Information Visualization
CMSC 838B – Spring 2003

Visual Design
Benjamin B. Bederson
University of Maryland
www.cs.umd.edu/~bederson

This presentation adapted from John Stasko

Semiotics
- The study of symbols and how they convey meaning

This presentation taken largely from John Stasko

Related Disciplines
- Psychophysics
  - Applying methods of physics to measuring human perceptual systems
    - How fast must light flicker until we perceive it as constant?
    - What change in brightness can we perceive?
- Cognitive psychology
  - Understanding how people think, here, how it relates to perception
One (simple) Model

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing

Stage 1 - Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs "automatically"
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called "pre-attentive" processing

Stage 2 - Sequential, Goal-Directed

- Slow serial processing
- Involves working and long-term memory
- More emphasis on arbitrary aspects of symbols
- Top-down processing
How does human visual system analyze images?
- Some things are done preattentively, without the need for focused attention
- Generally less than 200-250 msecs (eye movements take 200 msecs)

How Many 3’s?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
909103020905959595732564675050678904567
8845789809821677654876364908560912949686

How Many 3’s?

128176875638976546984506985604982826762
9809858458224509856458945098450980943585
909103020905959595732564675050678904567
8845789809821677654876364908560912949686
What Kinds of Tasks?

- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
- Counting
  - How many elements of a certain type are present?

Hue

Determine if a red circle is present

Can be done rapidly (preattentively) by people Surrounding objects called "distractors"

Shape

Determine if a red circle is present

Can be done preattentively by people
**Hue and Shape**

Determine if a red circle is present

- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

**Fill and Shape**

Is there a boundary?

- Left can be done preattentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

**Hue versus Shape**

Is there a boundary?

Left: Boundary detected preattentively based on hue regardless of shape
Right: Cannot do mixed color shapes preattentively
Hue versus brightness

Is there a boundary?

Left: Varying brightness seems to interfere
Right: Boundary based on brightness can be done preattentively

Example Applet

- Nice on-line tutorial and example applet
  - [http://www.csc.ncsu.edu/faculty/healey/PP/PP.html](http://www.csc.ncsu.edu/faculty/healey/PP/PP.html)
  - Chris Healey, NC State

Potential Preattentive Features

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- intensity
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction
Key Perceptual Properties

- Brightness
- Color
- Texture
- Shape

Luminance/Brightness

- Luminance
  - Measured amount of light coming from some place
- Brightness
  - Perceived amount of light coming from source

Color Models

- RGB
- HSB (HVS) model
  - Hue - what people think of color
  - Saturation - intensity, whiteness
  - Brightness (Value) - light/dark
Contrast

- Important for fg-bg colors to differ in brightness

Color for Categories

- Can different colors be used for categories of nominal variables?
  - Yes
  - Ware’s suggestion: 12 colors
    - red, green, yellow, blue, black, white, pink, cyan, gray,
      orange, brown, purple

Color Categories

- Are there certain canonical colors?
  - Post & Greene '86 had people name different colors on a monitor
  - Pictured are ones with > 75% commonality
Color for Sequences

Can you order these (low->hi)

Possible Color Sequences

Color Purposes

- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data
  - Example, Ware and Beatty '88
    - x,y - variables 1 & 2
    - amount of r,g,b - variables 3, 4, & 5
Texture

- Appears to be combination of
  - orientation
  - scale
  - contrast
- Complex attribute to analyze

Shape, Symbol

- Symbols should be rapidly perceived and differentiated
- Application for maps, military, etc.

Basic Symbolic Displays

- Graphs
- Charts
- Maps
- Diagrams

1. Graph

- Graph - Show the relationships between variables' values in a data table
  - Visual display that illustrates one or more relationships among entities
  - Shorthand way to present information
  - Allows a trend, pattern or comparison to be easily comprehended

Issues

- Critical to remain task-centric
  - Why do you need a graph?
  - What questions are being answered?
  - What data is needed to answer those questions?
  - Who is the audience?

Graph Components

- Framework
  - Measurement types, scale
- Content
  - Marks, lines, points
- Labels
  - Title, axes, ticks
Basic Data Types

- Nominal (qualitative)
  - (no inherent order)
  - city names, types of diseases, ...
- Ordinal (qualitative)
  - (ordered, but not at measurable intervals)
  - first, second, third, …
  - cold, warm, hot
- Interval (quantitative)
  - list of numbers

Common Graph Formats

- Line graph
  - Y-axis is quantitative variable
  - See changes over consecutive values
- Bar graph
  - Y-axis is quantitative variable
  - Compare relative point values
- Scatter plot
  - Two variables, want to see relationship
  - Is there a linear, curved or random pattern?

Graphing Guidelines

- Independent vs. dependent variables
  - Put independent on x-axis
  - See resultant dependent variables along y-axis
- If there are two independent variables, often place them along the 2 axes (you choose which) and then the mark may encode the dependent variable
2. Chart

- Structure is important, relates entities to each other
- Primarily uses lines, enclosure, position to link entities

Examples: flowchart, family tree, org chart, ...

3. Map

- Representation of spatial relations
- Locations identified by labels

Choropleth Map

Areas are filled and colored differently to indicate some attribute of that region
Cartography

- Cartographers and map-makers have a wealth of knowledge about the design and creation of visual information artifacts
  - Labeling, color, layout, ...
- Information visualization researchers should learn from this older, existing area

4. Diagram

- Schematic picture of object or entity
- Parts are symbolic

Examples: figures, steps in a manual, illustrations,...

Tufte’s Design Principles

- 1. Tell the truth
  - Graphical integrity
- 2. Do it effectively with clarity, precision...
  - Design aesthetics

1. Graphical Integrity

- Your graphic should tell the truth about your data

Show entire scale

Show in context
Measuring Misrepresentation

“Lie factor” = 2.8

- Visual attribute value should be directly proportional to data attribute value
- Height/width vs. area vs. volume

\[
\text{Lie factor} = \frac{\text{Size of effect shown in graphic}}{\text{Size of effect in data}}
\]

2. Design Principles

- Maximize data-ink ratio

\[
\text{Data ink ratio} = \frac{\text{Data ink}}{\text{Total ink used in graphic}} = \text{proportion of graphic’s ink devoted to the non-redundant display of data-information}
\]

Design Principles

- Avoid chartjunk
  - Extraneous visual elements that detract from message

\[\text{don’t be the duck of architecture}\]
Design Principles

- Utilize multifunctioning graphical elements
  - Graphical elements that convey data information and a design function

Design Principles

- Use small multiples
  - Repeat visually similar graphical elements nearby rather than spreading far apart

Design Principles

- Show mechanism, process, dynamics, and causality
  - Cause and effect are key
Design Principles

- Escape flatland
  - Data is multivariate
  - Doesn’t necessarily mean 3D projection

- Utilize layering and separation

- Utilize narratives of space and time
  - Tell a story of position and chronology through visual elements
Design Principles

- **Content is king**
  - Quality, relevance and integrity of the content is fundamental
  - What’s the analysis task? Make the visual design reflect that
  - Integrate text, chart, graphic, map into a coherent narrative

Graph and Chart Tips

- Avoid separate legends and keys – Put that in the graphic
- Make grids & labeling faint so that they recede into background

Proper Color Use

- To label
- To measure
- To represent or imitate reality
- To enliven or decorate
Guides for Enhancing Visual Quality

- Attractive displays of statistical info
  - have a properly chosen format and design
  - use words, numbers and drawing together
  - reflect a balance, a proportion, a sense of relevant scale
  - display an accessible complexity of detail
  - often have a narrative quality, a story to tell about the data
  - are drawn in a professional manner, with the technical details of production done with care
  - avoid content-free decoration, including chartjunk

Graphical Displays Should

- Show the data
- Induce the viewer to think about substance rather than about methodology, graphic design the technology of graphic production, or something else
- Avoid distorting what the data have to say
- Present many numbers in a small space
- Make large data sets coherent
- Encourage the eye to compare different pieces of data
- Reveal the data at several levels of detail, from a broad overview to the fine structure
- Serve a reasonably clear purpose: description, exploration, tabulation, or decoration
- Be closely integrated with statistical and verbal descriptions of a data set