Using Mental Rotation as a Methodology to Evaluate Shape Perception in Computer Graphics

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Abstract and Introduction

Understanding the shape of 3D objects is particularly significant in scientific visualization and CAD/CAM applications, however objective measurements of how various rendering techniques affect object perception has not received enough attention. We propose a methodology which uses the Vandenberg and Kuse [1978] mental rotation paradigm as a mechanism for evaluating how well viewers are able to encode and match novel shapes presented in a computer graphics display. The established methodology and body of research on mental rotation provides a basis for its use to probe the influence of rendering on 3D shape perception. Our approach is complementary to techniques that evaluate perception of local shape properties and the adjustment of gauge figures to match local surface orientation [Koenderink et al. 1992]. We demonstrate the methodology with an experiment showing that at least in some circumstances, subjects are more accurate at shape perception with Blinn-style rendering than with Lambertian-style rendering.

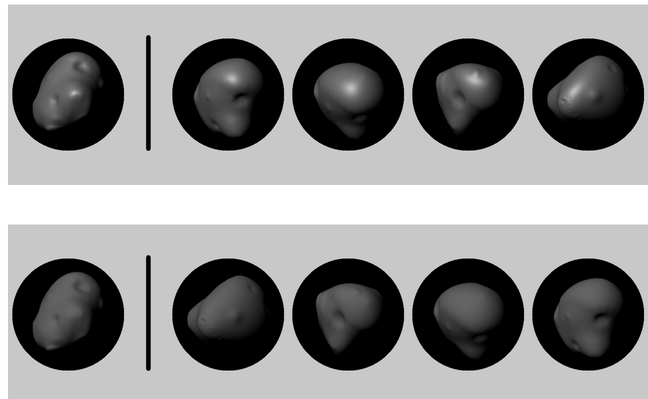

Figure 1: *Example trials: Choose which two of the four shapes on the right match the shape on the left. Blinn shading on top, Lambertian shading below.*

1 Method

To assess whether rendering technique would affect subjects' performance we created a computer based experiment similar to the Vandenberg and Kuse [1978] experiment. In this mental rotation paradigm subjects are presented with five objects, the leftmost object is the target object and they are to choose which two out of the other four objects match the target object. See figure 1 for examples. We varied the visual styles of the stimuli to include two rendering conditions. One style used Lambertian shading and the other used Blinn shading [Blinn 1977] which has a specular component added for the simulation of highlights. Blinn shading [1977] could be more effective than Lambertian shading in conveying shape because the specularity highlights the curvature of an object.

Subjects had to correctly respond by choosing both of the objects that matched the target to get the trial correct. Objects were rotated either around the horizontal axis parallel to the image plane, hereafter horizontal axis, or rotated around the vertical axis parallel to the image plane, hereafter vertical axis. Objects were rotated between 0° and 90° in 15° increments from their original position. 18 subjects (9 females, 9 males) participated in the experiment.

2 Results

A 2 (rendering style) x 2 (axis of rotation) x 2 (gender) ANOVA was performed on the number of correct trials. Rendering and axis of rotation were within-subject variables, gender was a between-subject variable. Analysis showed the interaction between rendering style and axis of rotation were statistically significant, $F(1,16) = 7.98$, $p < .012$. Gender was also statistically significant, $F(1,16) = 4.73$, $p < .045$. There were no other statistically significant effects.

Because of the significant interaction between rendering condition and axis of rotation, a 2 (rendering style) x 2 (gender) ANOVA was computed on the number of correct trials for each axis of rotation. For rotation about the horizontal axis, accuracy was higher for the Blinn rendering condition (10.89 trials) versus the Lambertian rendering condition (9.5 trials), $F(1,16) = 4.57$, $p < .05$. The effect of gender was also statistically significant, $F(1,16) = 7.42$, $p < .015$, showing greater correct trials for males (23.22 trials) than females (17.56 trials). For rotation about the vertical axis, there were no statistically significant effects.

Performance was significantly affected by both rendering style and gender, though these effects occurred only with one of the axes of rotation. Additional work is needed to generalize this approach by 1) comparing this paradigm to current methodologies for shape perception and 2) varying stimuli to reflect actual visualizations.

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