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Recurrent Long-range Interaction for Corner Detection

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Introduction Cell responses of neurons in V1 are influenced by stimuli outside their 'classical receptive field' as measured by single bar stimuli. These influences may be mediated by horizontal long-range connections, which connect primarily cells with the same orientation preference (Gilbert, 1993). Recurrent interaction within V1 can further scale up the RFs and enhance activities which are consistent within a more global arrangement. In previous work (Hansen & Neumann, 1999) we have introduced a model of V1 long-range interactions for contour enhancement. Here we demonstrate that the computational competencies of the proposed circuitry also allow for the detection of higher order structures like corners or junctions.

Methods A model of long-range connections in V1 is proposed. The model consists of a feed-forward path which generates the input to a recurrent long-range interaction. Dendritic long-range connections in V1 layer 2/3 are modeled by a bipole filter, which is narrowly tuned to orientation. Functionally, long-range connections realize i) iso-orientation facilitation, ii) cross-orientation inhibition, and iii) gain enhancement of activity already present. Self-normalization guarantees saturation after a few recurrent cycles. Corner regions are characterized by high responses for more than one orientation within an orientation column. Local maxima of each corner region mark the estimated corner position. Results are compared to two corner detection methods in computer vision, based on Gaussian curvature (Beaudet, 1978; Zetzsche & Barth, 1990) or the structure tensor (Förstner, 1986), resp.

Results The model is applied to noisy synthezised as well as natural 2D stimuli. Compared to the feed-forward responses of the complex cells, three functional properties of recurrent long-range interaction can be identified: i) noisy activities are suppressed, ii) contours are enhanced, iii) corners are detected more reliable and with better localization. Sensitivity is lower than the method based on the structure tensor, but higher than the Gaussian curvature approach. Localization is in many cases more accurate compared to both methods.

Conclusion We developed a functional model of intra-cortical recurrent long-range interactions in V1. We propose that long-range connections implement a powerful, multi-purpose preprocessing mechanism for main vision tasks, namely contour enhancement and corner detection. Results suggest that distributed information within an orientation column is sufficient to characterize junction points and question the need for specialized detectors.

Beaudet, P. R. (1978). Rotationally invariant image operators. In *4th Int. joint conf. on pattern recognition* (pp. 578–583). Kyoto, Japan.

Förstner, W. (1986). A feature based correspondence algorithm for image matching. In *Int. arch. photogramm. remote sensing* (Vol. 26, pp. 176–189).

Gilbert, C. D. (1993). Circuitry, architecture, and functional dynamics of visual cortex. *Cerebral Cortex*, *3*(5), 373–386.

Hansen, T., & Neumann, H. (1999). A model of V1 visual contrast processing utilizing long-range connections and recurrent interactions. In *Proc. ICANN* (pp. 61–66). Edinburgh, UK.

Zetzsche, C., & Barth, E. (1990). Fundamental limits of linear filters in the visual processing of two-dimensional signals. *Vis. Res.*, *30*(7), 1111–1117.