Adding color is by no means the only way to extend a scatter plot to multiple dimensions, although it is one of the best techniques. In Chapter 5, we will consider other methods, which use shape and motion.

Conclusion

There has been more research on the use of color in visualization than any other perceptual issue. Nevertheless, the important lessons are relatively few, and we summarize them here.

- To show detail in a visualization, *always* have considerable luminance contrast between foreground and background information. Never make the difference only through chromatic variation. This should be obvious in the case of text, although many PowerPoint presentations still violate this rule. It also applies to such problems as the visual display of flow fields, where small color-coded arrows or particle traces are used.
- Use only a few colors if they are distinct codes. It is easy to select six distinct colors, but if 10 are needed they must be chosen with care. If the background is varied, then attempting to use more than 12 colors as codes is likely to result in failure.
- Black or white borders around colored symbols can help make them distinct by ensuring a luminance contrast break with surrounding colors.
- Red, green, yellow, and blue are hard-wired into the brain as primaries. If it is necessary to remember a color coding, these colors are the first that should be considered.
- When color-coding large areas, use muted colors, especially if colored symbols are to be superimposed.
- Small color-coded objects should be given high-saturation colors.
- When a perceptually meaningful ordering is needed, use a sequence that varies monotonically on at least one of the opponent color channels. Examples are red to green, yellow to blue, low saturation to high saturation, and dark to light. Variation on more than one channel is often better, such as pale yellow to dark blue.
- If it is important to show variations above and below zero, use a neutral value to represent zero and use increases in saturation toward opposite colors to show positive and negative values.
- Color contrast can cause large errors in the representation of quantity. Contrast errors can be reduced with borders around selected areas, or by using muted, relatively uniform backgrounds.
- For the reproduction of smooth color sequences, several million colors are needed under optimal viewing conditions. In this case, care must be taken to calibrate the monitor and to take into account monitor gamma values.

- When reproducing complex, continuously shaded images, it is critical to preserve the color relationships and to make sure that, under the particular lighting conditions, neutral values are perceived as neutral.
- Beware of oversaturating colors, especially when a printed image is to be the end product.

It is impossible to keep a discussion of color entirely segregated in one chapter. Color affects every aspect of visualization and is mentioned in many other chapters, especially Chapter 5, which places color in the context of other methods for coding information.