Texture Perception and Edge Detection

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Outline

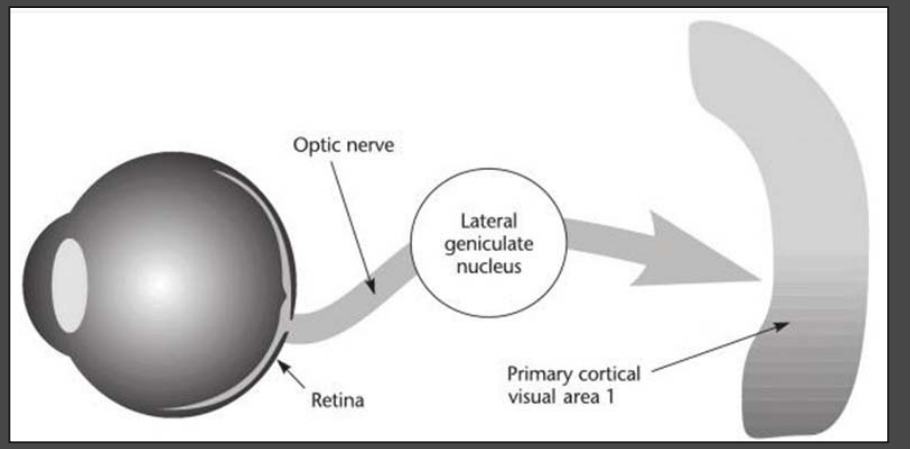
- Edge detectors (Gabor filters)
- Texture Segmentation
  - Texture coding
  - Camouflage
- Shape from Texture
  - Art/Graphics
  - Contours in maps

Why texture?

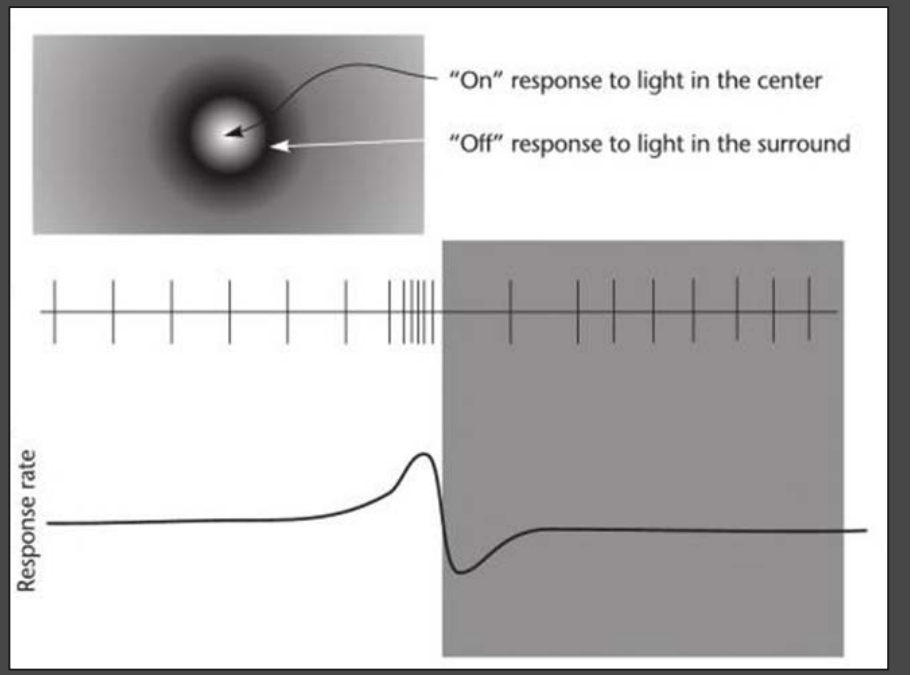
- Like color, we use texture to analyze our surroundings
  - Finding boundaries between objects
  - Recognition / visual search
  - Inferring surface properties
  - Inferring shape (3D)
- Texture can be perceived even for brief moments, and for distant objects

Edge Detectors

- Recall “tuned” DOG filters in retina and LGN
  - Normalize illumination
- Second layer of “tuned” filters in cortex (V1/V2)[1]
  - Color
  - Motion
  - Elements of Form
  - Texture (focus of this presentation)



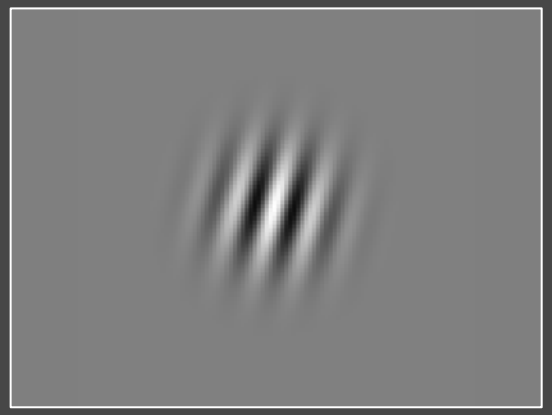
Early visual processing steps

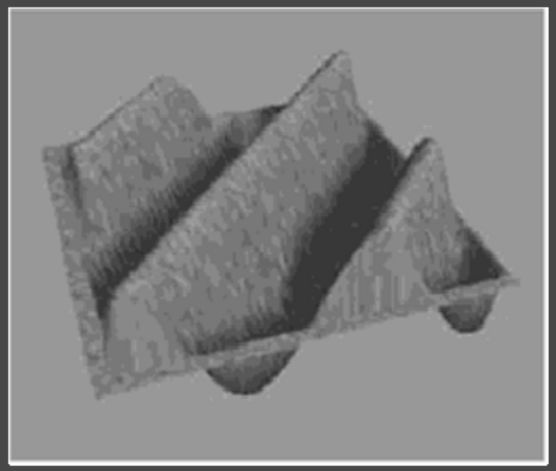


Tuned “blob” filter in retina/LGN

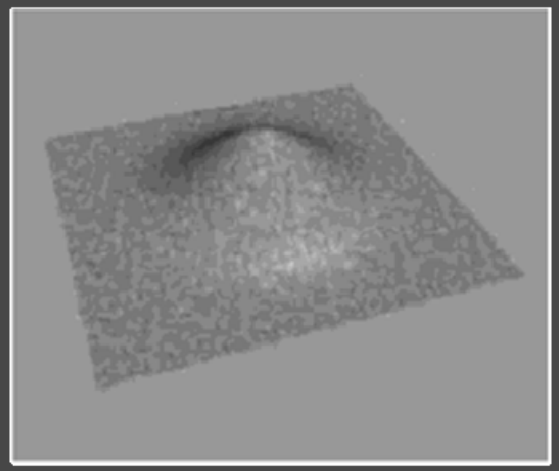
Texture Detection in V1

- Array of neurons tuned for detecting blobs of various size, position, orientation, contrast
- Operate on lightness
- Gabor model (aka fuzzy bar detector)
  - Excitation and inhibition
  - Combination of cosine and Gaussian
  - Vary by contrast, orientation, and size

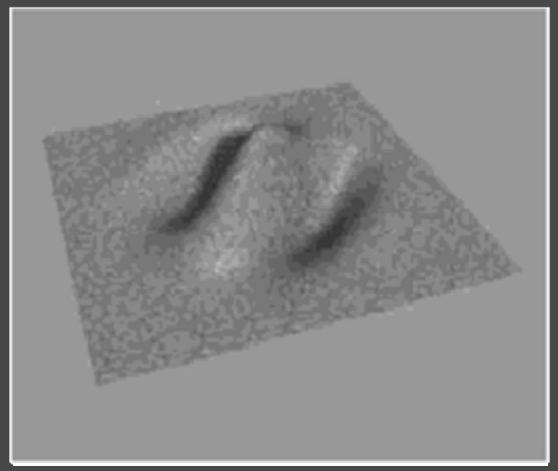




Cosine x



Gaussian =



Gabor

Graphemes

- Primitive visual elements
  - ...from which meaningful perceptual objects are constructed[1]
- Deconstruct retinal image into basic elements[2]
- What happens next?
  - We don't really know
  - Graphemes compared (with another set of filters?)
  - Somehow derive objects and form

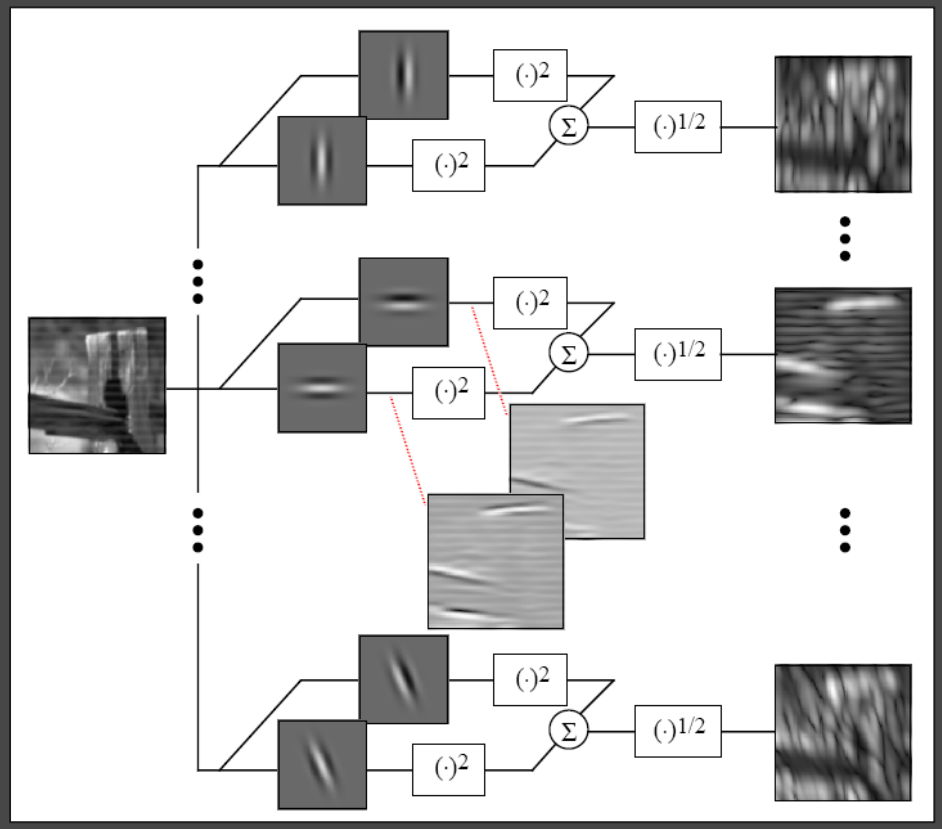
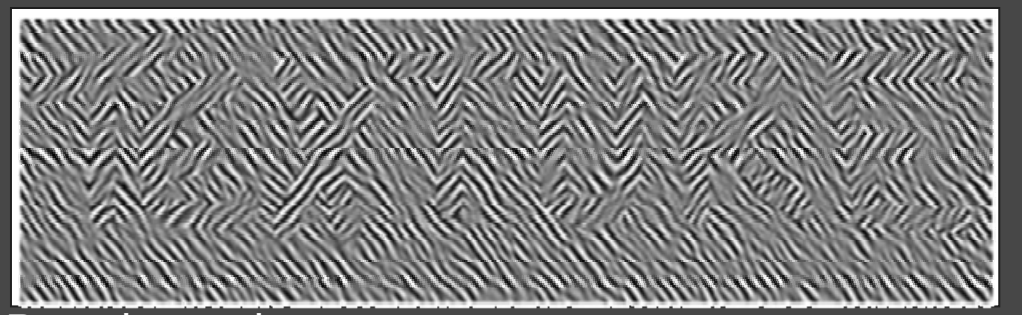


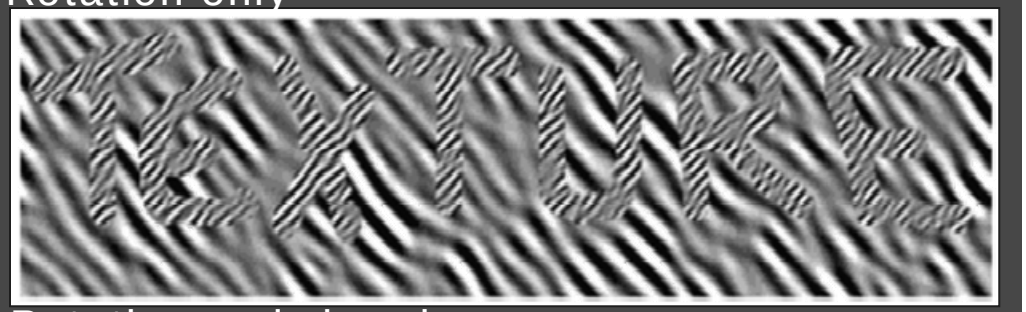
Image deconstruction with Gabor filters

Texture segmentation

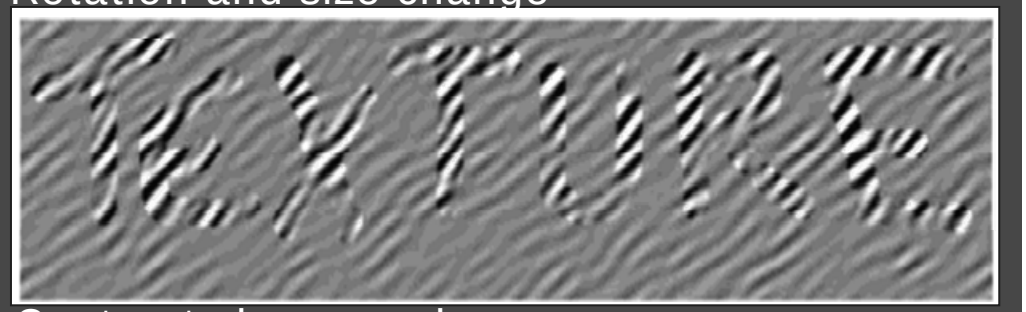
- Like color, we detect boundaries between textures[1]
- Like color, the greater the difference, the more noticeable
- Easy to detect
  - 30 degrees rotation
  - 3-4 factor in size
- Possible to resolve
  - ~5 degrees rotation
  - ~9% factor in size



Rotation only



Rotation and size change



Contrast change only

Design Example: Texture Coding

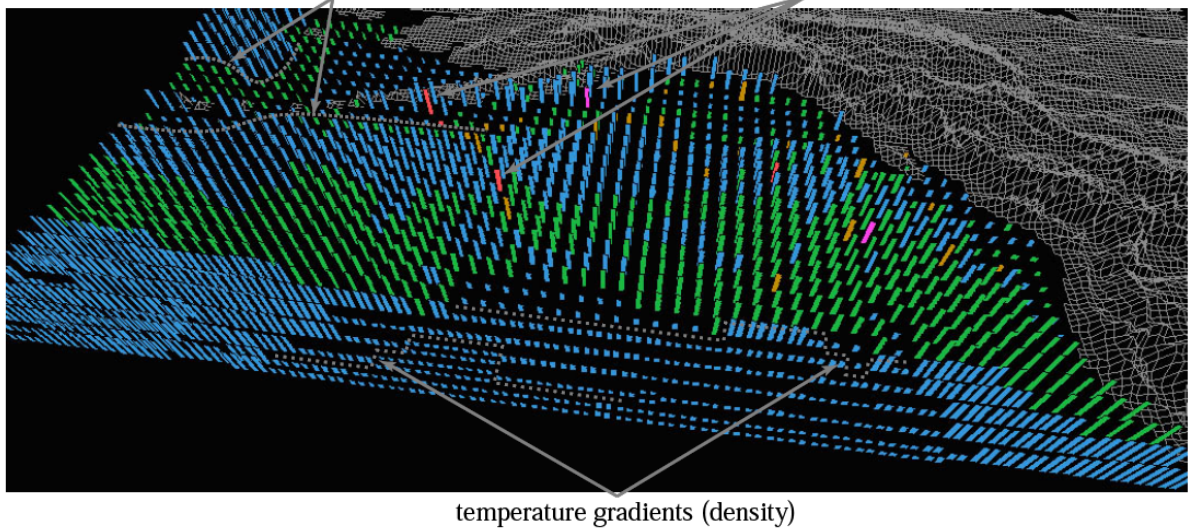
- Use texture to display more dimensions in same area
  - Encode data with orientation, size, contrast[7]
  - Combine with color…
- *Uncertainty principle*[1]
  - Larger textures are less precise
  - Limits the range of textures we can use in visual design

Multivariate Data Coding with "Natural Textures"

V1: Texture color
V2: Texture size
V3: Texture shape (rocks vs weave)

Design Example: Texture Coding

- Warning: Ad-hoc mapping of data to texture is bad[8]
- Need for a system like ColorBrewer (TextureBrewer?)
  - Do we understand enough about texture yet?
  - like color – *above all, do no harm…*
- Untapped potential?[7]



Multivariate Data Coding with “Pexels”

V1: Texture color
V2: Texture size
V3: Texture density

Design Example: Camouflage

- Visual search is aided by texture segmentation/recognition
- Good camouflage blends into surroundings
  - Most animals have some form of camouflage
  - Disrupt segmentation (outline of the body)
  - Disrupt recognition (appear as some other surface)

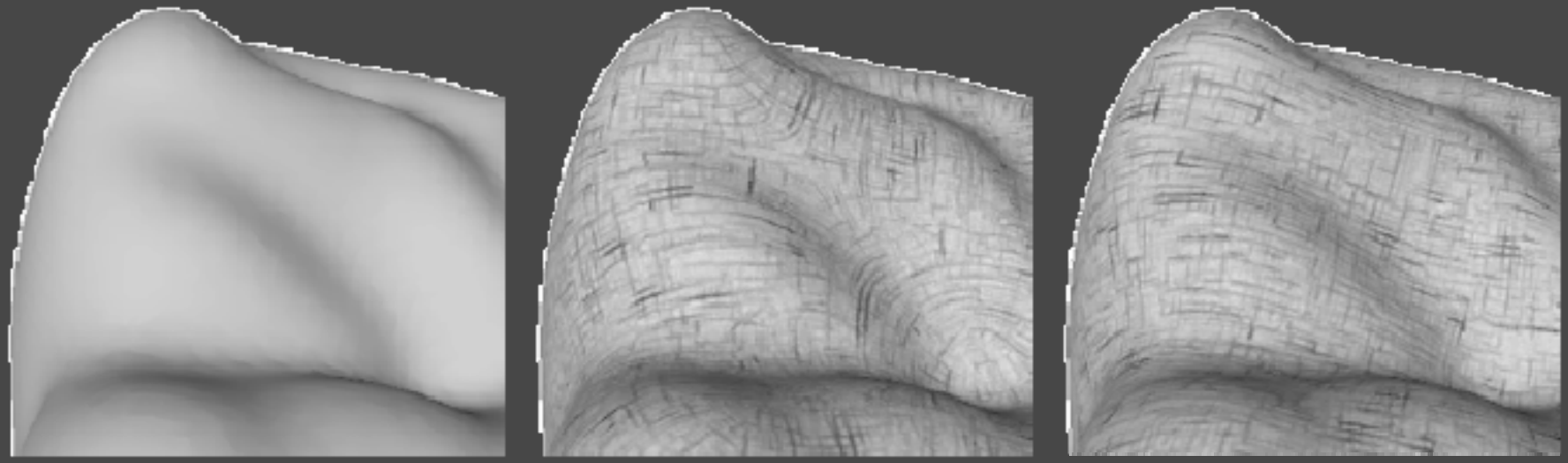
Sneaky Octopus

Gumleaf grasshopper

Egyptian Nightjar

Shape from Texture

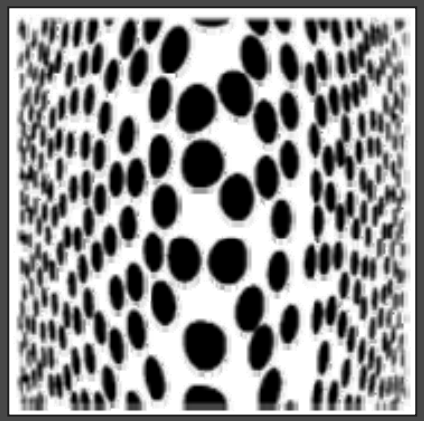
- Textures help us to infer shape of 3D objects[3]
  - Since they are distorted by perspective
  - Reinforce / supplement other visual depth cues (shading, motion parallax, stereopsis, etc)
- Bias towards interpreting lines following principle directions[4]



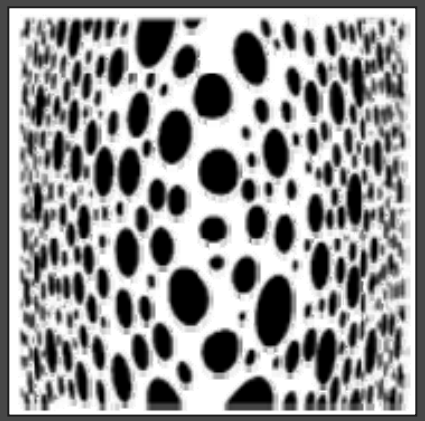
No texture | Following principle directions | Following constant directions

Design Example: Art/Graphics

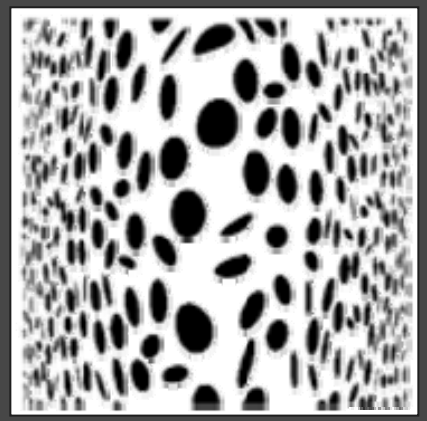
- In art: When elements of a pattern appear to recede by consistently becoming smaller, denser, and fainter, then the illusion of three-dimensional space is enhanced[6]
- Applications for computer graphics[5]
  - How to render realistic surfaces (creating depth)
  - How to guess at 3D shape (measuring depth)



Random dots



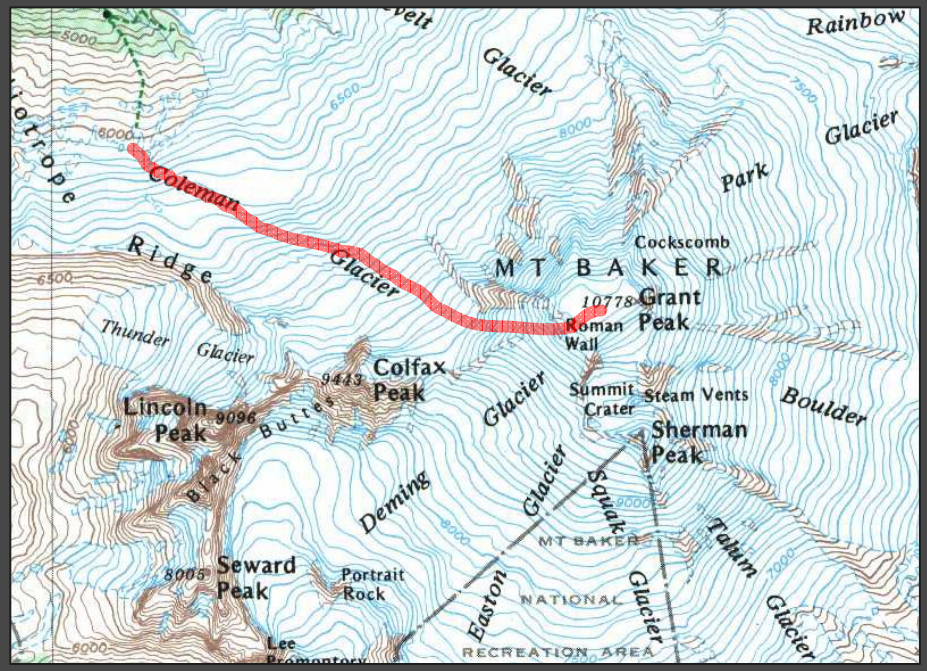
Variable size dots



Variable shape ellipses

Design Example: Contours in Maps

- Use texture to show elevation in maps – contours
  - Lines follow *principle direction* of surface
- Closer together indicates steeper terrain
- Real-life example - contoured countryside?



Contours showing steepness

Contoured countryside

Summary

- Texture plays an important role in how we perceive our surroundings
  - Segmentation
  - 3D shape
- Not yet very well understood for visual design applications
  - Untapped potential?
  - Do no harm…

References

- [1] C. Ware, *Information visualization: perception for design*, 2004
- [2] C. Taylor et al, "Image Quality Assessment with a Gabor Pyramid Model of the Human Visual System," *International Symposium on Electronic Imaging Science and Technology,* Vol 3016, pg58-69, 1997
- [3] S. Kim et al, "Conveying Shape with Texture: experimental investigations of texture's effects on shape categorization judgments," *Visualization and Computer Graphics*, Vol 10, Issue 4, pg471 – 483, 2004
- [4] P. Mamassian and M. Landy, "Observer biases in the 3d interpretation of line drawings," *Vision Research*, 38(18), pg2817–2832, 1998
- [5] J. Todd et al, "The effects of viewing angle, camera angle, and sign of surface curvature on the perception of three-dimensional shape from texture," *Journal of Vision,* Vol 7, Issue 12, Art 9, 2007
- [6] David, "Texture Perspective," posted in *art technique*, 2007 http://rourkevisualart.com/wordpress/2007/02/27/texture-perspective/
- [7] V. Interrante, "Harnessing Natural Textures for Multivariate Visualization", *Visualization Viewpoints*, 2000
- [8] C. Healy, "Large Datasets at a Glance: Combining Textures and Colors in Scientific Visualization," *IEEE Transaction on Visualization and Computer Graphics*, Vol 5, No 2, 1999