive)!
(Keller 1993; Ware, 2000)
Good Pubs


Color (again)

- **IBM Research and color maps:**

- **Human factors in visualization research**
  Tory, M.; Moller, T.;
  Visualization and Computer Graphics, IEEE Transactions on
  Volume 10, Issue 1, Jan-Feb 2004 Page(s):72 - 84
  [http://doi.ieeecomputersociety.org/10.1109/TVCG.2004.1260759](http://doi.ieeecomputersociety.org/10.1109/TVCG.2004.1260759)

- **Some guidelines for Sci Vis:**

- **More detail about CG color models**
  [http://www.ncsu.edu/scivis/lessons/colormodels/color_models2.html](http://www.ncsu.edu/scivis/lessons/colormodels/color_models2.html)
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Interpretation

• Perceiving enables interpretation
  – Perceptual processing identifies major display structures (rectangles, text strings, etc)
  – Users must interpret what these display structures mean in the system

• Designers must anticipate and support user reactions to interface elements
  – Choosing familiar images, symbols, words
  – Refining elements through abstraction
  – Promoting affordances that users can recognize
Depth Cues

Structure the world- locating objects and relationships in space

• Stereoscopy
• Motion parallax
• Relative size / scale
• Fog / atmosphere...
Patterns & Grouping

- Gestalt principles
- Also: continuation, closure, common fate
- Guiding Law of Pragnanz (simplest, most stable configuration)
Gestalt principles

• Palmer & Rock, 1990– review & update principles; grouping based on perceived proximity in 3D space (not 2D proximity on retina)

• Quinlan & Wilton, 1998 – study involving Gestalt conflict; proposed resolution mechanisms
Objects

• Feature Binding – putting the streams together for internal representation
  – color, form, motion
  – Just in time?
• 2.5 D sketch (Marr, 1982)
• Geons (Biederman, 1993)
Fundamental Data Types

• Spatial / perceptual data:
  \textit{geometry, colors, textures, lighting}

• Abstract data / world & object attributes:
  \textit{nominal, ordinal, quantitative}

• Temporal data / behaviors:
  \textit{states, dynamics}
## InfoVis: Visual Markers

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Quantitative</th>
<th>Ordinal</th>
<th>Nominal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graphical Representation</strong></td>
<td>position length angle / slope area volume color / density (Cleveland and McGill, 1980)</td>
<td>position density color texture connection containment length angle slope area volume (Mackinlay, 1986)</td>
<td>position color texture connection containment density shape length angle slope area volume (Mackinlay, 1986)</td>
</tr>
</tbody>
</table>
PathSim example
- Which state has highest income?
- Relationship between income and education?
- Outliers?

<table>
<thead>
<tr>
<th>State</th>
<th>College Degree %</th>
<th>Per Capita Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>20.6%</td>
<td>11486</td>
</tr>
<tr>
<td>Alaska</td>
<td>30.3%</td>
<td>17610</td>
</tr>
<tr>
<td>Arizona</td>
<td>27.1%</td>
<td>13461</td>
</tr>
<tr>
<td>Arkansas</td>
<td>17.0%</td>
<td>10520</td>
</tr>
<tr>
<td>California</td>
<td>31.3%</td>
<td>16409</td>
</tr>
<tr>
<td>Colorado</td>
<td>33.9%</td>
<td>14821</td>
</tr>
<tr>
<td>Connecticut</td>
<td>33.8%</td>
<td>20189</td>
</tr>
<tr>
<td>Delaware</td>
<td>27.9%</td>
<td>15854</td>
</tr>
<tr>
<td>District of Columbia</td>
<td>36.4%</td>
<td>18881</td>
</tr>
<tr>
<td>Florida</td>
<td>24.9%</td>
<td>14698</td>
</tr>
<tr>
<td>Georgia</td>
<td>24.3%</td>
<td>13631</td>
</tr>
<tr>
<td>Hawaii</td>
<td>31.2%</td>
<td>15770</td>
</tr>
<tr>
<td>Idaho</td>
<td>25.2%</td>
<td>11457</td>
</tr>
<tr>
<td>Illinois</td>
<td>26.8%</td>
<td>15201</td>
</tr>
<tr>
<td>Indiana</td>
<td>20.9%</td>
<td>13149</td>
</tr>
<tr>
<td>Iowa</td>
<td>24.5%</td>
<td>12422</td>
</tr>
<tr>
<td>Kansas</td>
<td>26.5%</td>
<td>13300</td>
</tr>
<tr>
<td>Kentucky</td>
<td>17.7%</td>
<td>11770</td>
</tr>
<tr>
<td>Louisiana</td>
<td>19.4%</td>
<td>10635</td>
</tr>
<tr>
<td>Maine</td>
<td>25.7%</td>
<td>12957</td>
</tr>
<tr>
<td>Maryland</td>
<td>31.7%</td>
<td>17730</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>34.3%</td>
<td>17224</td>
</tr>
<tr>
<td>Michigan</td>
<td>24.1%</td>
<td>14154</td>
</tr>
<tr>
<td>Minnesota</td>
<td>30.4%</td>
<td>14389</td>
</tr>
</tbody>
</table>
Scale

Hidden in the scale
Lying

From Tufte
1983
Human Limitations for Short-Term Memory

• Miller’s 7 +/- 2 magic number
  – People can recognize 7 +/- 2 chunks of information at a time and hold these chunks in memory for 15-30 seconds

• Chunking
  – Ability to cluster information together
  – Size of chunk depends on knowledge, experience, and familiarity
Chunking Example 1

HEC ATR ANU PTH ETR EET
Chunking Example 2

THE CAT RAN UP THE TREE
Other Chunking Examples

• Image sequences
• Facial recognition
• Word/letter familiarity
• Hierarchies of information
• Others?
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Making Sense

• Last step in crossing the ‘Gulf of Evaluation’
  – Information has been perceived and interpreted
  – Users must “make sense” of information by relating it to their tasks, goals, and interests

• Designers must support people’s abilities to detect patterns and relationships
  – Consistent use of shape, size, color, position
  – Information models (e.g., hierarchies) organize data
  – Dynamic displays cue users to structure
Important Considerations

• Understanding the domain
• Understanding the Research Question
• Understanding the purpose of the Vis
  – User and reader tasks
Which network is easier to understand?

See Graph Vis!
Context Required
Visual Analysis Overview

Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)
Immersive Virtual Environments

• Leveraging Spatial perception and knowledge
• Embodied interaction
• Examples
• More at last class!
Stereo Walls

TORG (active)
Andrews (passive)

3-4 additional in labs around campus
ParaView

• Use your knowledge to present the important aspects of the simulation data as:
  • An image
  • A movie