Visualization Viewpoints

Editor:
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From Abstract Painting to Information Visualization

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The well-established theory and techniques in abstract painting and practice can benefit information visualization—even though the two fields have significantly different objectives. This comparison reflects the spirit of aesthetic computing, a concept that could establish a new discipline on the convergence of art, science, and technology. Fishwick defines *aesthetic computing* as the application of aesthetics to computing.[1] As Healey argues, aesthetically pleasing displays would visually engage and motivate the viewer.[2] The objectives of symmetry and minimal crossing in graph drawing and various metaphoric representations of information in information visualization provide evidence of this. In addition to aesthetics, many principles applied to painting can act as the guideline for effective information visualization.

Abstract, from an art history perspective, typically refers to form and does not usually address color and texture. Art literature sometimes uses the term *nonobjective* in place of abstract to be more indicative of what abstract painting is really about. Abstract (or nonobjective or nonrepresentational) art is the art—which includes painting, sculpture, and graphic art—that does not represent recognizable objects (according to *Merriam-Webster's Collegiate Encyclopedia*). I will focus mainly on abstract painting in this article.

Information visualization

> … combines aspects of scientific visualization, human–computer interfaces, data mining, imaging, and graphics. In contrast to scientific visualization, which focuses on data, information visualization focuses on information, which is often abstract. Information in many cases does not automatically map to the physical world. This fundamental difference means that many interesting classes of information have no natural and obvious physical representation. A key research problem then is to discover new visual metaphors for representing information and to understand what analysis tasks they support.[3]

We can, therefore, observe a common characteristic of the two fields: they are both abstract and nonrepresentational.

Form, color, and texture

Paintings can be discussed in terms of three dimensions: form consisting of points, lines, and planes; color; and texture determined by the paint and painting surface.[4] Form has been traditionally singled out as the dimension that determines if a painting is objective or nonobjective. It therefore deserves more discussion than the other two dimensions. The three dimensions correspond well to information visualization and to visualization in general.

Form

Form relates to visual elements, such as point, line, and plane including its contour and shape, from one to three dimensions. In the context of visualization, we can consider form in a broader sense, determining the visual formalism used to convey information, such as diagrams, charts, and maps that consist of points, lines, and planes.

According to the pioneer abstract artist and art theorist Kandinsky, "the point digs itself into the plane and asserts itself for all time. Thus it presents the briefest constant, innermost assertion: short, fixed and quickly created."[5] As the most primal form, a point represents a location and a presence. Its realm is limitless.

A line in painting is typically understood as either an edge or a solid object. Kandinsky classifies straight lines into three types in terms of temperature: horizontal representing a cold and flat support on which humans stand and move; vertical representing an infinite, warm possibility of movement; and diagonal with an equal combination of cold and warm. All other straight lines are variations of the diagonal. He analyzes how forces apply to straight, zigzag, and curved lines, and concludes that the straight line to zigzag to curve symbolizes birth to youth to maturity (see Figure 1).

Relating lines to time, Kandinsky states "… the course of a straight line is, temporarily speaking, different from that of a curve, even if they are of the same length, and the more agitated a curved line is, the greater is its extension in time."[5]

A plane is determined by its location, size, and shape, and thus can be more complex than a point or a line. It plays a key role in composition and also empowers color and texture for rendering unlimited image effects. For example, shapes can imply orientations, and symmetrical shapes—such as circles and squares—suggest stability. Interpreting the interaction of forms within and with the plane using force, can give further insight into the principle for constructing an abstract painting. Kandinsky concludes the following as a general rule: a form approaches the edge of the plane, its tension

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increases until, at the moment of contact with the border, the tension suddenly disappears.[5]

These principles might help in guiding the design of aesthetic as well as meaningful information visualization systems. In computer graphics and visualization, a point can have color, shape, and size, conveying a useful meaning or semantics. Various line styles (for example, dotted, dashed, and patterned) simulate paint brushstrokes. Apart from an edge or solid object, other possible semantics can be given to a line in information visualization—such as a connection link or a quantitative trend. Depending upon the method of rendering and application, a straight line can suggest speed, direction, and tension; a curved line appears to have more freedom.

Applying force to graph elements can generate visually pleasing layouts. Numerous applications of the force-directed spring algorithm in information visualization give evidence to this. Figure 2 illustrates a result of the spring algorithm. Another useful feature of the spring algorithm is its stepwise application of forces that enables an intuitive animation of the gradual layout process, maintaining the viewer's mental map. Interestingly, such an animation is usually stable when the graph touches the display border.

Proper use and manipulation of planes can simulate a high-dimensional space and convey sophisticated information. Many industrial and architectural designs have successfully used such display power.

Color

Abstract artists use color as one of their most essential means of conveying ideas. The art community and, to a lesser extent, the computer graphics field have studied various color theories. For example, the Munsell color system specifies colors in three dimensions—hue, value, and chroma—and suggests how to make balanced and harmonious color combinations.[6] Some abstract artists tend to choose colors for their psychological impact—for example, purple to convey horror, pink for joy, and green for envy. Kandinsky calls black the symbol of death and white that of birth. He also systematically associates colors with lines and basic geometric shapes. Media research provides other colors' emotional connotations, for example, lime green and avocado indicating nausea, yellow combined with black implying a warning and sometimes power, and blue representing the most likable color.

In visualization, color can encode additional data attributes, using human color perception. The following example demonstrates that information visualization can usefully apply our commonly understood color use in painting. To assist the general public who are typically used to the color concepts in painting, Gossett and Chen proposed using subtractive color space with red, yellow, and blue as primary colors for visualizing multiattribute information.[7] For example, to visualize the presence of three populations (traits) in a state with one color representing each trait, the RGB map in Figure 3a (next page) displays Arizona as white due to the presence of all the three traits in the state. Common sense would then suggest that white implies the absence of any trait. In contrast, the RYB map in Figure 3b displays a more meaningful brown color for Arizona.

Texture

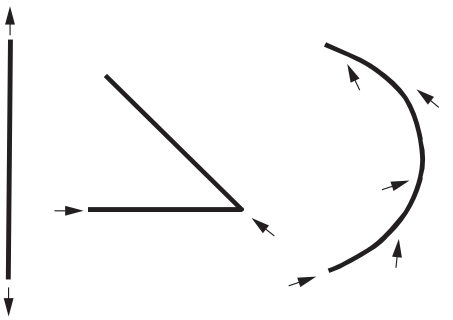
In painting, texture relates to the paints and the receiving surface, whose combined uses create various visual effects. With limited variations, raster can be manipulated to model texture effects. For example, Healey and Enns show the effect of brushstrokes typically used in oil painting for visualization of weather conditions.[2] A traditional weather map and its painterly simulated counterpart are displayed in Figures 4a and 4b. Table 1 illustrates the color schemes and brushstrokes that Healey and Enns used to encode different weather attributes. In Healey and Enns, viewers preferred the painterly visualization (see Figure 4b) for the majority of the tested tasks.[2]

Visual cognition

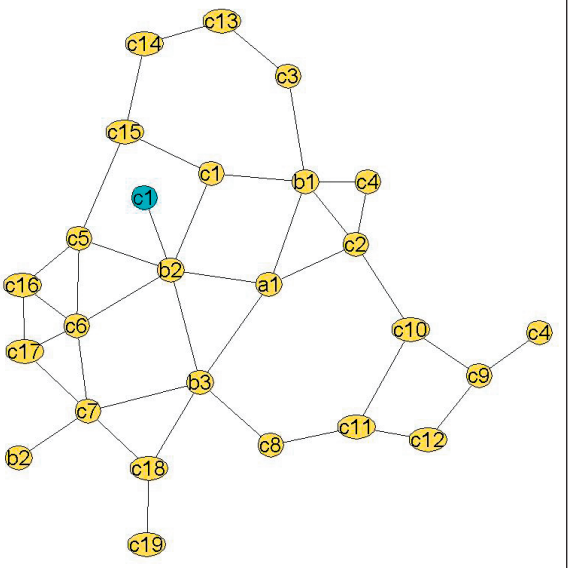
As with painting in general and abstract painting in particular, it's highly desirable for visualization designers to learn visual psychology and physiology, so that they can use the body's visual mechanisms effectively when organizing visual data. Useful approaches include visual grouping, object recognition, and depth perception.

Visual grouping

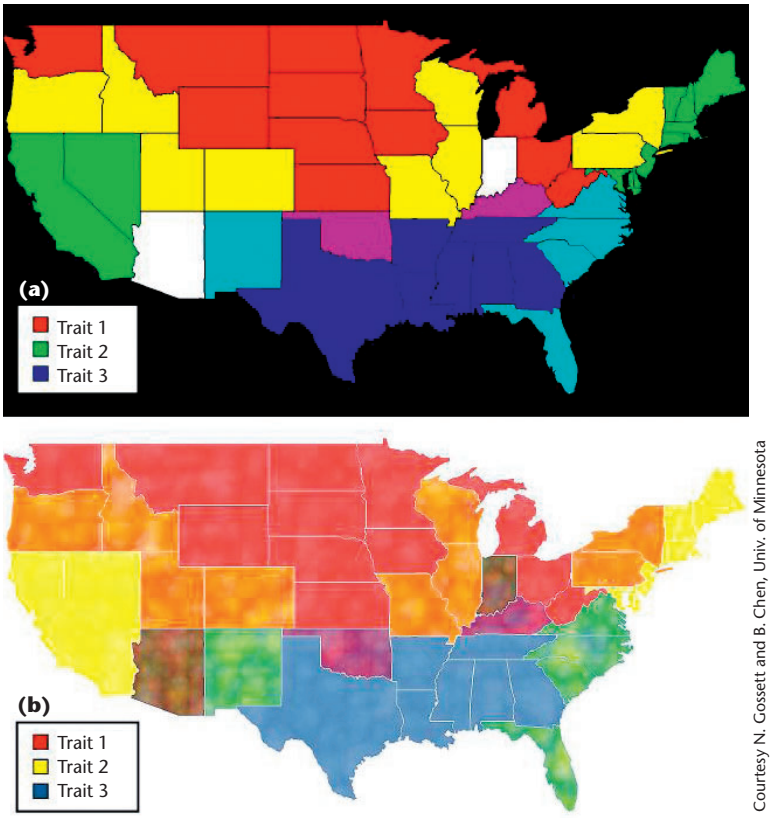
The focus of Gestalt theory is the idea of grouping, that is, characteristics of stimuli cause us to structure or interpret a visual field or problem in a certain way.



1 Forces in straight, zigzag, and curved lines.

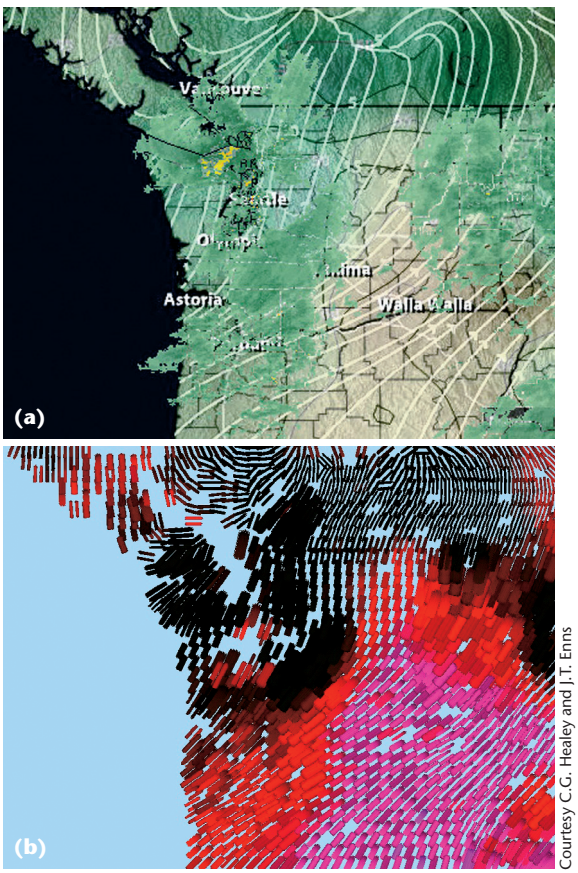


2 Force-directed graph layout.



Courtesy N. Gossett and B. Chen, Univ. of Minnesota

3 Using (a) RGB and (b) RYB to represent three population traits.[7]



Courtesy C.G. Healey and J.T. Enns

4 Weather conditions on a (a) traditional weather map and (b) simulated by brush strokes.[2]

The primary factors that determine grouping are the following:

- *Proximity.* Elements tend to be grouped together according to their nearness. For example, we perceive two columns of dots on the left and four groups of dot pairs on the right of Figure 5a.
- *Similarity.* Items similar in some respect tend to be grouped together. For example, we perceive Figure 5b as three columns rather than four rows, even though the horizontal gap is greater than the vertical gap.
- *Closure.* Items are grouped together if they tend to complete some entity. For example, we perceive Figure 5c as a triangle rather than a line.
- *Continuity.* Objects along a line are grouped. For example, we tend to view Figure 5d as two lines rather than scattered dots.
- *Simplicity.* Items are organized into simple figures according to symmetry, regularity, and smoothness.

These factors are called *the laws of organization*, and the perception and problem-solving contexts of Gestalt theory help to explain them. Data grouping, or data clustering, is one of the most important processes in visual data mining and information visualization.

Another organizing principle is our natural tendency of recognizing symmetry, particularly vertical and horizontal symmetry. We usually prefer symmetrical to asymmetrical forms.

Object recognition

Painters manipulate the viewer's attention to make a specific part of a painting perceived as the object of interest, while other areas are seen as background. In visualization, it is also critically important to be able to highlight the areas from which useful information or knowledge can be quickly obtained. Hyperbolic and fisheye views are the examples of such attempts.

Depth perception

Science has shown that depth perception is one of the elemental ways humans perceive order out of visual stimuli. Both painting and visualization involve techniques in fooling the human mind into seeing depth on a 2D surface. Three-dimensional visualizations use the perspective principle, with techniques such as rotation, change of viewpoint, and animation. Specifically, artists and visualization designers use the following techniques to suggest depth of view:

- *Relative size.* When one object is larger than another, the larger one appears closer.
- *Overlapping.* Space and specifically depth are suggested by overlapping one object on top of another.
- *Textual gradient.* Coarser textures are perceived more distant than finer textures. In visualization, this relates to granularity of visual elements. Sharp and well-defined contours, edges, and hues are perceived as being closer, while hazy, soft colors and contours are perceived as distant.

Table 1. Color and brushstroke encoding of weather attributes.

Color/Stroke Encoding	Traditional Map	Painterly Visualization
Temperature	High: yellow Low: green	High: bright pink Low: dark green
Pressure	High: bright Low: dark	High: dense Low: sparse
Wind direction	Contour direction	Stroke orientation
Precipitation	Radar trace	Stroke size

- *Linear perceptive.* Developed during the Renaissance, this is the perception that parallel lines recede in space and meet at one or more vanishing points along a horizon. Painting, computer graphics, and 3D visualization have used this principle.

Composition

Combining all the elements of form, color, and texture, composition represents the entire visual architecture of a painting or a visualization display. Useful principles for composition include the following:

- The visualization viewer should be encouraged to discover the underlying nature of a topic or problem (that is, the relationship among the visual elements).
- Gaps, incongruities, or disturbances are important stimuli for learning.
- Instruction should be based upon the laws of organization: proximity, closure, similarity, and simplicity.

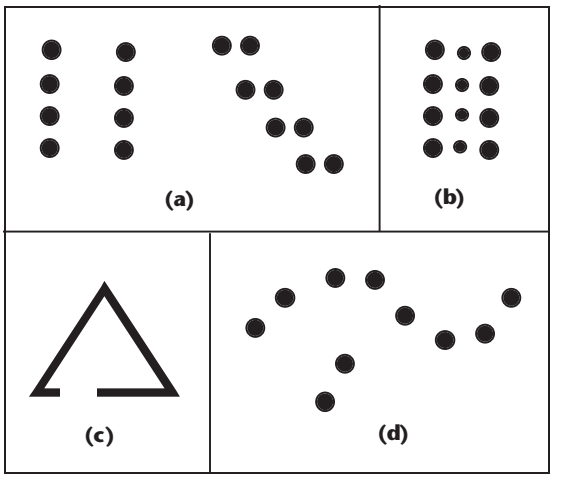
Applied among shapes and implied in space partitioning, the principles would enhance the effectiveness of information comprehension.

Shapes

In abstract painting, circles and rectangles are the simplest primary objects and tools for a composition. They give a sense of stability. Kandinsky claims that the circle is the most peaceful shape and represents the human soul.[5] For example, circles and rectangles are also the primary objects in many of the late British artist Ben Nicholson's compositional paintings, most notably *White Relief* and *Painted Relief*.

There is a close relation between abstract painting and modern Chinese calligraphy. Picasso said in his later years that, if he had been Chinese, he would have been a calligrapher. Visual composition plays a vital role in modern Chinese calligraphy. In comparison with painting, calligraphy attracts attention more by its form rather than by its colors. One of the best-known and pioneering modern Chinese calligraphers, Gu, has created many masterpieces characterized with squares and circles. One example is his work of five characters for "every day is a nice day."[8] Of the five characters, there are four for "day," making it difficult to compose since repetition is undesirable in Chinese calligraphy. Using circle and rectangle shapes, the five characters can be composed harmoniously.

Circles and rectangles have been the most popular shapes in information visualization. They are, however, primarily used independently as different visual formalisms or glyphs without a harmonious integration into each other.



5 Examples of visual grouping.

Space partitioning

Dividing the paint area into balanced rectangular forms creates visually pleasing compositions. Piet Mondrian is best known for his nonrepresentational paintings that he called *compositions*. Such a painting consists of rectangular forms of red, yellow, blue, or black, separated by thick, black rectilinear lines, making a beautiful composition.

Skog, Ljungblad, and Holmequist attempted Mondrian-inspired visualization with the weather visualization in Figure 6 (next page).[9] The squares encode cities with their relative locations, the size of a square encodes the temperature, and color encodes weather conditions. Having installed the weather visualization (and bus traffic visualization using similar techniques) for real use and having obtained user feedback, Skog and colleagues gained useful experience. They concluded that aesthetics can almost be considered an added bonus, or at least a by-product when striving for readability and effectiveness.

Rectangular division with symmetry and balance is also a critical aesthetic requirement for an abstract painting and calligraphy. The contemporary abstract artist Pete Hubbard (see http://www.petehubbard.com/theory.php) proposes the grid theory in determining where to put objects on the canvas with the 4:3 or golden ratio to make visually pleasing compositions.

For instance, with the 4:3 ratio, a grid structure can be drawn in pencil or even explicitly emphasized with color as the background. The foreground can then be drawn with objects in harmonious proportion.

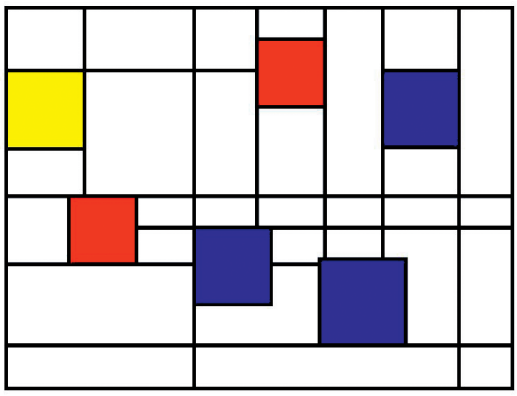
Information visualization has applied aesthetic space partitioning, particularly for visualizing hierarchical tree structures, such as tree-map, space-filling, and rectangle-packing algorithms.

As an example of hierarchical information visualization based on tree maps, Figure 7 shows a Web site mapping of the entire University of Texas at Dallas at its top five levels (approximately 8,115 pages), which users can navigate within the context and with a focus view. This visualization provides an informative abstract view of the site and the interrelationships among its pages. Intermediate pages are organized in nested rectangles. Thus, a Web administrator can easily identify the site's structural behavior. For example, this visualization immediately shows that the page "search" at the bottom-left contains the largest numbers of subpages.

Conclusions

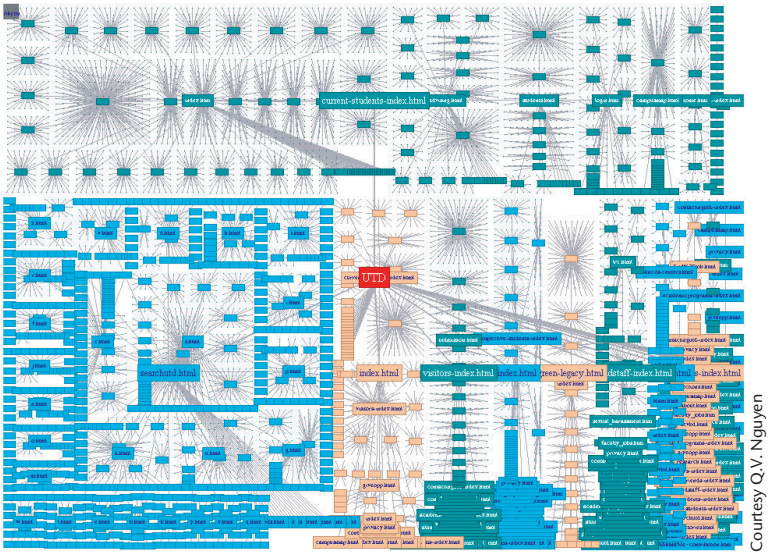
Information visualization as a discipline can benefit from the techniques successfully used in art and science disciplines. Tufte provides a comprehensive examination of this idea and states that "to envision information—and what bright and splendid visions can result—is to work at the intersection of image, word, number, art."[10]

Here, I've attempted to bridge abstract painting with information visualization, so that the latter could learn from the former in creating more aesthetic visualizations and thus making the viewer's visualizing process a pleasant experience. To conclude, I cite an interesting lesson learned by Skog, Ljungblad, and Holmequist: "basing a visualization on an artistic style need not hinder—and might even support—the readability and comprehension of [an] ambient infovis installation."[9] ■



Courtesy T. Skog

6 Weather visualization for six world cities.[9]



Courtesy Q.V. Nguyen

7 An example of visualizing the entire University of Texas at Dallas' Web site map.

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