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Geometrical Computations Explain Projection Patterns of Long-Range Horizontal Connections in Visual Cortex

Ohad Ben-Shahar
ben-shahar@cs.yale.edu
Steven Zucker
zucker-steven@cs.yale.edu
Department of Computer Science and the Interdepartmental Neuroscience Program, Yale University, New Haven, CT 06520, U.S.A.

Neurons in primary visual cortex respond selectively to oriented stimuli such as edges and lines. The long-range horizontal connections between them are thought to facilitate contour integration. While many physiological and psychophysical findings suggest that collinear or association field models of good continuation dictate particular projection patterns of horizontal connections to guide this integration process, significant evidence of interactions inconsistent with these hypotheses is accumulating. We first show that natural random variations around the collinear and association field models cannot account for these inconsistencies, a fact that motivates the search for more principled explanations. We then develop a model of long-range projection fields that formalizes good continuation based on differential geometry. The analysis implicates curvature(s) in a fundamental way, and the resulting model explains both consistent data and apparent outliers. It quantitatively predicts the (typically ignored) spread in projection distribution, its nonmonotonic variance, and the differences found among individual neurons. Surprisingly, and for the first time, this model also indicates that texture (and shading) continuation can serve as alternative and complementary functional explanations to contour integration. Because current anatomical data support both (curve and texture) integration models equally and because both are important computationally, new testable predictions are derived to allow their differentiation and identification.

1 Introduction

The receptive fields (RFs) of neurons in visual cortex characterize their response to patterns of light in the visual field. In primary visual cortex, this response is often selective for stimulus orientation in a small region (Hubel & Wiesel, 1977). The clustered long-range horizontal connections between such cells (Rockland & Lund, 1982) link those with nonoverlapping RFs and

