10.4 Other Channels

While the previously discussed channels pertaining to position and color are highly salient, other visual channels are also an important part of the visual encoding design space. Other magnitude visual channels include the size channels of length, area, and volume; the angle/orientation/tilt channel; and curvature. Other identity channels are shape and motion. Textures and stippling use combinations of multiple channels.

10.4.1 Size Channels

Size is a magnitude channel suitable for ordered data. It interacts with most other channels: when marks are too small, encodings in another channel such as shape or orientation simply cannot be seen. Size interacts particularly strongly with color hue and color saturation.

Length is one-dimensional (1D) size; more specifically, height is vertical size and width is horizontal size. Area is two-dimensional (2D) size, and volume is three-dimensional (3D) size. The accuracy of our perceptual judgements across these three channels varies considerably.

Our judgements of length are extremely accurate. Length judgements are very similar to unaligned planar position judgements: the only channel that is more accurate is aligned planar position.

In contrast, our judgement of area is significantly less accurate. Stevens assigns a power law exponent of 0.7 for area, as shown in Figure 5.7. The area channel is in the midde of the rankings, below angle but above 3D depth.

The volume channel is quite inaccurate. The volume channel is at the bottom of the rankings, in an equivalence class with curvature. Encoding with volume is rarely the right choice.

A larger-dimensional size coding clearly subsumes a smaller-dimensional one: length and area cannot be simultaneously used to encode different dimensions. Similarly, the combination of smaller-dimensional sizes is usually integral rather than separable, as illustrated in Figure 5.10 where the combination of small width, large width, small height, and large height yielded three groups rather than four: small areas, large areas, and flattened areas. It is possible that people asked to make area judgements might take the shortcut of simply making length judgements.

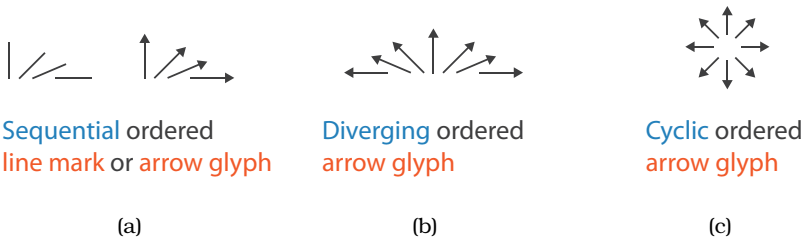


Figure 10.14. Tiltmaps using the angle channel to show three different types of ordered data. (a) A sequential attribute can be shown with either a line mark or an arrow glyph in one quadrant. (b) A diverging attribute can be shown with two quadrants and an arrow glyph. (c) A cyclic attribute can be shown with all four quadrants and arrow glyphs.

10.4.2 Angle Channel

The *angle* channel encodes magnitude information based on the **orientation** of a mark: the direction that it points. There are two slightly different ways to consider orientation that are essentially the same channel. With **angle**, the orientation of one line is judged with respect to another line. With **tilt**, an orientation is judged against the global frame of the display.* While this channel is somewhat less accurate than length and position, it is more accurate than area, the next channel down on the effectiveness ranking.

★ The terms *angle*, *tilt*, and **orientation** are often used as synonyms.

Angles can act as a sequential channel within a single $90°$ quadrant, as shown in Figure 10.14(a). However, as shown in Figure 10.14(c), an angle also has cyclic properties: a mark returns to its starting position after it swings all the way around. A simple line mark cycles four times when swinging around a full circle of $360°$. A more complex shape like an arrow, where the top can be distinguished from the bottom, cycles once for each full circle turn. Tilting an arrow glyph through a half-circle range of $180°$ yields a diverging **tiltmap**, as shown in Figure 10.14(b), where the central vertical position acts like the central neutral color that is the zero point in a diverging colormap, lying between orientations to the left or right.

The accuracy of our perception of angle is not uniform. We have very accurate perceptions of angles near the exact horizontal, vertical, or diagonal positions, but accuracy drops off in between them. We can tell 89° from 90°, 44° from 45°, and 1° from 0°; however, we cannot tell 37° from 38°.

10.4.3 Curvature Channel

The **curvature** channel is not very accurate, and it can only be used with line marks. It cannot be used with point marks that have no length, or area marks because their shape is fully constrained. The number of distinguishable bins for this channel is low, probably around two or three; it is in an equivalence class with volume (3D size) at the bottom of the magnitude channel ranking.

10.4.4 Shape Channel

The term **shape** is a catch-all word for a complex perceptual phenomenon. Vision scientists have identified many lower-level features that we can preattentively identify, including closure, curvature, termination, intersection, and others. For the purposes of analyzing visual encoding with marks and channels, I simplify by considering shape as a identity channel that can be used with point and line marks. Applying shape to point marks is the common case, and is easy to understand. Applying the shape channel to line marks results in stipple patterns such as dotted and dashed lines, as discussed below. The shape channel cannot be applied to area marks because their shape is constrained by definition.

If the point size is sufficiently large, the number of discriminable bins for the shape channel is dozens or even hundreds. However, there is a strong interaction between shape and size. When the region in which the shape must be drawn is small, then far fewer discriminable bins exist. For example, given a limit of 10×10 pixels, with careful design it might be possible to create roughly a dozen distinguishable shapes.

Shape can interfere with other channels in the same way that size coding does, and it can interfere with size coding itself. For example, filled-in shapes like disks are a good substrate for also encoding with color hue. Sparse line-oriented marks like crosses have fewer pixels available for color coding, so that channel will be impaired.

10.4.5 Motion Channels

Several kinds of **motion** are also visual channels, including **direction** of motion, **velocity** of motion, and flicker **frequency**. In order to use motion for visual encoding given a fixed spatial layout, the typical motion is a cyclic pattern where items somehow oscillate around their current location, so that they do not move outside

the viewpoint, as would occur if they just continued to move in a single direction.

Motion is less studied than the other visual channels, but some results are known already. Motion is extremely salient, and moreover motion is very separable from all other static channels. In particular, it is strongly separable from the highly ranked channels typically used for showing groups and categories, such as color and spatial position.

The strength and weakness of motion is that it strongly draws attention; it is nearly impossible to ignore. The idea behind using separable channels for visual encoding is that the viewer can selectively attend to any of the channels; however, directing attention selectively to the nonmoving channels may be difficult when motion is used. Flicker and blinking are so difficult to ignore that they can be very annoying and should only be used with great care.

It is not clear whether different motion channels are separable from each other, or how many discriminable bins exist in each. A safe strategy with motion is to create a single combined motion channel and use it for a binary category of just two levels: items that move versus items that don't move. Thus, although an individual motion subchannel such as velocity could in theory act as a magnitude channel, I simplify the complex situation by classifying motion as a identity channel, much like shape.

The motion channels are most appropriate for highlighting, where drawing the user's attention away from the rest of the scene is exactly the goal, particularly when the highlighting is transitory rather than ongoing. Temporary highlighting is often used with lightweight actions such as mouseover or clicking, as opposed to more heavyweight actions such as using search, where a text string is typed into a control panel. Many uses of highlighting are indeed binary, where the selected items just need to be distinguished from the nonselected ones. Even blinking could be appropriate in cases where very strong emphasis is desired, for example with dynamic layouts where new items at multiple locations have just been added to the view in a single timestep.

► Section 11.4.2 covers highlighting.

10.4.6 Texture and Stippling

The term **texture** refers to very small-scale patterns. Texture is also a complex perceptual phenomenon that can be simplified by considering it as the combination of three perceptual dimensions: orientation, scale, and contrast. The first two pertain to the individual texture elements and have obvious mappings to the angle

and size channels, respectively. Contrast refers to luminance contrast, which is related to the *density* of the texture elements; it maps to the luminance channel.

Texture can be used to show categorical attributes, in which case the goal is to create patterns that are distinguishable from each other using the combination of all three channels. In this case, with sufficient care it is possible to create at least one or two dozen distingishable bins.

Texture can also be used to show ordered attributes, for example, by mapping separate attributes to each of the three channels. In this case, no more than three or four bins can be distinguished for each. Another possibility is to use all three channels in combination to encode more bins of a single attribute; with careful design, around a dozen bins can be distinguishable.

The term **stippling** means to fill in regions of drawing with short strokes. It is a special case of texture. Stippling is still in regular use for lines; a familiar example is the use of dotted or dashed lines. Stippling was heavily used for area marks with older printing technology because it allows shades of gray to be approximated using only black ink; now that color and grayscale printing are cheap and pervasive, area stippling is less popular than in the past.*

★ The terms **hatching** and **cross-hatching** are synonyms for *stippling* in two-dimensional areas.

10.5 Further Reading

The Big Picture Ware's textbook is an excellent resource for further detail on all of the channels covered in this chapter [Ware 13].

Color Theory Stone's brief article [Stone 10] and longer book [Stone 03] are an excellent introduction to color.

Colormap Design The design of segmented colormaps has been extensively discussed in the cartographic literature: Brewer offers very readable color use guidelines [Brewer 99] derived from that community, in conjunction with the very useful ColorBrewer tool at http://www.colorbrewer2.org. Early guidelines on quantitative colormap creation and the reasons to avoid rainbow colormaps are in series of papers [Bergman et al. 95, Rogowitz and Treinish 96, Rogowitz and Treinish 98], with more recent work continuing the struggle against rainbows as a default [Borland and Taylor 07]. An empirical study of bivariate colormaps showed their serious limitations for encoding two categorical attributes [Wainer and Francolini 80].