CORTICAL MECHANISMS FOR SURFACE SEGMENTATION

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30.1 INTRODUCTION

Physiology has shown that the neural machinery of "early vision" is well suited for extracting edges and determining orientation of contours in the visual field. However, when looking at objects in a scene our perception is not dominated by edges and contours but rather by surfaces. Previous models have attributed surface segmentation to filling-in processes, typically based on diffusion. Though diffusion related mechanisms may be important for perceptual filling-in [4], it is unclear how such mechanisms would discriminate multiple, overlapping surfaces, as might result from occlusion or transparency. For the case of occlusion, surfaces exist on either side of a boundary and the problem is not to fill-in the surfaces but to determine which surface "owns" the boundary [1][3]. This problem of boundary "ownership" can also be considered a special case of the binding problem, with a surface being "bound" to a contour.

We propose a model of intermediate-level visual processes responsible for surface segmentation. The basic function of the model is to bind contours to surfaces by determining the direction of figure for points along a contour. We present computer simulations showing how these cortical processes, as part of a larger model of depth-from-occlusion [1], discriminate multiple and/or occluding surfaces. Finally, we test the model with ambiguous and "illusory" surfaces, and show that the model behaves in a manner consistent with human perception.

30.2 DIRECTION OF FIGURE

The "direction of figure" (DOF) is defined at each point of a contour as the
direction towards that surface which "belongs" to the contour. The DOF of a contour segment is represented as the distributed activity of units within a "column" (we have used columns consisting of units tuned to eight different directions). The neural circuitry within a DOF column can be divided into two mechanisms; DOF-stellate and DOF-bipolar. Since long-range horizontal connections [2] play a critical role, the names of the two mechanisms have been chosen to reflect the pattern of these connections. Figure 1 is a simplified schematic of the two circuits (not all units are shown). The dashed rectangles represent units within a single DOF column, assumed here to be operating on a vertical segment of contour. All units have an associated phase ($\Phi$); points belonging to the same contour have the same phase [1]. In discussing how the two mechanisms work, we assume all input to the column originates from units responding to other segments of contour in the visual scene.

**DOF-stellate**

For figures having object contours which are not excessively convoluted, the DOF-stellate mechanism determines direction of figure by comparing the number of intersections made by two sets of rays (represented in the model by integration of input over long-range horizontal connections). Each set of rays emanates in all directions, forming a "stellate" pattern, and the two sets have origins on either side of the contour. The side of the contour having the set of