A Review of *Perceptual Principles for Effective Visualizations* by Rheingans and Landreth

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Introduction

- "Visualization is the science of representing data visually in order to enhance communication or understanding."
- Complex and powerful capabilities of human visual channel can be harnessed to help understand large quantities of information.
- Attention to vision system characteristics can improve effectiveness of visualizations.
- Paper discusses number of perceptual principles for construction of effective visualizations.

Single-Variable Visualizations

- Showing value of single variable over a domain.
- Exploit familiar scenarios
  - Lighting - Humans are accustomed to illumination from above objects in a scene. Lighting from below may cause confusion.
  - Shadows - Powerful method for conveying 3D structure and placement of 3D object. Without shadows objects' structure and placement may be misinterpreted.
  - Other Cues - hidden line and surface removal, perspective, intensity depth-cuing, and stereo display.
- Emphasize the interesting
  - Take care that most striking features are also most important. Features that are likely to catch eye are those that are brightly colored, moving or changing, defined by sharp boundaries, or highly saturated.
  - Double-ended Color Scales - Data sets with positive and negative values with zero point. Deviation from zero is interesting. Good example of beach erosion and deposition visualization. Double-ended color scales extends to bivariate color scales (mappings from two scalar values to a color). Useful for situations where two variables are expected to be correlated.

  - Missing Values - Sometimes things that are not shown can distract. Gaps with missing data tends to draw eye from real data. Can display approximations in the no data gaps (but there is danger of misrepresenting the data). Ideally, both interpolated and iblanked visualizations will be available to user.

- Say it again (Use redundant mappings)
  - Visualization that represent data values with multiple parameters can portray more effective visualization of data. There are a number of reasons why:
    1. Different params convey different types of information more effectively.
    2. Can overcome visual deficiencies (e.g., ambiguity or ineffectiveness of a display parameter).
    3. Multiple display params can enforce each other.
  - Color and Height - Humans more experienced judging patterns of surface from shape than color. Redundant representation conveys location of global maxima more clearly than just using height-mapping.
  - Redundant Color Scales - For example, data values can be mapped to both hue and lightness. Empirically confirmed utility of redundant color scales. Description of Ware study of this topic given. Suggests color scale that varies in luminance and hue can be used to accurately represent both metric and surface properties. Heated-object scale goes from black through red, orange, and yellow to white, with brightness increasing monotonically. More distinguishable values and more contrast between levels than grey scale. Heated-object scale has stronger perceived natural ordering than rainbow because of monotonic increase in brightness and because color order is based on experience.
  - Explicit Redundancy - Same data field mapped to two or more redundant objects, each has distinct single attribute. Accuracy in metric readings maximized while maintaining optimal clarity of object's form.
  - More Redundant Techniques - Combining size and color, opacity and color, and color and texture.

- Minimize Illusions
  - Avoid conditions that give rise to illusions.
  - Color-size Effects - Some experiments suggest color of object influence perceived size. Rectangles with higher saturations perceived closer. Warm colors (red, orange, yellow) appear larger than cool (blue, green). Rectangles with same size, saturation, and brightness appear to be different sizes when colored red-purple, yellow-red, purple-blue, or green. Implications for statistical maps. Color of map region influences perceived size of region (effect strongest for very saturated)

- Control of level of detail
  - Amount of detail should be in proportion to information displayed.
  - Segmented vs. Holistic Representation
    * Particularly striking when datasets are animated as time sequences.
  - Color Scale Detail
    * Fine structure of value distribution can be made more apparent by using color scales with high frequency components. Makes it impossible to look up value represented by color (a single color can represent many values).

- Surface Detail
  - Can facilitate perception of fine surface structure. Adding surface detail to a height-mapped or iso-value surface.

Multivariate Visualizations

- Show two or more variables over a single spatial domain.
- Basic challenges of multivariate data are to:
  1. Clearly show spatial relationship of different variables.
  2. Keep different variable representations from interfering with one another.
  3. Facilitate the understanding of joint distributions.
  4. Show as many variables as can be effectively displayed.
- Show multiple surfaces
  - Contributions of different variables occupy different regions of space.
- Use Orthogonal Display Parameters
  - Displaying two or more sets of data in single visualization.

References

[1] P. Rheingans and C. Landreth, "Perceptual Principles for Effective Visualizations," *Perceptual Issues in Visualizations*, G. Grinstein and H. Levkowitz, eds., Springer-Verlag, 1995, pp. 59–74, "http://www.cs.umbc.edu/ rheingan/pubs/perception.ps.Z (current 14 Sep. 2006)".