

THE STRUCTURE OF CORTICAL HYPERCOLUMNS: RECEPTIVE FIELD SCATTER MAY ENHANCE RATHER THAN DEGRADE BOUNDARY CONTOUR REPRESENTATION IN V1^{*†}

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Abstract

The spatial relationship of orientation mapping, ocularity, and receptive field (RF) position provides an operational definition of the term “hypercolumn” in V1. Optical recording suggests that pinwheel centers and blobs are spatially uncorrelated. However, error analysis indicates a 100–150 micron systematic pinwheel center positional offset. This analysis suggests that pinwheel singularities and cytochrome oxidase blobs in primate V1 may in fact be coterminous. The only model to date that accounts for this detailed spatial relationship of ocularity, orientation mapping, and RF position is the *columnar shear model* (Wood and Schwartz, *Neural Networks*, 12:205–210, 1999). Here, we generalize this model to include RF *scatter*, which is observed to be in the range of one third to one half of the local RF size. This model provides a computational basis to address the following question: How is the existence of RF scatter consistent with accurate edge localization? We show that scatter of about one half the average RF size can provide an accurate representation of region and edge structure in an image based on a simple form of local inhibition between the blob (spatially low-pass) and interblob (spatially band-pass) neurons resulting in a process equivalent to nonlinear diffusion. The advantages afforded by this mechanism for edge preservation and noise suppression are that it avoids the slowness of diffusion (where time is proportional to distance squared) and is fully consistent with a correct understanding of the structure of the cortical hypercolumn. We demonstrate the effectiveness of this algorithm, known in the computer vision literature as the *offset filter* (Fischl and Schwartz, *IEEE PAMI* 22:42–48, 1999), by providing results on natural images corrupted with noise. This work emphasizes the importance of an un-normalized, low-pass response to accurate edge-representation—a function usually attributed to the intensity normalized, band-pass response of extra-blob neurons.

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