(1) Motivation and Background

Current state of affairs

- A central notion in texture segregation is feature gradient.
- Existing results in orientation-based texture segregation (OTS) link perceptual boundaries to orientation gradients. Outward orientation gradients signal perceptual singularities and boundaries.
- Most OTS research is based on piecewise-constant orientation-defined textures (ODTs).

New observations: Perceptual singularities in smooth ODTs

- Smoothly varying ODTs sometimes also exhibit salient perceptual singularities.
- These perceptual singularities have no apparent relationship to the orientation gradient.
- Stimuli of identical orientation gradients can exhibit drastically different perceptual structures.

Research questions

- Are perceptual singularities without feature gradient significant visual events consistent across observers?
- Are perceptual singularities without feature gradient indeed dissociated from feature gradient?
- If orientation gradient is not the determinant factor, what theory would make correct predictions about the occurrence and spatial location of these perceptual singularities in smoothly varying ODTs?
- Would the derived model apply to classical cases of perceptual singularities due to feature gradients?
- What are the implications to theories of texture perception and segregation in general?

(2) Experiment 1: Free Viewing Segregations

- Stimuli: 24 dense ODT stimuli (both piecewise-constant and smoothly varying), all intensity modulated as to create fading circular margins t minimize effect from image margins. Piecewise smooth ODTs were generated from random quadratic orientation functions.
- Task: tracing salient boundaries and curves. Free-viewing conditions with no time limit. Only piecewise-constant stimuli (i.e., no smoothly varying ones) were shown during instructions.
- 7 naïve subjects.
- Results compared qualitatively both for (i) between-subjects consistency and for (ii) correspondence with regions of high orientation gradients. All subjects traced multiple curves on the smoothly varying ODTs in a highly consistent manner and always independently of the orientation gradient.

Conclusions: Salient structure and perceptual singularities in smoothly-varying ODTs are dissociated from the orientation gradient of the texture.

(3) Experiment 2: Proactive Discrimination

- Stimuli: 10 phase-paired with 90° phase shift.
  - 7 smoothly varying pairs
  - 3 piecewise-constant pairs
- Each trial incorporated either
  - two identical ODTs
  - two different ODTs
  - two ODTs with the (critical trials)
- 15 naïve subjects. 300 trials/strip.
- Task: 2AFC discrimination between the ODTs in the sequence.
- Results: while discrimination of different ODTs and identification of identical ODTs was equally accurate and nearly flawless (95%), regardless of stimulus type, discrimination accuracy for phase-paired pairs was significantly better for smoothly-varying ODTs than piecewise-constant ones (52% vs. difference, p < 0.0005).

(4) A novel saliency theory and a Perceptual Singularity Measure (PSM)

A different (differential) geometrical point of view

- A moving (Frenet) frame representation leads to two ODT curvatures, one tangential (σ) and one normal (ν). The pair (σ, ν) fully generalizes and extends the orientation gradient.
- While neither curvature by itself predicts perceptual singularities and saliency in smoothly-varying ODTs, a measure combining them both does so very accurately (Ben-Shahar, 2001).

Conclusions: Salient structure and perceptual singularities in smoothly-varying ODTs are dissociated from the orientation gradient of the texture.

(5) Summary

- Perceptual organization, saliency, and perceptual singularities in texture perception cannot be determined reliably from feature gradient: although outstanding feature gradient often do signal perceptual singularities, the lack of the former does not imply perceptual coherence.
- Salient structure and perceptual singularities in smoothly-varying ODTs are dissociated from the orientation gradient of the texture.
- Accurate localization of perceptual singularities in smoothly varying ODTs (extends to any ODT) emerges directly and solely from their curvature properties and can be modeled by the proposed PSM.

(6) Conclusion

...and a solved mystery

The theory and results presented here also solve a decade-long open question [Field, 1987; and, 1991]. Why would there be a perceptual hallucination in line array textures with fixed orientation differences throughout? The answer clearly relates to the perceptual singularities discussed here. The perceptual structure in [Field et al. 1991] is accurately predicted by the presented theory!