Op-Glyph: A Tool for Exploring Op Art Representation of Height and Vector Field Data

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ABSTRACT

We report our experiences with application of the optical art techniques of Victor Vasarely and Bridget Riley to visualization of height field and vector field data. The bold use of color and simple form in Op Art engages the preattentive processing ability of the human visual system, facilitating a nearly instantaneous perception of image properties without the need for extended scrutiny of component parts. A software system called Op-Glyph was constructed to illustrate the Op Art method for data visualization, providing a user with extensive control over a visual representation's primitives, including shape, size, and color. Initial results suggest that this glyph-based approach to data visualization may be a viable alternative or complement to more complex representation schemes, particularly in situations where there are limited processing or graphical capabilities, such as with PDAs.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *screen design*. I.3.8 [**Computer Graphics**]: Applications.

General Terms

Human Factors.

Keywords

Information visualization, glyph, optical art, non-photorealistic rendering.

1. INTRODUCTION

The optical artists Victor Vasarely [10] and Bridget Riley [1] are noted for their abstract imagery composed of boldly rendered simple shapes. Whether reproduced in a catalogue, installed as an architectural mural, or exhibited in an art gallery, these images maintain their visual integrity and strong communication ability, despite mammoth changes in scale. This concept of optical scalability may be leveraged for creating visualizations that are interpreted on computer displays at the visual extremes from low resolution PDAs to video walls. Thus, the purpose of this research was to investigate optical art methods for the display of height field and vector field data. During the course of this research, a program called Op-Glyph was created that allows a user to quickly explore a wide variety of optical art representations of visualization data.

The next section contains the background to this research. A description of Op-Glyph's capabilities is given in Section 3. Discussion of results follows in Section 4. Finally, Section 5 presents suggestions for future work.

2. BACKGROUND

The goal of optical art (Op art) is to invoke an instantaneous response from the viewer [16]. It does so by playing into two perceptual processes: preattention and Gestalt. Preattentive processing is a low-level component of the visual system that detects visual elements without the need to focus attention. Gestalt is German for form, and refers to the visual systems innate ability to perceive multiple objects as a group [19].

Gestalt perceptual cues are proximity, similarity, and good figure. Objects that satisfy the proximity cue are near to one another, and tend to form a group. Similar things tend to group and thus stimulate the similarity cue. Good figure is a cue that allows prediction of a total entity with a minimum amount of information stimuli. Goodness means that a visual entity is perceived as complete, its elements share a common fate, or are related by symmetry. Figure 1 shows an image in the style of Victor Vasarely that demonstrates the Gestalt principles. Clusters of parallelograms and rotated squares are perceived as entities apart from the uniform grid of squares because similar objects in close proximity are discernable as rectangular shapes.

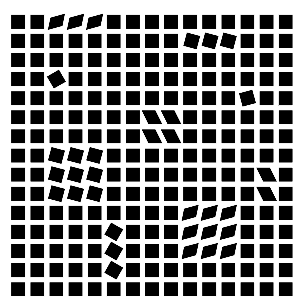

Figure 1. Image in the style of Victor Vasarely

Healy and coworkers take this visualization process one step further by testing whether image recognition can be performed preattentively, in less than 200ms. This is the time required for a single glance, in which the visual system can not change its focus of attention [6]. Preattentive cues are visually unique features such as color or shape that segment an image into perceptual groups. For example, Figure 2a shows an image of a grid of oriented square glyphs. Because there is no unique feature with which to segment the image, the perceptual system consolidates the glyphs into arcs. Figure 2b shows black and white used to segment this image. The boundary that materializes on a portion of the mathematical surface represents where the surface's positive (white) region transitions into its negative (black) region. As a result, the region of nodal transition is observed. A similar result could have been effected by using two different glyphs.

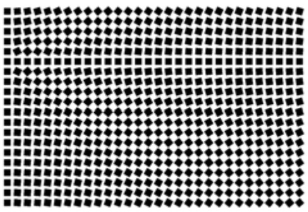

Figure 2a Single glyph representation of height field.

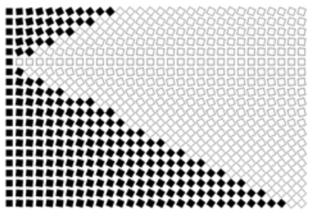

Figure 2b Figure 2a augmented with two shades.

Visual features that have been shown to be preattentively processed are hue, orientation, intensity, size, curvature, and line length. Healy and coworkers have built a visualization tool to demonstrate that preattentive processing is particularly useful for multivariate data analysis of static images and real-time display. They have found that simple glyphs augmented with color facilitate rapid and accurate detection of boundaries, assessment of shape, and quantitative estimation [6].

The research findings of these authors' may be applied naturally to visualization of height field and vector data. In particular, their concepts combined with the design principles of Op art are useful for the representation of low-density height field data displayed on tiny low-resolution, less powerful PDAs. Moreover, the move toward distributed collaborative visualization environments in which PDAs are growing in importance [2, 13, 15], creates opportunities for alternative artistic representations.

Artistic approaches to information visualization have recently appeared. Healy, et al have summarized much of the work in the SIGGRAPH 2001 Course Notes [8]. Researchers have applied expressive (or non-photorealistic) rendering methods [5] such as impressionistic painting and line drawing to visualize surfaces [9], volumes [18], and flow fields [11].

Use of glyphs for multivariate display continues to be an area of active research [3, 4, 12, 17, 20]. 2D and 3D glyphs have been applied to analysis of scanning electron microscope images [20], hydrodynamic simulations [3], document analysis [4], and automobile development [12]. Healey has taken a painterly approach to glyph representations of multivariate data with an eye toward the glyphs creating a coherent image [7]. Finally, Manchester and coworkers have analyzed genomic data with a multivariate charting method they call *Vasarely Charts* [14]. Their method uses a small grid of rectangular cells, each occupied by a circular glyph. The shades of cells and glyphs vary, based on the statistical nature of the data. The resultant images look similar to some of Vasarely's artwork.

3. SOFTWARE SYSTEM

Op-Glyph was written as a Java applet. It is designed to render height field and vector field data as glyphs and solid contours. The program makes no assumptions about how data is represented. The user controls glyph-type and attributes such as size, body and edge color, and degree of shading.

The program's capabilities will be demonstrated by working through example data. All data used was sampled in two ways. Surface data were generated at a 900 x 600 pixel resolution and gridded data for glyph illustration were sampled at a resolution of 30 x 20 and rendered in patches of 30x30 pixels.

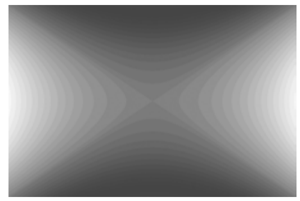

Figure 3a. $z = x^2 - y^2$ in 32 shades of gray

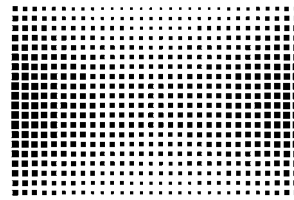

Figure 3b. Square glyph rendering scaled by surface height.

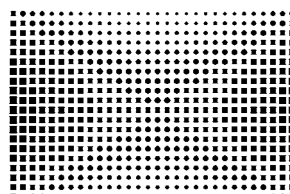

Figure 3c. Two glyph rendering scaled by height

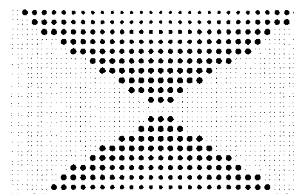

Figure 3d. Figure 3c augmented with second shade.

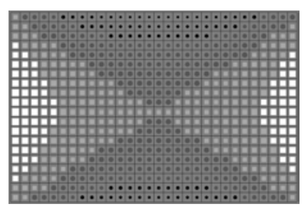

Figure 3e. Previous image rendered in four shades of gray a 50% gray background and black gridlines

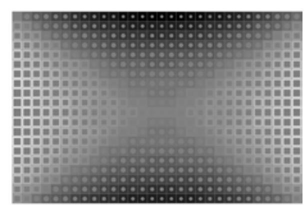

Figure 3f. Grid of 30x20 patches rendered in 32 shades of gray. Glyphs in 50% gray superimposed over surface with gray gridlines.

Figure 3a shows a color contour surface of the function $z = x^2 - y^2$ rendered in 32 shades of gray. A saddle point is clearly visible. Figure 3b shows the same function using gridded data employing a square glyph scaled over the function's height values with smallest and largest glyphs representing minima and maxima, respectively. The saddle point is obscured, but the general curvature of the surface can be sensed. A second glyph may be added to emphasize the saddle point and nodal plane transition. This is seen in Figure 3c where a circle has been used to represent data values below zero. The saddle point is now visible, but could be emphasized further by adding a second shade. Figure 3d shows positive function values rendered with white squares and negative function values with solid black circles. The two sections of the surface and saddle point are now clearly visible.

Glyph representation of a surface may be enhanced in two ways. The first is to increase the number of shades. Glyph shading is increased to four shades of gray in Figure 3e. Edge color has changed from black to 50% gray. Two lighter shades represent values above and two darker shades represent values below zero. A background of 50% gray has been added to emphasize the nodal plane. A black grid has been added as well. Surface structure begins to appear, but more shades of gray will convey a better sense of surface curvature. Figure 3f shows the surface rendered with at the grid resolution of 30x20 patches in 32 shades of gray. Superimposed upon these patches are the scaled glyphs rendered in 50% gray.

Op-Glyph allows the use of color as well (Plate 4). Two glyphs rendered in 32 shades from yellow to blue are superimposed over the height field of $z = \sin(x)\cos(y)$ rendered as shaded patches in 32 shades of gray from white to black in Plate 4a. Plate 4b shows the $z = x^2 - y^2$ surface rendered with patches in 8 shades of gray and two glyphs imaged in red and blue.

A better sense of surface curvature is communicated using oriented glyphs. Taking the first derivative of the function with respect to x and y produces two components of a vector that orients each glyph. Figure 5a shows an oriented glyph representation of the $z= x^2 - y^2$ surface rendered in black and white over a gray background. Glyph orientation gives a clear representation of surface shape. Figure 5b shows this image augmented with 16 shades of gray for the glyphs, gray outlines, and 256 shades of gray for the patches. Here, additional visual detail does not convey any substantially more important information.

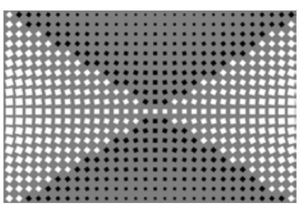

Figure 5a. Oriented square glyph rendering of $z = x^2 - y^2$ scaled by surface height. White designates positive values black negative.

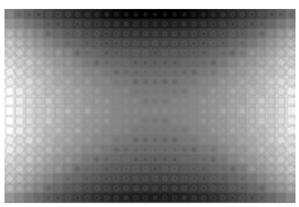

Figure 5b. Glyph representation superimposed over 256 shaded gray patches. Glyphs in 16 shades from white to black with gray edges.

Finally, vector fields are rendered employing oriented glyphs. Figure 6a shows a traditional hedgehog plot of a vector field associated with the $z = \sin(x)\cos(y)$ surface. It is rendered again in Figure 6b with a solid rectangle. The thick rectangle enhances the contrast between object and background, making recognition easier. A rectangle provides greater surface area than the hedgehog for the addition of color, as can be seen in Plate 6c. Plate 6d shows the vector field with a different glyph.

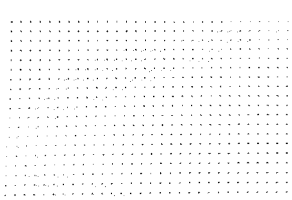

Figure 6a. Hegehog plot of $z = \sin(x)\cos(y)$.

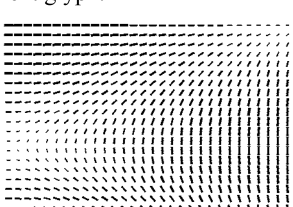

Figure 6b. Rectangular glyph plot of $z = \sin(x)\cos(y)$.

4. DISCUSSION

Op-Glyph was designed to provide a user with complete freedom to visually represent data. Visual manipulation of data, the ability to readily transform it, turn it over in the mind's eye, is an integral part of the data analysis process. Yet, complete control comes with a cost. Many images created may violate rule of color and representation, and may produce artistically garish results. For example, Plate 7a contains a reference image of a complex superposition of sine waves at 900x600 resolution rendered with a 32 shade colormap. Plate 7b shows the same function using a 30x20 grid of patches. Here the surface details are barely perceptible. Superimposing a rectangular glyph atop the surface to show its curvature creates an artistically interesting image but no structure (Plate 7c). Changing the glyph to an oriented square the same size as the patch brings out the surface structure (Plate 7d). Without the ability to manipulate the visual representation at will, the final image would not have been found.

The process of creating all images was trial-and-error: varying colormaps, edge colors, background, and patch properties. Many combinations of representations give viable visualizations. The images presented here are a small subset of a much larger sampling. Both color and black and white produce good images, but the simplicity of black and white and the fact it that maximizes luminance contrast, gives it an edge over color. In particular, Figures 3d, 5a, and 6b elicit a quick perceptual response for shape and contour recognition. The shaded images (Figures 3f and 5b) require more time to review, but are more representative of the shaded contour surface (Figure 3a). Color allows more creativity. Plate 4 shows two images with surface patches in shades of gray and glyphs in two colors. The glyphs act as textures, giving the discontinuous surface patches continuity. They also provide a binary cue for upper and lower surface features.

In conclusion, the images created by Op-Glyph give a good representation of surface shape and contour even with small data samples. And the small images rendered in few colors with simple glyphs can be readily visualized.

5. FUTURE WORK

Op-Glyph may be expanded in a number of ways. First, the simple r,g,b color model can be replaced with a perceptual color space. Second, a glyph creator-editor would allow the user complete control over creativity. Finally, Op-Glyph was not only built as an experiment to test the capabilities of glyph-based visualization of height field data, but also as a test of how well low resolution data maybe displayed. These positive results suggest that the next step be taken – porting the system to a PDA system. We are actively pursuing this extension.

6. ACKNOWLEDEGMENTS

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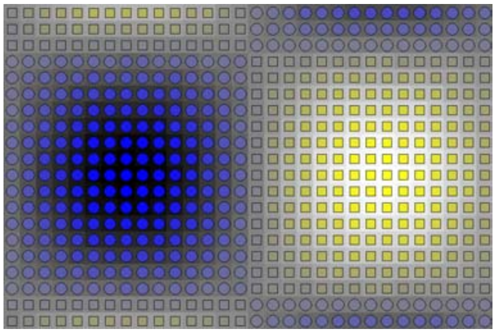

Plate 3a. ***z*** **= sin(*x*)cos(*y*) surface in two glyph scaled by height. Grid patches in 32 shades of gray. Two colors for glyphs.**

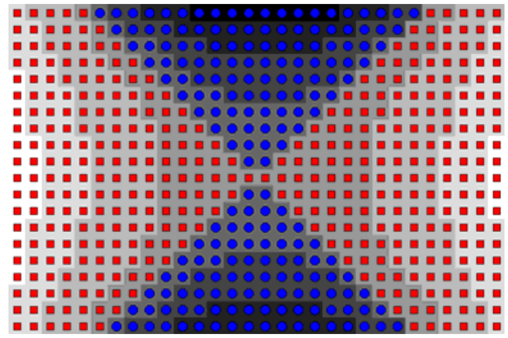

Plate 4b. Two glyph rendering of $z = x^2 - y^2$ surface Grid patches in 8 shades of gray. Two colors for glyphs.

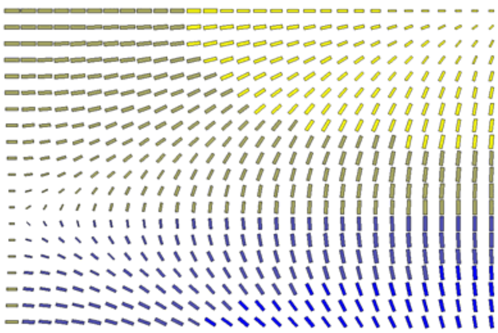

Plate 6c. Rectangular glyph plot of *z* = sin(*x*)cos(*y*). Glyphs rendered in four colors.

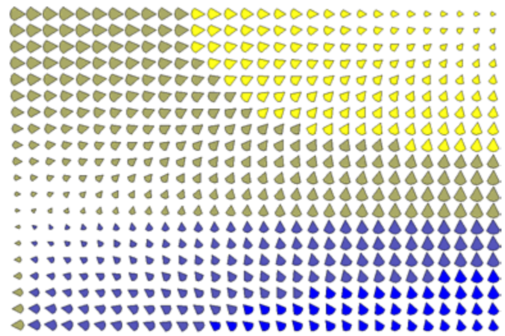

Plate 6d. Rounded arrow glyph plot of *z* = sin(*x*)cos(*y*). Glyphs rendered in four colors.

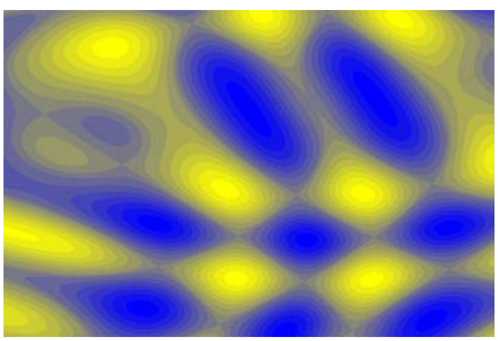

Plate 7a: Superimposed sine function with 32 color contours.

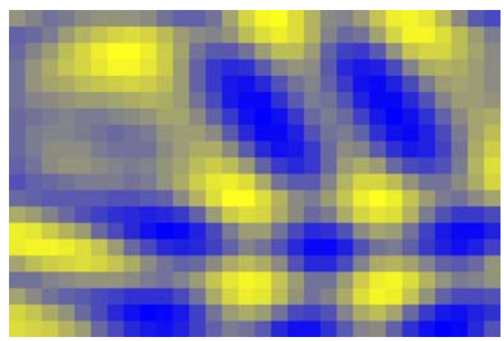

Plate 7b. 30x20 grid of patches in 32 shades.

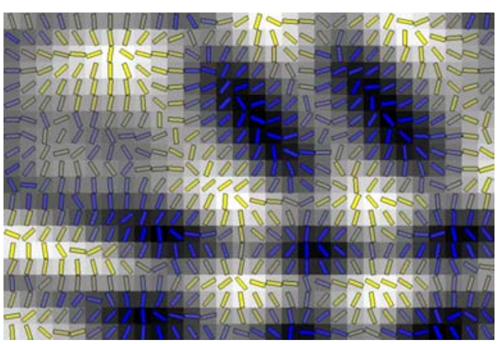

Plate 7c. 30x20 grid of patches in 32 shades from white to black; oriented rectangular glyphs in 8 shades from yellow to blue.

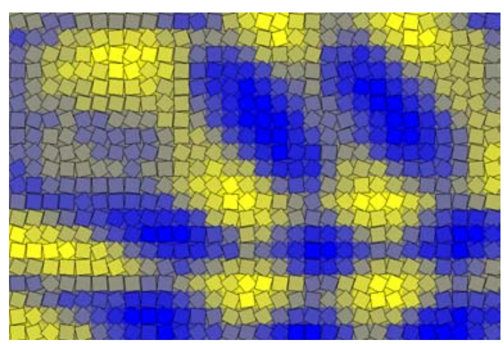

Plate 7d. 30x20 grid of patches in 32 shades from yellow to blue; oriented square glyphs in 8 shades from yellow to blue.