Title: "A model of surface detection and orientation tuning in primate visual cortex."

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Abstract (100 words):

In this contribution we propose that surface detectors, responding to areas of homogeneous gray-level may be used to support orientation selective cells in V1. By inhibiting orientation detectors within their input region, surface detectors act as local feedback system, emphasizing objects with large, continuous contours and enable the fast generation of an initial hypothesis about the input. The performance of this model is demonstrated, using a set of real-world images. We demonstrate that for images with a high degree of low-frequency clutter the performance of orientation detection can be considerably improved.

Summary (1000 Words):

In primates there are two major pathways through which information flows from the retina via the LGN to the primary visual cortex. The parvocellular (P) and the magnocellular (M) pathway. M-cells in the LGN have large receptive fields and are highly contrast sensitive. P-cells have smaller receptive fiels and their contrast sensitivity is comparatively low, however, they are sensitive to color (wavelength). M and P cells account for 90% of all LGN relay cells. The remaining 10% belong to a third, less well investigated pathway, the so-called koniocellular pathway, which is thought to be a phylogeneticly old part of the visual system.

K-cells have large receptive fields and their projections to V1 terminate in the cytochrome-oxidase (CO) blobs of the superficial layers. In contrast, inputs from the M and P pathway terminate in layer IV. Moreover, while M and P cells exclusively project to V1, K cell inputs have been identified in higher areas of the ventral visual pathway.

Because of their large receptive fields, K cells are not able to resolve fine details, however, they may provide information about large homogeneous regions. Tuning of orientation selective cells in layer IV is relatively broad, while it is considerably sharper in layers II and III. We propose that surface information, provided by the koniocellular pathway supports orientation selectivity in layer II/III and, thus, contributes to their improved tuning.

In this contribution, we present a computational model, which demonstrates how surface information can be used to support and enhance the response-properties of orientation selective cells in V1.

We assume that surface detectors are located in the blob regions of the superficial layers and get their input from two major sources: The koniocellular LGN cells and color selective cells in layer IV, which are driven by the parvocellular stream. Although the koniocellular pathway is slower than the parvocellular, its activity can arrive in time, since the parvocellular activity enters V1 in layer IV from where it has to cross one more synapse before it arrives in the superficial layers.

In our model surface detectors respond best, if their receptive field is covered by an area of homogeneous color or gray-level. If a surface detector is activated, it inhibits all orientation detectors which have their receptive field inside the larger receptive field of the surface detector. At the borders of the surface patch, tangential orientations are not inhibited. Thus, surface detectors are able to focus the activity of orientation detectors to areas along prominent, continuous contours.

In this contribution, we use rate-code model neurons with sigmoidal transfer function. However, we are also investigating a spike-based model of integrate-and-fire neurons.

The model system consists of 4 topographically organized layers. The first layer represents the koniocellular relay cells of the LGN. Its activity is calculated from an input image, using a Gaussian shaped receptive field. The receptive field is assumed to be five times the size of that of a simple V1 cell.

The K-cell layer projects to a layer of surface detectors. Each surface detector gets input from a number of K-cells and evaluates the variance in this input set. The surface detectors project one to one to an interneuron layer.

Finally, there is a layer of orientation detectors. Here, however, each topographic position contains a set of different orientations. The input to each orientation detector has two main components: the first component is driven by the input image and corresponds to a simple oriented gabor filter. The second component is the inhibition, driven by the surface detectors.

Thus, the layer of surface detectors acts as a local feedback system which emphasized objects with large, continuous contours and suppresses fine, supposedly unimportant details in the image. It may, thus, support the fast generation of an initial hypothesis about the input. In the following steps, top-down feedback may be used to suppress the surface driven inhibition an enable access to fine details of the input.

The performance of this model is demonstrated, using a set of real-world images. We can demonstrate that for images with a high degree of low-frequency clutter the quality of orientation detection can be considerably improved. Moreover, the performance is robust with respect to the type and size of the image used, if the threshold of the surface detectors is dynamically adjusted to the mean luminance of the input.