Perceiving semitransparent surfaces

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A model that captures how people view a multilayer 3D terrain may lead to better visualization schemes.

For medical and geographic applications, scientists often visualize multiple overlapping surfaces. These users need a technique for viewing an entire structure that still allows them to distinguish individual layers. Yet it has proved challenging to depict 3D surfaces so that distances between them can be estimated quickly and accurately. Traditional visualizations use transparent surfaces that are blended together, enabling the viewer to see all the layers. But this approach does not resolve the conflict between transparency and the ability to perceive structure and shape. Motion parallax helps people notice structure and shape but prevents them from seeing surfaces from a specific point of view. Stereoscopy provides a strong depth cue that allows very accurate distinctions in 3D space. Yet, to easily fuse stereoscopic images, people need distinct visual features, which are not present with blended transparent surfaces.

To circumvent these difficulties, visualizations may use semitransparent textures, in which only some parts of the surface are colored (see Figure 1). In common techniques like isolines, regular grids, and curvature-oriented strokes, the opaque parts on the surface allow for stereoscopic fusion. Interrante and colleagues compared the three approaches to see which was best. They found the regular grid method to be superior to transparent shading but not significantly different from curvature-oriented strokes. They hypothesized that both semitransparent techniques conveyed surface shapes equivalently well, despite their obvious visual differences. However, subjects reported that curvature-oriented strokes were more immediate and intuitive. Because their experimental design did not consider subjects’ response times, they could not measure how efficiently participants interpreted the visualizations.

To build on their work, we measured both how accurately and how efficiently subjects perceived interlayer distances. We asked participants to estimate the distance between a specific point on an opaque ground layer and an overlaid surface represented by isolines, curvature-oriented strokes, and traditional transparent shading. We employed a stereoscopic visualization system and shutter glasses for the haploscopic separation. To minimize eye discomfort, we used shaded terrain and slanted viewing angles. Subjects’ estimates of the distance between semiopaque surfaces was 70% more accurate than their estimates of those between purely transparent ones. There was no significant difference in accuracy between isolines and curvature-oriented strokes. Nonetheless, participants responded faster to curvature-oriented strokes than to isolines.

To explain these results, we developed a quantitative model of user perception. This approach may also help predict the performance of other representation schemes. We hypothesized that users visually integrate the available 3D positions and thereby come to a distance estimate. In our model, patterns on the surface guide visual attention differently, leading to alternative strategies for estimating and integrating spatial relations within...
the structure. Based on earlier work,3,4 we described this process as several attention shifts. During these shifts, interobject relations are represented as noisy values with a specific variance. By employing Bayesian inference, the visual system directs attention to locations matching a given interobject relation that is encoded in a prior step. This leads to statistical models of single, sequential assessment steps.

The time span for a single visual attention shift is well known and can be found in the literature. We can then calculate response times using the expected number of assessment steps. The model predicts a specific correlation between the density of elements in the semitransparent surfaces and response times. Currently, we are conducting follow-up experiments to measure density as an independent variable. In order to analyze the process even further we are tracking eye movement, which requires the use of an autostereoscopic display. A comparison of model predictions to experimental results will be presented at the upcoming SPIE conference on human vision and color perception.

Our work shows that semitransparent surfaces allow users to perceive distances and structure better than transparent shading. In addition, our statistical model predicts accuracy and efficiency based on the density of elements, which may help us better understand the perceptual process and design improved visualizations. Ongoing work is analyzing eye movements to test the model’s predictions.

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References