A central notion in texture segregation is orientation discontinuity. Three dominant orientations at each point are used to biologically model perceptual singularities to the normal circuit. The experimental results for separating the dominant orientations, computing the PSM representation, leads from transforming a differential equation to a dual space, where derivatives can be computed as a solution of a vector field problem. This happens in both classical (piecewise constant) and smoothly-varying ODTs. Hence, we hypothesize that any multi-oriented texture (i.e., oriented pattern with more than one dominant orientation at a point), can be decomposed into n different piecewise-smooth oriented manifolds, each of which gives rise to its own perceptual singularities.

A biologically-plausible model for curvature-based texture segregation

A biologically-plausible model for curvature-based texture segregation

(i) Introduction : Perceptual singularities in smooth ODTs

• A central notion in texture segregation is feature gradient.
• Existing results in orientation-based texture segregation (OBTS) link perceptual boundaries to orientation gradients: outstanding orientation gradients signal perceptual singularities and boundaries.
• Most OBTS research is based on piecewise-constant orientation-defined textures (ODTs). However, [Ben-Shahar, PNAS 2006]
• Lack of outstanding orientation gradient does not guarantee perceptual coherence.
• In fact, smoothly varying ODTs almost always exhibit salient perceptual singularities.
• These perceptual singularities have no apparent relationship to the orientation gradient.
• Sometimes, perceptual singularities in smoothly-varying ODT are more salient than perceptual singularities from orientation discontinuity.

Visual saliency via curvatures

A moving (Frenet) frame representation leads to two ODT curvatures, one tangential (k_t) and one normal (k_n). The pair (k_t,k_n) fully generalizes and extends the orientation gradient.

While neither curvature by itself predicts perceptual singularities and saliency in smoothly-varying ODTs, measure combining them both does so very accurately [Ben-Shahar, 2008].

(ii) Perceptual singularities in multi-oriented textures

A suppression of two different ODTs reveals perceptual singularities in multi-oriented textures. This happens in both classical (piecewise constant) and smoothly-varying ODTs. Hence, we hypothesize that any multi-oriented texture (i.e., oriented pattern with more than one dominant orientation at a point), can be decomposed to n different piecewise-smooth oriented manifolds, each of which gives rise to its own perceptual singularities.

Transformation to a dual space:

\[ f_i(\theta, \theta_o) = 0, \theta_o + \theta_i \]

\[ \theta \to \theta' = \theta - \frac{\theta_i}{\theta_i f_i - \theta_j f_j} \]

From which curvatures are calculated directly from the PDE:

\[ \kappa_t(\theta) = \theta \theta_o \theta_i \left( \frac{\cos \theta \sin \theta}{\cos \theta \sin \theta} - f_i \theta_i f_j \right) \]

\[ \kappa_n(\theta) = \theta \theta_o \theta_i \left( - \cos \theta \cos \theta + \theta_i \theta_j f_i f_j \right) \]

Since both curvatures share the same denominator, we define two modified curvatures:

\[ F_t(\theta) = \theta \theta_o \theta_i \left( \frac{\cos \theta \sin \theta}{\cos \theta \sin \theta} - f_i \theta_i f_j \right) \]

\[ F_n(\theta) = \theta \theta_o \theta_i \left( - \cos \theta \cos \theta + \theta_i \theta_j f_i f_j \right) \]

The PSM is calculated and the “union” of all PSMs at position (x,y) is being taken by MAX:

\[ PSM(\theta) = \max \{ \sum \{ PSM(\theta) \} \} \]

This can be extended and generalized for arbitrary number of N overlapping orientation manifolds.

(iii) A computational model for multi-oriented textures segregation

Main Idea: The computation of the orientation derivatives (i.e., curvatures) is done without separating and grouping the orientation measurements into smooth oriented manifolds. Instead, this goal is achieved by transforming the problem to a dual space, where derivatives can be computed as a solution of a differential equation.

Prediction of perceptual singularities in a multi-oriented texture

1) Estimate the multiple dominant orientations via non-maxima suppression of the response of orientation selective filter bank.

2) Separate the dominant orientations, compute the PSM on each, and combine the results, to predict the perceptual structure in the multi-oriented pattern.

(b) Model outputs

The PSM can be calculated from an input image in a biologically plausible manner.

A three-layer circuit in which both even-symmetric and odd-symmetric receptive fields are used to compute all possible directional derivatives of the dominant orientation, from which the tangential and normal curvatures at each spatial position are selected using nonlinear shunting inhibition [Ben-Yossef&Ben-Shahar, JOSA 2008].