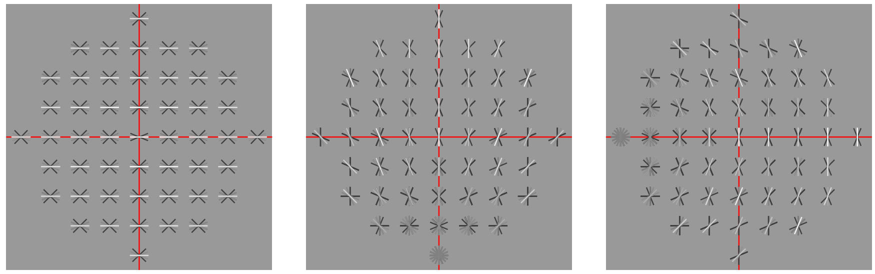

Fig. 18. Three examples of texture flow compatibility structures for various tuning values for orientation and curvatures. Bright/dark indicates excitatory/inhibitory connections. (Left) Horizontal orientation tuning with both curvatures equal zero. (Center) Vertical orientation tuning positive normal curvature. (Right) Vertical orientation tuning positive tangential curvature.

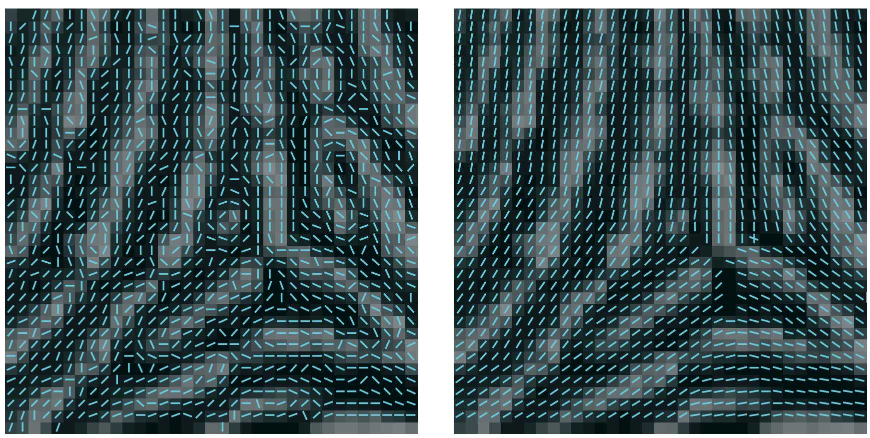

Fig. 19. Example of texture flow computation with the columnar machine. In this piece of a fingerprint image the perceptual structure is overwhelmed by the noisy measurements of local orientation (left). Based on the right helicoidal model for good continuation discussed in the text (see [5] for details), the columnar machine can extract the perceptually coherent structure (right) in few iterations of relaxation labeling.

this object takes the form of a right helicoid [52] and it is the only geometrical object that does not prefer either of the two curvatures over the other. Using this object we then designed compatibility structures to be used in the columnar machine (Section 2), examples of which are illustrated in Fig. 18. The same "neural" machinery equipped with this new set of "long range horizontal connections" is now able to integrate and infer 2D coherent texture flows, as is exemplified in Fig. 19. Indeed, both this class of connections, as well as the one based on cocircularity, have now been shown to be biologically plausible by correctly predicting the distribution of long range horizontal connections in visual cortex [53].

## 6. Shading flows and fold-type edges

While texture flows are a generalization of perceptual organization beyond curves, they are still a somewhat special class of patterns. It is therefore difficult to understand why the cortex might have evolved specialized circuitry for them. We believe an important part of the answer to this question is that there are other, more universal perceptual features that share the basic structural properties of texture flows. Prominent among these features is the *shading flow field*—the vector field of tangents to the iso-brightness contours (or intensity level sets) of the gray level image of smooth surfaces [6]. Measured from a shading distribution as opposed to from surface markings, the shading flow is directly analogous to the texture flow discussed earlier. Its geometry is a precursor to shape [16], and its interaction with edge geometry provides useful information for edge classification [21].

When applied to shading flow fields instead of textures, a successful organization of coherent flow structure constrains the geometry of the smoothly curved surface which gives rise to the scene. The singularities of the shading flow field can arise from shape discontinuities and spectral highlights, and thus its reliable recovery, while preserving its discontinuities and singularities, is an important step toward the robust interpretation of shape from shading.

The shading distribution takes on a particular form in the neighbourhood around an edge. Recall that we earlier discussed how edges which correspond to object boundaries arise when the tangent plane to a surface "folds" out of sight. Such edges are distinct in appearance in that they enjoy a stable pattern of shading with respect to the edge. This shading pattern is illustrated in