Week 7: Parallel visual pathways and perceptual organization

1) Why edge detection?
2) How edge detection?
3) Front end of BCS
4) Neon color spreading
5) How thin is "thin"?
6) Spatial and orientational completion
7) Hypereacuity

Facets of theory:
- Long-range completion (details next week)
- End cuts and endstopping
- Rectification and spatial scale
- Oriented detectors

BCS mechanisms:
- Long-range completion
- End cuts
- Boundaries and features

Neon color spreading:
- Uncertainty: Signal-to-noise performance vs. localization
- Oriented and unoriented detectors

Classical issues in edge detection:

WHAT IS AN EDGE?

WHAT TO WATCH FOR
Taxonomy of world’s sources of variation in luminance (contrast):

- Pigment changes
- 3-D corners or bends
- Shadows
- Highlights
- Occlusions
- Textures

These, and more, can generate perceptual “edges.”

Do all perceptual boundaries have corresponding luminance discontinuities? NO, ... not all along the visible boundary.

There is a huge machine vision / AI literature on edge detection:

1) Detection signal to noise:
   - Avoid: Missing an actual edge
   - Avoid: False positives

2) Localization: Max response should be at correct location.

3) Want: One response per edge

Computation ease?

Kind of operator?
   a) 1st derivative (peaks)
   b) 2nd derivative (zero-crossings)

Secondary issues include:

Even symmetric?

Odd symmetric?
Horn (1986), Marr (1982) and Marr & Hildreth (1980) argue for isotropic operators, (e.g. DOG) because we “ought” to treat edges in all orientations equally. But: if could group the upper Glass pattern would not also group the lower one.

**Prazdny's (1984) point:** There is no principled reason why a Marr-style algorithm that could group the upper Glass pattern would not also group the lower one.

The perceptual grouping "breaks."

Half (e.g., the "rotated" set) of the dots are made considerably larger.

"Normal" Glass pattern induces a grouping percept.

---

"Toughly, "edge detection" + "regularization" + "completion"

**CLAIM:** Grouping is an intrinsic part of boundary finding.

We (as opposed to Marr, Canny, et al.) also want:

- isotropic operators, (e.g. DOG)
- (oriented; elongated)
- (radially symmetric)

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Prazdny's (1984) point: there is no principled reason why a Marr-style algorithm that could group the upper Glass pattern would not also group the lower one.

**Prazdny** on Glass Patterns

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"Normal" Glass pattern induces a grouping percept.

---


"Figure 1: A random-dot Glass pattern can be perceived because the visual system can somehow detect local orientations (there are no elements in the display with inherent orientations) and combine this information into a global percept.

Figure 2. When the energy of one set of dots is too large (in relation to the size of the other set) it is difficult to perceive the global percept."

It is difficult to explain the results reported in this paper within the framework of existing theories of human perception. The findings suggest that the visual system can somehow detect local orientations (there are no elements in the display with inherent orientations) and combine this information into a global percept.
HOW TO BUILD AN ORIENTED OPERATOR

Roberts, Sobel, Pratt: Begin by smoothing in the direction of the 2-D image intensity gradient. Then compute derivative in the direction of the gradient.

For Canny filter:

\[ \text{Localization gets worse with increasing filter size.} \]

\[ \left( f \right)^{VM} = \left( M f \right)^{V} \]

as a function of filter size, \( M \).


LOCATION, LOCATION, LOCATION

For Canny filter:

\[ \text{How does } \Lambda, \text{ a localization measure*, vary as a function of filter size, } M? \]

\[ \Lambda_{fwf} = \left( \frac{1}{x} f \right) = (\frac{M}{x}) f = (x)^M f \]

Localization gets worse with increasing filter size. (Surprised?)


SIGNAL/NOISE

For Canny filter:

\[ \text{How is } \Sigma, \text{ signal-to-noise ratio*, a function of filter size, } M? \]

\[ \Sigma_{fwf} = \Sigma_{fwf} \text{ Filter response in presence of an edge, divided by (max) filter response in presence of noise.} \]

Signal-to-noise ratio increases as \( M \) with larger support.


IN MEMORY OF SLAVA

Result of Canny’s analysis:
Uncertainty principle
For varying filter sizes, the product of signal-to-noise ratio $\Sigma$ and localization measure $\Lambda$ is constant.

Canny filter has a complicated analytic form. (I.e. the formula takes many lines of text to write out.)

Although the Canny paper is an oft-cited reference for its construction of an “optimal” edge detector, a great deal of the space of that paper is devoted to extending or completing edges, from contours where the detector works well (with a certain threshold) to regions of weak or ambiguous evidence that are not visible, as they will belong to occluded sections of objects. In subsequent weeks we will see why this is a bug, not a feature. In subsequent weeks we will see why this is a bug, not a feature. In subsequent weeks we will see why this is a bug, not a feature.

Ironically, the “Canny completion” strategy is a core premise of the development of the BCS. It is built “from the ground up” to accomplish such a goal.

Just so we’re clear: The idea of “extending” edges from regions of high evidence to regions of weak or ambiguous evidence is a core premise of the development of the BCS. It is built “from the ground up” to accomplish such a goal.

Although the Canny paper is an oft-cited reference for its construction of an “optimal” edge detector, a great deal of the space of that paper is devoted to extending or completing edges, from contours where the detector works well (with a certain threshold) to regions of weak or ambiguous evidence that are not visible, as they will belong to occluded sections of objects.

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The "continuous blurring" proposal of Witkin

Adapted from Witken, 1983

"scale-space" filtering

For a 1-D "image" (i.e., a cross-section of a 2-D image), incoercibly blurred values of the original image (from bottom to top) yield patterns such as:

Contours of zero crossings of the second derivative of incoercibly blurred representations of the same initial image yield patterns such as:

Again, scale increases from bottom to top,

but with continuous representation of scale parameter.

That discrete samples of scale parameter.

The "continuous blurring" proposal of Witkin

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CONTINUOUS SCALE VARIATION

CONTINUOUS SCALE VARIATION

"scale-space" filtering


Consider blurring an image over a continuous parameter, a continuous scale parameter.

If edge and another does not?

Having edge detectors at many scales potentially requires

"abstraction" among scales.

zero-crossings as scale is varied.

Witkin's idea is to look for "structure" over the traces of as in the classical heat equation (Kemeny, 1964).

\ldots was noted to be equivalent to diffusion (Green's function)

This image stolen from scale space tutorial available at:

http://www.medal.kyoto-u.ac.jp/~rtoy/cmr-review/cm-space.html

ANISOTROPIC DIFFUSION

Malik & Perona (1987) published a seminal paper on anisotropic diffusion, a.k.a. “geometry-driven diffusion,” “conductance-based diffusion.” The basic idea is to blur only those regions of an image that you suspect should “really” be homogeneous, while preserving those sharp discontinuities that you believe signal “real” edges.

Note: This cartoon ignores issues of 2-D diffusion.

FEELING EDGY

Recent alternatives to the Malik/Perona procedure include work on “offset filters,” whose “on” and “off” subregions maybe separated by a neutral zone that is wider than typically found in DOGs or DOOGs. (Cf. Neil Bomberger, CNS).

FENWARD TO BCS

Note: Work on “steerable filters” (Freeman . . .)

UNREQUITED LOVE

The bottom line on the computational theory of edge detection -- viewed as an exercise in local labeling of image gradients that “matter” (cf. Marr) -- is disappointing: The best computational edge detectors: “find” edges that are not there (in the sense that they do not correspond to anything in the world), and miss edges that are important (in the sense that they do correspond to something important in the world).

ONWARD TO BCS

Note that anisotropic diffusion treats homogeneous regions and edges differently within the same representation, i.e. image intensity. That is, you iteratively generate new images and edges differently, while keeping homogeneous regions as they are.

BCS/FCS puts the boundary finding and smoothing in separate (but interacting) subsystems.

Criteria for perceptual boundary formation include factors of perceptual organization, not just local gradient measures.

The next “computational” move is generally to appeal to a “classifier,” if possible one endowed with domain knowledge.

By dynamical systems theory, we will take a different path, inspired by the Gestaltists and Bays/FCS (Kemp).
Should "edge detection" use oriented or unoriented operators?

Marr & Hildreth (1980): UNoriented

Physiological evidence? Clearly both oriented and unoriented receptive fields exist.

What are the functional roles of these receptive fields?

More luminous image region with excitatory region of mask?

10. What about "spurious" responses from isolated overlap of
vertical edge exists.
7. Contrast difference detected, even though no (unbroken)
position and orientation
6. No response for homogeneous regions of any intensity
5. Some response; parameters define isolated shifts in
orientation.
4. No response: exactly wrong orientation
3. No response: rectification (wrong contrast polarity)
2. No response: ideal orientation; position and contrast polarity
1. Max response: ideal orientation, position and contrast polarity

Model simple cell behavior

1. Max response: ideal orientation, position and contrast polarity
   - Monocular pre-processing
   - ++ + + +
   - +

2. No response (rectification) wrong contrast polarity
   - No edge detected
   - + + + +

3. No response: exactly wrong orientation
   - + + + +

4. Some response; parameters define isolated shifts in
   orientation and position
   - + + + +

5. Contrast difference detected, even though no (unbroken)
   vertical edge exists.
   - + + + +

6. No response for homogeneous regions of any intensity
   - No response

"Front end" of BCS does something not entirely unlike
"M & H's zero-crossings of Laplacian of Gaussian"

What are the functional roles of these receptive fields?

"Spurious" responses from isolated overlap of
vertical edge exists.

Marr & Hildreth (1980): UNoriented

Physiological evidence?

"Edge detection" use oriented or unoriented operators?
As the Hubel & Wiesel, 1962 model suggested:

 Primarily a feedforward process.
 Is cortical orientational selectivity

DYNAMICS OF ORIENTATIONAL SELECTIVITY

Some recent thinking suggests "no".

Chris Pack, Eric S. and Aaron Seitz disagree, however, claiming that the Hubel and Wiesel model can account for observed degree of orientational tuning.

 Recall the question: Is cortical orientational selectivity

(HUBEL/WIESEL MOVIE)

...as the Hubel & Wiesel, 1962 model suggested?

Primarily a feedforward process,
Is cortical orientational selectivity

A narrow tuning

A broad tuning

most simple cells get inputs from both ON-center and OFF-center cells. Most simple cells get inputs from both ON-center and OFF-center cells. Most simple cells get inputs from both ON-center and OFF-center cells. This diagram suggests that only one type of center-surround cell (ON-center) inputs to an even-symmetric simple cell with an excitatory central ridge.
You might think that 40 years after Nobel-prizewinning work we would have the origin of orientational selectivity pretty much "settled." Why is this still considered a current research topic?

"FRONT END" OF BCS complex:

Compare Spitzer & Hochstein, (1985) cat complex cell data and model

Note: The output of the front end of the BCS is INSENSITIVE TO DIRECTION OF CONTRAST, (at the scale of complex cells), BUT the components that feed into the complex cells (i.e. simple cells) are themselves sensitive to direction of contrast.

Advanced topic:

Believe it or not, the very existence of two distinct classes of cells in V1 (or V2) called "simple" and "complex" is under dispute. There are a variety of criteria proposed for making the distinction (e.g. phase sensitivity, modulation of "on" and "off" subregions, etc.) under dispute:

OCTOB 08 OF BCs

NOW SIMPLE?

Pollen & Jacobson object to the BCS front end, pointing out that input from both even-symmetric and odd-symmetric simple cells is needed to model complex cell data:

NOTE: The icons in the upper right may represent just a minimal basis set.

Nothing more is definitively needed, relative to G & M, 1985, equations.

advanced topic:

LOCALIZATION REFERENCES:

Ask Ennio if you want to pursue this and have trouble separating over/under of "on" and "off" subregions.

"See" a more fundamental underlying continuum and some "see" two populations (simple and complex) where others "see" a more fundamental underlying continuum of cells' behavior, whereby certain researchers "see" a "lumpy continuum," etc.

There are some sort of a "lumpy continuum" of cells, there's some sort of a "lumpy continuum," etc.

Two populations (simple and complex) where others "see" a more fundamental underlying continuum of cells' behavior, whereby certain researchers "see" a "lumpy continuum," etc.

Poll: 8 Jacobson object to the BCS front end, pointing out that input from both even-symmetric and odd-symmetric simple cells is needed to model complex cell data:

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advanced topic:
Consider the following question that has come up in the context of the even/odd symmetric complex cell discussion:

Given that even-symmetric simple cells exist in vivo, is the BCS model not obliged to include them?

If you answer "yes," where do you draw the line? I.e., must you include all "known" cell types, ending up with a model as complicated as what you are trying to explain? Or, do you only include a physiological fact when you need it to explain something else in the scope of what your theory is trying to address?

MODELER'S LAMENT

In this case, BCS/FCS is a physiologically-based theory of perception, not a theory "of" physiology. How "not biologically implausible" is it?

Which facts about the brain "belong" in a theory?

When and why do you compromise your model in theory building?

Theories should be "as simple as possible, but no simpler." How "not biologically implausible" is it (this is a joke)?

MULTIPLE SPATIAL SCALES

Model simple cells can come in multiple sizes (scales).

What is the "best" form for early oriented contrast filters (e.g., Gabor functions, wavelets, elongated DOGs, etc.)?

In vivo for image processing (e.g., Gabor functions, wavelets, elongated DOGs, etc.)

"All boundaries are invisible." or, to put it more correctly, "Complex cell output is insensitive to contrast polarity."

Which is closer to the truth in vivo?

Or, should their activity be normalized within each scale?

Should their maximum possible activation increase proportionately with increasing kernel size?

"Complex cell output is insensitive to contrast polarity."

"All boundaries are invisible."

Model simple cells can come in multiple sizes (scales).

*Some version of this question comes up in many neural models.

Hint: Consider bicameral legislatures, like the U.S. Congress.

Why would you or wouldn't you want to do this?

QUESTION: Which is closer to the truth in vivo?

Or, should their activity be normalized within each scale?

Should their maximum possible activation increase proportionately with increasing kernel size?

Model simple cells can come in multiple sizes (scales).

DETAILS OF MODEL SIMPLE CELLS

What is the "best" form for early oriented contrast filters (e.g., Gabor functions, wavelets, elongated DOGs, etc.)?

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Or, to put it more correctly, "Complex cell output is insensitive to contrast polarity."

Which is closer to the truth in vivo?
**DETAILS OF MODEL SIMPLE CELLS, II**

BCS is "pluralistic" ("agnostic"?) about possible early filters. It concentrates on later interactions among outputs of such filters.

"Boundary contours" are more complex than any edge that could be the output of feedforward filtering alone. BCS is "pluralistic" ("agnostic"?) about possible early filters.

**BOUNDARY COMPLETION ANOMALIES**

Remember:
1) Perceptual boundaries can exist where there is no corresponding image contrast. (Kanizsa, Ehrenstein, etc.)
2) Boundaries can be "killed" (or weakened) where there is image contrast, as we will next explore.

**INTRO TO NEON COLOR SPREADING**

What is so special about neon color spreading that earned it mention in the title of an early report on the BCS/FCS theory -- at a time when neon was not on the radar among psychophysicists?

You would never arrive at BCS/FCS complementarity if you only considered "1-D" phenomenal psy

**Cf. FIRE theory of G., 1983, where boundaries and features are coded in the same signal.**

Building on a probe of adaptive mechanisms? Question: Are visual illusions a silly distraction from theory? Why do they occur?

Claim: These effects are functionally and mechanistically related. Corresponding image contrast (Kanizsa, Ehrenstein, etc.) can amplify effects of aliasing from small (e.g. 3 x 3 pixels) filters.

Danger of coarse implementation: CC Loop nonlinear feedback is used to gate the diffusion, also diffuse the very signal whose gradient is used to diffuse. Geometry-based diffusion, conductivity-based diffusion, anisotropic diffusion (a.k.a. inhomogeneous diffusion) are all methods in machine vision for CP. FIRE theory of G., 1983, where boundaries and features are coded in the same signal.

**BRAIN'S NEON COLORS**

The record shows that Grossberg has on occasion criticized (retracted) his own model. How this was done for FIRE vs. BCS/FCS merits some attention.

Note that most current schemes in machine vision for anisotropic diffusion (a.k.a. inhomogeneous diffusion) can amplify effects of aliasing from small (e.g. 3 x 3 pixels) filters.

* The record shows that Grossberg has on occasion criticized (retracted) his own model!
WHY BOUNDARY AND FEATURE CONTOURS

The distinction of boundary contours * and feature contours * is counterintuitive, because: "Real" luminance steps always generate both, and boundary contours and feature contours are generally perceived individually, while BCS/FCS signals usually get "put back together" in a way that makes it hard to suspect information from the two contour signals usually gets perfectly aligned in perceptual space; those originating directly from luminance steps certainly are. Perception of original contour, therefore, often cannot be possible at all.

REALITY VS ILLUSION

We differentiate between "Real" contours of small cross cannot enclose red featural quality; "Illusory" contours of Ehrenstein figure do!

* What, in general, is a contour?

A red cross placed inside an Ehrenstein figure produces color spreading.

BCS/FCS theory explains how:

RECALLING VS ILLUSION

Recalling that the locus of original contours is informative about BCS/FCS geometry and dynamics. The resulting illusion is informative about BCS/FCS geometry and dynamics. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone.

REALITY VS ILLUSION

Recalling that the locus of original contours is informative about BCS/FCS geometry and dynamics. The resulting illusion is informative about BCS/FCS geometry and dynamics. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone. Spatial interactions within and between BCS and FCS result in a final configuration that neither could achieve alone.
Why does color spread?

Relative contrast with background:

- BCS: First Competitive Stage employs shunting inhibition.
  - Inhibition of cells at (a) is balanced; at (b) cells of black edge are more active than those at red edge due to higher contrast with background.

- BCS's First Competitive Stage employs shunting inhibition.
  - "End cuts" of perpendicular boundary signals — enhancements to "end cuts" of position inhibition combine with an "across position" inhibition to generate the "same orientation, across position" inhibition.

- "End cuts" of perpendicular boundary signals occur via the first and second competitive stages.

- "Disinhibition" of perpendicular boundary signals.

Emergent boundary formation:

- The cooperative-competitive loop (CC Loop) combines long-range cooperation with short-range inhibition to choose coherent boundaries and suppress alternatives.

- The "same orientation, across position" inhibition combines with an "across orientation, same position" inhibition to generate the "same orientation, across position" inhibition.

Relative contrast with background:

- MP: Inhibition lower-contrast boundary signals are weakened.

- FCS: No inhibition feature signals survive and disperse.

NOTE: Strength of neon effect varies with amount of contrast.

(van Tuijl & de Weert, 1979; Redies & Spillmann, 1981)
STIMULUS CONDITIONS FOR NEON inducer color to be spread background

Leaving aside Grossberg et al.'s modeling, what stimulus conditions foster the perceptual phenomenon of neon color spreading? What is the significance of "thin" lines for neon spreading in the Ehrenstein configuration? That is, does the phenomenon require thin inducers and "spreadable" lines? Must the inducer touch the line whose color will spread? What are the effects of changing the relative orientations of inducer and spreading lines? Is there a spreadable "thin" lines phenomenon? What is the significance of "thin" lines for neon spreading in the Ehrenstein configuration?
HOW THIN IS "THIN"?

For a given receptive field size:

Inputs of two thicknesses:

For a thin line, no detector perpendicular to line end can respond "enough" based on bottom-up input alone.

End cuts simulations of C & M 85a refer to such a situation. Why not?

Claim: we cannot just use smaller filters. Why not?

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Visual system must synthesize a line end.

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End cuts simulations of C & M 85a refer to such a situation. Why not?

Claim: we cannot just use smaller filters. Why not?
Where does the synthesis of line end boundaries (end cuts) occur?

BCS model: First and Second Competitive Stages

Analog in vivo: "Hypercomplex" (i.e., end-stopped complex) cells

BCS model: First and Second Competitive Stages

First: across locations
Second: across orientations

End cuts (via 1985 mechanism)

(1985): Mechanism for generating end cuts

* Not just between perpendiculars

* Simple cells

* Complex cell

Dotted box above symbolizes that all receptive fields overlap.

RFs have different orientations but same position:

(i.e., they have common centers).

(2004.1) Two stages of short-range competition

First: across locations
Second: across orientations

Later:

Mechanism for generating end cuts

(1985):

* Not just between perpendiculars

weak output

First Published Endcut Simulation

G & M, 1985a, Figs 22a, 23a

Mask size?

BCS: SHORT-RANGE COMPETITION

„Simple cells“

„Complex cell“

+ [ ]

+ [ ]

+ [ ]
ENDSTOPPED CELLS

-         +          -
+          -
solo*

Complex and (even) "simple" cells may be endstopped.

How can you tell?

Response:

Never diagram or same model equations.

Two stages of short-range competition:

Mechanism for generating end cuts:

"Lateral inhibition" among neighboring cells with similarly oriented receptive fields can generate endstopping.

** Perhaps the response is only severely reduced from maximum.

Moral: Take NOTHING for granted!

ASIDE: BAD PLAY ON WORDS

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Moral: Take NOTHING for granted!
Note that this short-range competition among orientationally-sensitive cells occurs in all later versions of BCS/FCS, including the FACADE "successor" model, even though later publications rarely, if ever, show a diagram like that of the previous panel.

FOR THE RECORD

Summary to this point:
Perpendicular induction of BCS signals occurs at line ends. Later, arguments will be advanced that the induction process is:
- positionally hyperacute, but orientationally fuzzy.

Note: Much of the material in the next several panels is of "historical interest" (at best!) in particular, details about the equations that follow for the First and Second Competitive stages of the BCS will not be "on the test." These mechanisms, first discovered by analysis of weird illusions, are critical for "normal" perception of everyday scenes. They are presented to help communicate the evolution of model mechanisms that are still "operative," employed in models that have not proven robust for larger and more complex images. Pointers to improved formulations appear in notes for Week 8.

"Historical interest" (at best)
and normalization across orientations.

accomplishes both "push-pull" competition at perpendiculars

where orientation $k$ is perpendicular to orientation $K$ followed by . . .

Alternative version of second competitive stage (from G & M, 1987): OLD AND IMPROVED

Old and improved normalization across orientations:

A DOG/(A+SOG) equation for interactions among orientations:

$$w_u \sum \left( \frac{O}{J} + \frac{O}{J} \right) - w_u \sum \left( \frac{O}{J} - \frac{O}{J} \right) + \frac{O}{J} - \frac{O}{J} = \frac{O}{J}$$

(total activity over all orientations at one position is roughly constant.

Annihilation by push-pull competition, "artifact cancelation"?

from nearby position:

different icons; same structure

from nearby position(s):

excitatory

inhibitory

end cut from nearby position(s):

excitatory

inhibitory

Alternate version of second competitive stage (from G & M, 1987):

A DOG/(A+SOG) equation for interactions among orientations:

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(total activity over all orientations at one position is roughly constant.

Annihilation by push-pull competition, "artifact cancelation"?

from nearby position:

different icons; same structure

from nearby position(s):

excitatory

inhibitory

end cut from nearby position(s):

excitatory

inhibitory

Grove, G & M (1995): The above is still not good enough

"milder" end cuts . . .

"smoother" across orientations than 1985 version

Heeger's normalization model (1993)

Cf. Grossberg, 1973 and "Heeger normalization model" (Heeger, 1993)
Spatial Localization and Hyperacuity


found ". . . two separate underlying mechanisms, one concerned with the luminance distribution within a restricted region and the other reflecting interactions between features."

Influence of a flanking line on perceived position of a test line.

Independent evidence for front end of BCS:

"Outside this central zone repulsion effects are obtained independent of the contrast polarity of the flank . . ."

More Localization and Hyperacuity

Is the BCS "just another edge detection algorithm"?

More Localization and Hyperacuity

Is more comprehensive than just "edge detection."

Physiologist poking around V1 can be divided into two groups, who (act as if they) believe:

(1) simple and complex cells really "like" thin lines and edges, or

(2) the "right" way to study simple and complex cells is to use stimuli that are narrow-band in the spatial frequency domain.

A question that few if any physiologists seem to be asking is how do cells "know" how and when to switch from "edge detection" mode.

Not Your Father's Edge Detector

Is the BCS "just another edge detection algorithm"?

More Localization and Hyperacuity

preference may respond over a wide region, whereby many cells of similar orientation

to "smooth shading" or "shallow-gradient" mode, whereby a few cells respond strongly and suppress

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how do cells "know" how and when to switch

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MORE LOCALIZATION AND HYPERACUITY

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