



Figure 1. Harry Beck's map of the London Underground from 1933. Beck straightened the lines and more evenly spaced the stops to visually emphasize the sequence of stops along each line.

communicative intent of visualizations by carefully applying principles of good design. These principles explain how visual techniques can be used to either emphasize important information or de-emphasize irrelevant details; for example, the most important information in a subway map is the sequence of stops along each line and the transfer stops that allow riders to change lines. Most subway passengers do not need to know the true geographic path of each line. Based on this insight, map designer Harry Beck redesigned the map of the London Underground in 1933 using two main principles: straightening the subway lines and evenly spacing

the stops to visually emphasize the sequence of stops and transfer points (see Figure 1).

Such design principles connect the visual design of a visualization with the viewer's perception and cognition of the underlying information the visualization is meant to convey. In the field of design, there is a long-standing debate regarding the interaction of aesthetic and functional properties of designed artifacts. We do not seek to engage in this debate here; rather, we focus on how particular design choices affect the perception and cognition of the visualization, not the aesthetic style of the visualization. Accordingly, we use the term “design principle” as

a shorthand for guidelines that help improve viewers' comprehension of visually encoded information.

Design principles are usually not strict rules, but rules of thumb that might even oppose and contradict one another. For instance, Beck did not completely straighten the subway lines; he included a few turns in them to give viewers a sense of a line's overall spatial layout. Skilled visual designers implicitly apply the relevant design principles and balance the trade-offs between them in an iterative process of creating example designs, critiquing the examples, and improving the designs based on the critiques. Designers usually do not directly apply an explicitly defined set of design principles. The principles are a form of tacit knowledge that designers learn by creating and studying examples. It is far more common for books on visual design to contain visual examples rather than explicit design principles.

Many of the analysts and end users inundated with data and charged with creating visualizations are not trained designers. Thus, our work aims to identify domain-specific design principles, instantiating them within automated visualization design systems that enable non-designers to create effective visual displays. While other researchers have considered specific ways to use cognitive design principles to generate visualizations (see the online appendix) we have been developing a general, three-stage approach for creating visualization design systems:

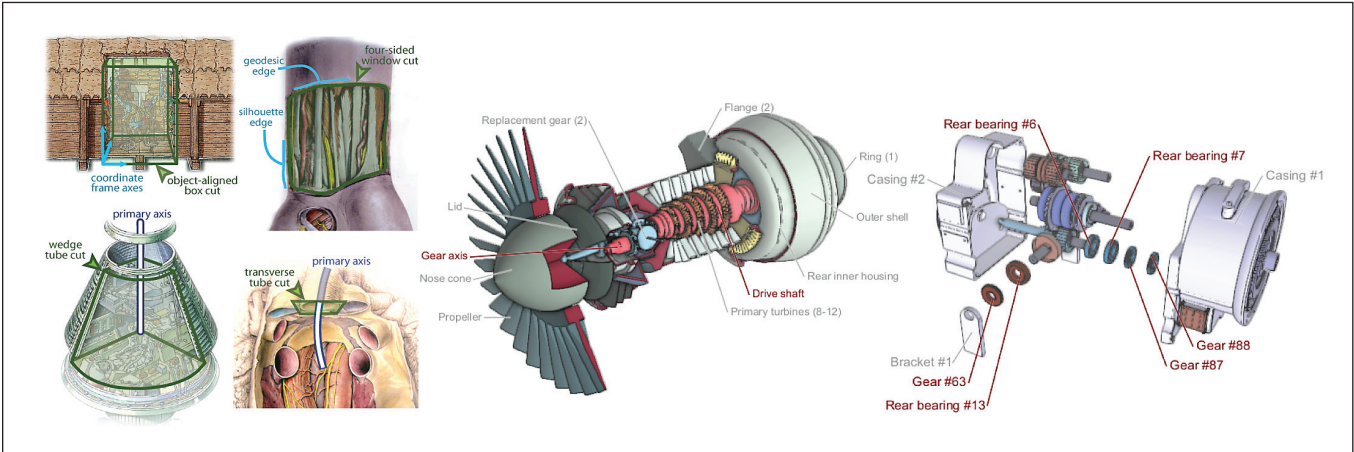


Figure 2. Hand-designed cutaway and exploded-view illustrations (left) design the cuts and explosions to emphasize the shape of the missing geometry and spatial relationships among parts. Our system incorporates such principles to generate interactive cutaway and exploded-view illustrations (middle, right).