Implications of Two and Three Dimensional Information on the Perception of Solid Objects

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In a recent article, Pelli (1999) performed a set of perceptual experiments based on the portrait paintings of Chuck Close. Close’s work is similar to the “Lincoln” portraits of Harman & Julesz (1973) in that they are coarsely sampled into individually painted, mostly homogeneous cells. Pelli concluded that perceived shape was dependent on size, refuting findings that perception of this type of scale is scale invariant. In an attempt to broaden this finding and to remove the potential bias of subject matter (human faces) we designed a series of experiments to investigate the interaction of two dimensional scale and three dimensional structure on our perception of 3-D shape.

A RenderMan program was written to approximate the style of Close’s markings. This program was applied to three different classes of stimuli: human faces, ecological images, and artificially created objects. The synthetic objects were created within a range of 3-D spectra including those of human facial features and more complex environmental scenes. The resulting stimuli varied in both 2-D spatial frequency and 3-D geometric complexity. An initial experiment was performed where field of view, spatial frequency, and stimuli within a given class were manipulated. Observers indicated if the subject matter appeared to be two or three dimensional on each trial.

A second experiment was performed where only artificial stimuli were used. These stimuli systematically varied in the amount of geometric structure that was present in any given object. FOV and spatial frequency were varied as in Experiment 1, the task was identical.

Experiment 1:
Using facial stimuli we obtained results analogous to Pelli’s. When judging ecological images, observers were less likely (42% vs. 56%) to perceive solid objects. Results using low complexity synthesized objects mimic facial stimuli. Results for synthetic objects show the same slight bend in the criterion function as the ecological stimuli.

Experiment 2:
As expected, observers were sensitive to all three factors. Synthetic objects with less geometric structure required less image information to be perceived as 3D. Highly structured objects required a significantly larger amount of image information to be perceived as 3D.

Our findings suggest that perceived shape is dependent on the scale of 2-D information as well as 3-D geometric structure. We found no significant bias for faces over other classes of stimuli. Interestingly, our synthetic objects required less information than Nyquist would predict for proper categorization. The 50% threshold for classification of an image as being of a 3-D object is described by the equation:

$$\text{features per object} = -0.002 \times \text{fov}^2 + 0.003 \times \text{freq} \times \text{fov} + 0.15 \times \text{fov} + 0.004 \times \text{freq}^2 + 1.05 \times \text{freq} + 4.85$$

This result can be used as a perceptual “level of detail” function, approximating the circumstances when objects will be perceived as having depth.