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Transformations and Symmetry Optimization in Visual Perception

Visual perception readily lends itself to conceptualization as an optimization process. A primary difference between perceptual theories concerns the nature of the optimized quantity. Most theories suggest that this is either economy of coding or some form of likelihood (Palmer, 1999).

A smaller number of theorists have sought to explain perception in terms of maximizing symmetry (e.g., Leyton, 1992). On our version of this view, the perceptual system subjects image elements to multiple transformations and represents structure by the parameters of those transformations that maximize correspondence with the current sensory input (Vickers, Navarro, and Lee, in press). This paper examines two applications of this approach.

Perception of Projections of the Platonic Solids

In an early experiment, Hochberg and Brooks (1960) showed that the tendency to see outline figures as two- or three-dimensional was a function of the number of angles and line segments required to specify them in two or three dimensions. According to a transformational approach, whichever perception is associated with more symmetry-preserving transformations will occur more readily than one associated with fewer such transformations.

To test this prediction with stimuli that are representative of major classes of geometrical objects, we asked 50 observers to rate printed examples of 16 and 18 orthographic projections, respectively, of the first two of the regular polyhedra (the Platonic solids): the cube and the tetrahedron. The projections were generated in Mathematica by systematically rotating the figures around the two axes orthogonal to the line of sight

The means and standard deviations in observers' preferences for a two- or a three-dimensional interpretation covaried in a continuous manner that was (weakly) predicted by both the discontinuous differences in the symmetries of the two- and three-dimensional figures and by a count of the number of distinguishable elements. Further analyses suggested that the data may be better accounted for in terms of subjectively perceived symmetry, either as rated by observers or as estimated by the symmetry maximizing program developed by Vickers, Navarro, and Lee (in press).

Memory and the Perception of Process History

Leyton (1992) has argued that visual perception consists of recovering the process-history undergone by an object. According to Leyton, this recovery proceeds by progressively removing asymmetries or "distinguishabilities", so as to infer an original object that is maximally symmetric. A similar evolution towards regularity is claimed for the successive reproductions of random arrays (Giraudo & Pailhous, 1999). However, there has been no quantitative investigation of either of these tendencies towards symmetry.

An experiment, modeled on Bartlett's (1932) method of serial reproduction, was carried out, in which 44 observers, tested in five groups of 4 to 13, were asked to reproduce briefly presented, irregular heptagons, drawn randomly from an original pool of 168 figures. Observers were then presented with each other's (randomly allocated) reproductions and asked to reproduce them. This process was repeated until each observer had made 20 reproductions. In agreement with Leyton's hypothesis, analysis of the 57 (or more) figures that were reproduced at least 10 times showed that observers had a progressive tendency to reproduce figures with a smaller perimeter and with more nearly equidistant vertices, as measured by a reduction by a quarter and a third, respectively, in the mean and the standard deviation (normalized for perimeter size) of the lengths of the edges.

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