UNC-CH Comp/Phys/Apsc 715

2D Scalar: Color, Contour, Height Fields, (Glyphs), Textures, and Transparency

Example Videos

- Vis 2006: ritter.avi
  - Displaying vascular structures using strokes
- Vis2006: krueger.avi
  - Interactive Hot Spot visualization

Administrative

- Homework 1 ready
  - Lead: schedule with partner (doodle.com)
  - Post questions to Russ
  - Due next Thursday midnight
  - Fill out review forms individually and email Russ
- Use perceptual information from Ware Ch3&4
  - Guide color, contrast, display type choices
  - NOTE the guidelines from Ware you used by number and how they led to your choices!
  - NO PEEKING: Don't upload until your design is done

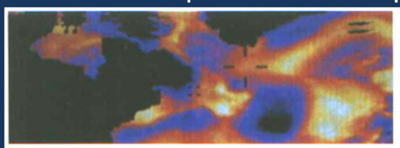
Administrative

- Post by next Thursday, midnight
- Post reviews before Monday evening

2D Scalar Techniques

- Pseudocolor maps
- Contour lines and bands
- Height fields
- Textures
- Transparency
- (Glyphs)

Pseudocolor Sequences for Maps



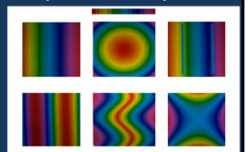
- Application 3 from Ware Chapter 4
- Represent continuously-varying map data using a sequence of colors
- Not showing surface shape, but laying data on top of plane (or other geometry)

Which Pseudocolor Sequence?

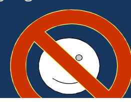
- Labeling
  - Spectrum approximation (Rainbow)
  - Nominal coding (maybe custom to data set)
  - Custom sequences: Geographical (Terrain approx.)
- Showing values (perceptually ordered)
  - Opponent channels
    - Grayscale (Intensity), Red/Green, Yellow/Blue
  - Blackbody radiation spectrum
    - And its five kindred
  - Saturation Scales (sometimes isoluminant)
  - Double-ended scales

Spectrum Approximation (Rainbow)

- Not Perceptual
  - Ordering (Roy G. Biv)
  - Random banding
    - Just-Noticeable Differences vary
  - Uncontrolled luminance change



- Flat regions interleaved with rapidly-changing regions produces spurious slope estimates
  - Actively misleads



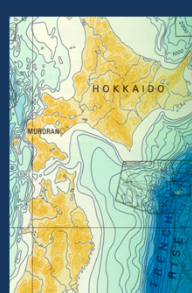
See reasons above

Nominal Coding

- May be a better choice than rainbow for labeling
- Ware suggests using these colors, from left to right:

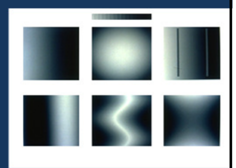
Custom Sequences

- Particular to problem domain
  - Map onto relevant colors
- Geography
  - Green lowlands through brown to white mountain peaks
- Charting
  - Deeper blue for deeper water, darker brown for higher land
  - Double-ended scale

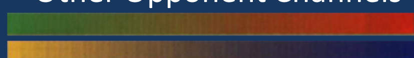


Values: Luminance (Grayscale)

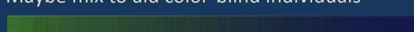
- Perceptual
  - Ordered
  - JND mapping known
- (Ab)uses surface perception machinery
  - Good for high-freq. data
  - 20% errors on abs value
- Not as good for labeling
  - 4-5 levels



Other Opponent Channels

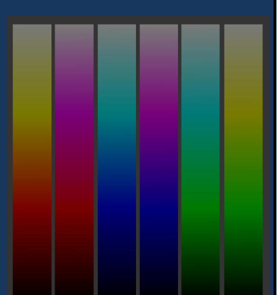


- Green/Red and Yellow/Blue
- Perceptually ordered
- Can change luminance
  - Better for higher frequencies
- Can be Isoluminant
  - "Plays well with others"
- Maybe mix to aid color-blind individuals



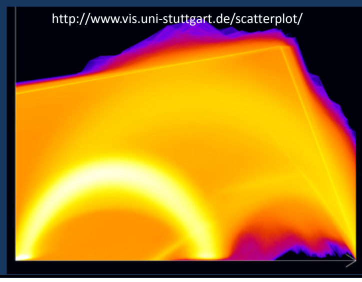
Blackbody Radiation and Kin

- Heated-object scale
  - Each of R,G,B up in 1/3
- Longer path than grayscale
- Perceptually Ordered
  - 1st, 3rd, and last?
  - Ordinal scale
- Not uniform JNDs here →
  - Could be normalized
  - Not for Interval sets



Blackbody + Blue

- Increases luminance monotonically
- Adds another color range to the path



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Saturation Scale

- Perceptually ordered
  - Can be made uniform on given monitor
- Can change luminance
  - Better for higher frequencies
- Can be Isoluminant
  - "Plays well with others"

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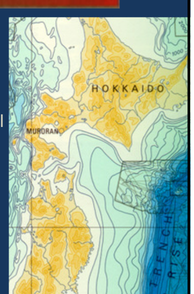
Double-Ended Scales

- Two back-to-back perceptual scales
  - Ordered
  - Could be made uniform if needed
- Along opponent or other channels
- Through gray or other to indicate special value
- Can change luminance →
  - Better for higher frequencies
- ← Can be Isoluminant
  - "Plays well with others"



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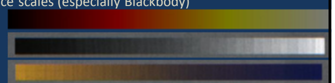
Pseudocolor for Maps: What to use?

- Single Scalar Fields
  - Nominal: Labeling up to 12 ranges
    - Based on these colors →

  - Ordinal: Perceiving shape of maximal/minimal areas
    - Increasing-luminance scales (especially Blackbody)
    - Opponent scales
    - Saturation scales

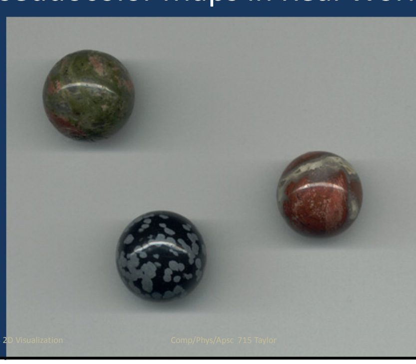


  - Ordinal with Special Values
    - ← Double-ended scales (perhaps with middle zone)
  - *Not normally* Interval / Ratio for any scale
    - Up to 20% *average* errors

Pseudocolor for Maps: Rules of Thumb

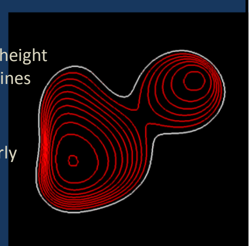
- More detail → Luminance variation required
  - Avoid obscuring shape → Isoluminant
- Ordered: opponent or saturation, not hue
  - Even smoothly-changing hues seem abrupt
  - May not match actual data boundaries → miscategorize
- Nominal: use Ware's 12 colors
- Ware: Upward spiral in color space (Black/bluebody)
  - Each hue higher luminance than the prior
  - Color change reduces luminance contrast effects
- Watch for R/G and B/Y color blindness

Pseudocolor Maps in Real World



Contours

- Lines drawn along isovalues in data
- Example:
  - Red contours at regular steps in height
  - White line drawn every ten red lines
- Benefits:
  - Can show quantitative data clearly
    - Interval/Ratio data display
  - Can reveal 2D shape of specific regions (land mass)



Bands

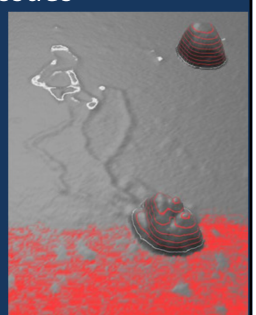
- Fill areas between contour levels with color
  - Quantitative values at the transition lines
  - Labels regions

Banding in the real world

- Door paint-wear
  - Black, blue, white, pink
  - Where people push door

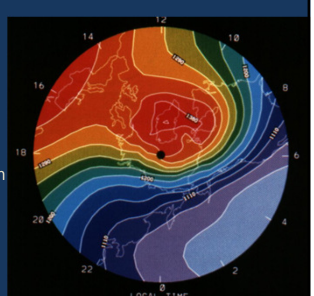
Contour Issues

- Contours at non-data-relevant values are confusing or misleading
- Flat areas at contour value can cause problems



Combining Contours and Bands

- Two Contours
  - Isothermals
  - Land/sea borders
- Bands
  - Isothermals
  - Group and Distinguish
- Labels
  - Indicate values
  - Contrasting Surround



Combining Contours and Bands

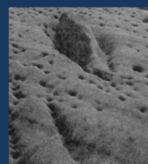
- Several Contours
  - Iso-Altitude
  - Land/sea (and river) borders
  - Regions within sea
- Bands
  - Iso-Altitude
  - Group and Distinguish
  - Double-ended, ordinal scale

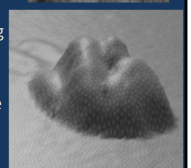
Contours and Bands Summary

- Both indicate regions
  - Contour by showing the boundaries
  - Bands by showing the interiors
- Benefits
  - Good for showing 2D shape of important features
  - Provide quantitative (interval, ratio) measurements
  - Varying width can indicate slope to some extent
- Negatives
  - Miscategorize if levels not at relevant data values
  - Not as good as height-field at showing 3D shape

Height Fields

- Map data value to height above 2D plane
  - Use geometry + lighting to show 3D shape
  - Ware recommends + texture + shadows
- Applies to any 2D scalar field
  - If data is height, this is the natural mapping
    - May exaggerate or reduce height scale
    - Say so if you do!
  - If data is some other field, still can be done
    - Nominal field requires imposing some order





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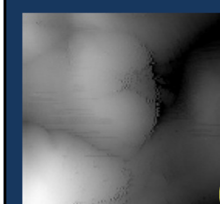
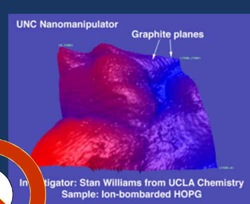
Height Field for 3D Shape

- Shows details over the entire height range
- Sensitive to lighting direction





Non-isoluminant color

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Height Field for 3D Shape

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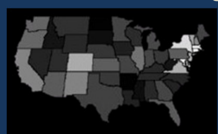
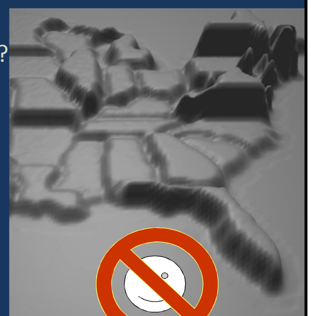
Height Field for Nominal?

- Which are same level?
- Maine obscured
- 3D view adds nothing





See reasons above

Height Field for 2D Regions

- High-frequency 2D boundaries destroyed
- Value comparisons not improved

See reasons above

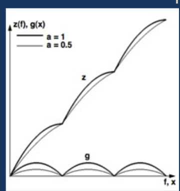
Height Field Characteristics

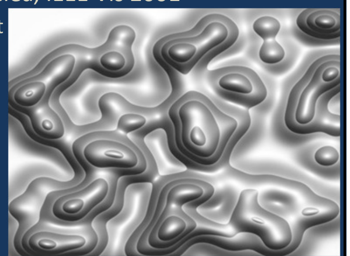
- Enables best understanding of 3D shape
- Enables viewing of details in context
- Qualitative interval and ratio data
  - accurate locally?
- Forms surface to apply other techniques on top of

- Not well suited for:
  - Nominal data display
  - Display of fine features in 2D regions
  - Quantitative estimate of relative height of distant areas?

Enridged Contour Lines: Using Height for Contour

- Van Wijk and Telea, IEEE Vis 2001
  - Bands in height
  - Parabolic map





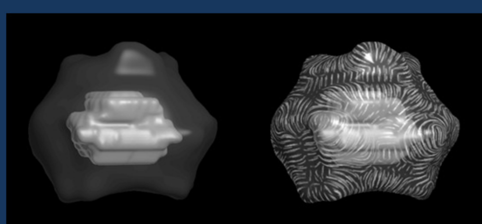
Textures for Data Display

- Uses of texture:
  - Improve surface shape comprehension
  - Display of data independent of surface shape
    - (Multivariate display comes later)
- Dimensions for data display:
  - Orientation
  - Density (scale)
  - Regularity
  - Intensity (presence of a texture component)
  - Surface normal adjustment (geometric detail texture)
  - Surface albedo adjustment (shiny, dull, etc)
  - Frequency content, details of the texture (vague)

Regular Texture Improves Surface Comprehension

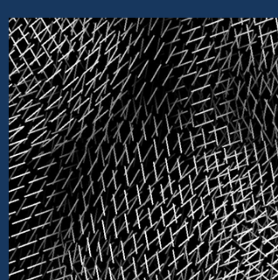
Texture Improves Surface Comp.

- Victoria Interrante



Texture Dimensions: Orientation

- Can tell +/- 15 degrees
  - preattentively
- Angle:
  - Nominal, Ordinal, Interval
- Presence at angle:
  - Ordinal
  - Interval?
  - Hard to see regions
  - Background helps contrast

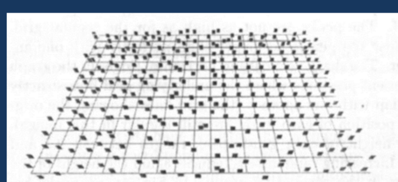


Density (Scale)

- Note the size illusion (both patches same scale)

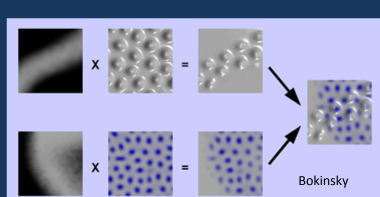
Regularity

- A regular patch of texture in a field of irregular texture [Healey and Enns]



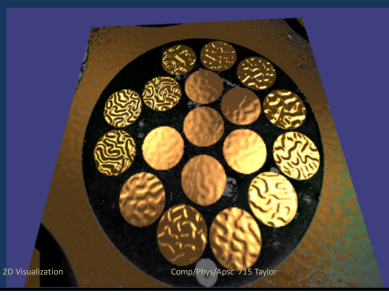
Other Texture Dimensions

- Intensity: Presence of texture modulated by data
- Surface normal adjustment: Geometric Detail



Other Texture Dimensions: Albedo

- Albedo: Surface reflectance changes



Albedo in the Real World

Frequency Content / Appearance

- Texture for labeling
  - More numerous than colors
  - Need large patches to see

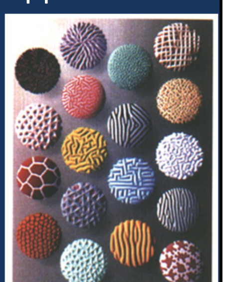


Figure 5.20 Textures from Witkin and Kass (1991).

Texture Characteristics

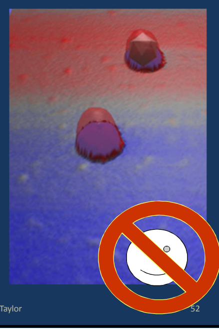
- Can improve understanding of surface shape
  - Required to make transparent surface shape perceptible
- Effective for:
  - Nominal: different textures for different areas
  - Ordinal: Presence of the texture
  - Interval: Orientation
- Can be used to show multiple data sets
  - Mixture of similar texture elements
  - Presence of particular texture element indicates data
  - More on this topic in “multivariate” lecture

Uses of Transparency

- Enable seeing through to another object
- Comparing the relative shapes of two objects
- Displaying a separate data set

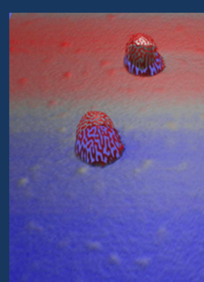
Seeing Through to Objects

- Translucent surface
  - Lose shape of front surface
    - Except at silhouette
  - Difficult to compare shapes
- Only makes sense in 3D
  - 2D → mix with background



Comparing Relative Shapes

- Erode portion of surface
  - Preserves perception of shape
  - Enables comparison
- Best with stereo + motion



Displaying Separate Data Set

- Transparency is a poor choice for this
  - Destroys surface shape perception in 3D
  - Is the same as mixing color in 2D
- Perhaps for visualizing uncertainty?

Transparency Characteristics

- Often obscures perception of closest object
  - May be useful for visualizing uncertainty
  - Useful when foreground object is not important (gives context)
- Enables comparison of 2+ objects
  - Requires texture to perceive first-object shape
- Only makes sense combined with surface

(Glyphs)

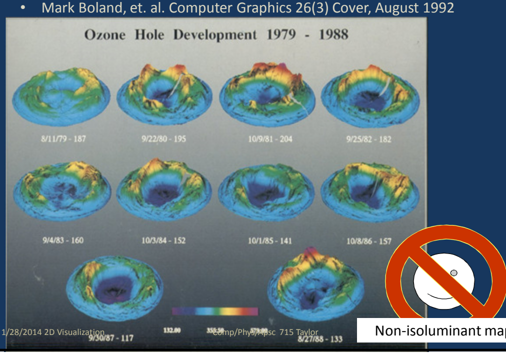
- Used to display multiple data sets
- Described in the later lecture on this topic

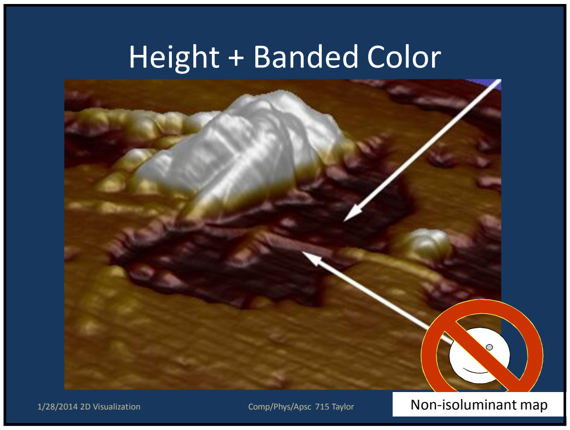
2D Techniques: Mix and Match

- Redundant Encoding
  - Shows the same thing multiple ways
  - Get advantages of multiple techniques
- Displaying Multiple Data Sets

Height + Color

- Mark Boland, et. al. Computer Graphics 26(3) Cover, August 1992




Height + Banded Color
Non-isoluminant map
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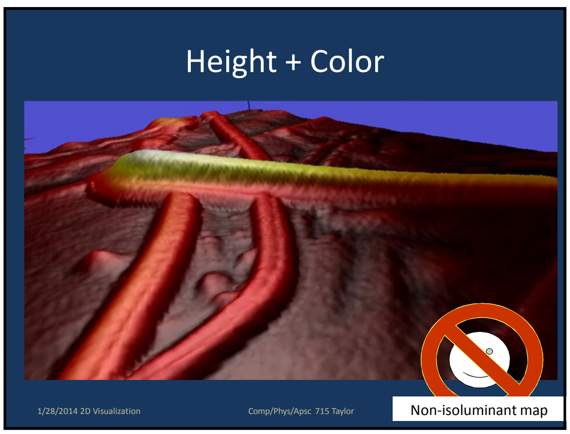
Height + Color
Non-isoluminant map
1/28/2014 2D Visualization
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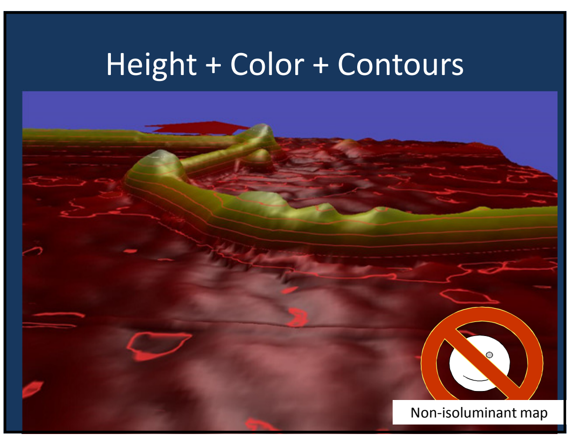
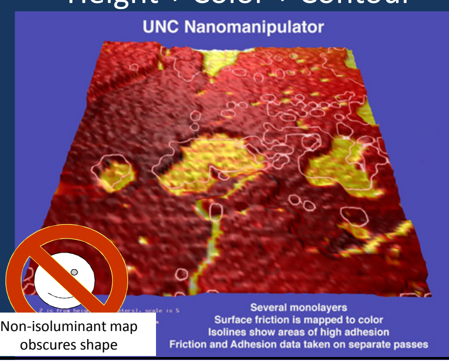

Height + Color + Contours
Non-isoluminant map

2D Techniques: Mix and Match

- Redundant Encoding

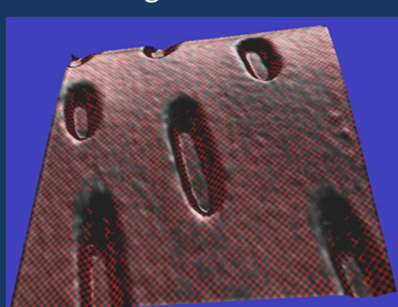
➢ Displaying Multiple Data Sets
  - Explored in detail in Multivariate Display
  - Careful to not mask one by adding another

Height + Color + Contour

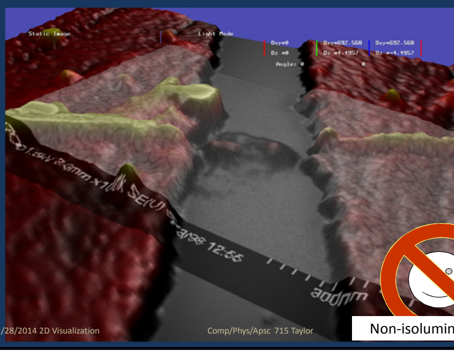


Non-isoluminant map obscures shape

Height + Texture



Height + Color + Intensity



Non-isoluminant map

Height + Color + Contour

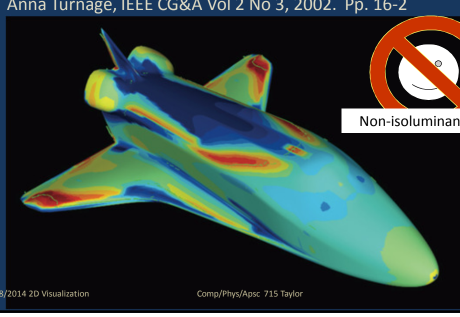
Topography of Food Network's Fan Base

A look at where all the 906,539 comments on FoodNetwork.com come from.

Cliff Huang, Wired 10/29/2013
http://www.wired.com/design/2013/10/26-amazing-food-infographics

Color + Model

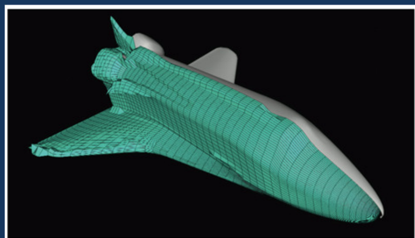
- Anna Turnage, IEEE CG&A Vol 2 No 3, 2002. Pp. 16-2



Non-isoluminant map

Height Field over Model

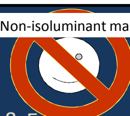
- Anna Turnage, IEEE CG&A Vol 2 No 3, 2002. Pp. 16-21



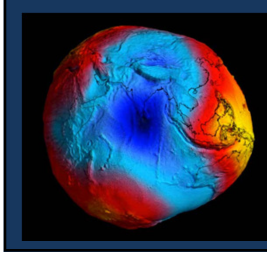
6 Boundary-layer thickness displayed as a scaled elevated surface.

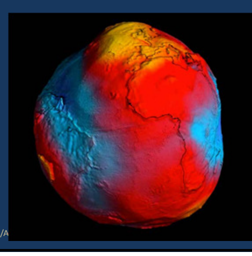
Height Field + Surface detail

Non-isoluminant map



- "Potato Earth": BBC NEWS Science & Environ
  - Deformation and color from gravity at surface





Color + Enridged Contour Lines

- Van Wijk and Telea, IEEE Vis 2001

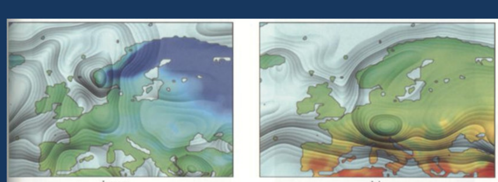


Figure 11: Average temperature (color) and precipitation (height) in Europe

Color + Enridged Contour Lines

- Van Wijk and Telea, IEEE Vis 2001

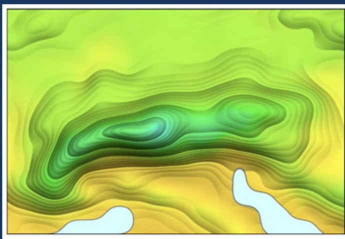
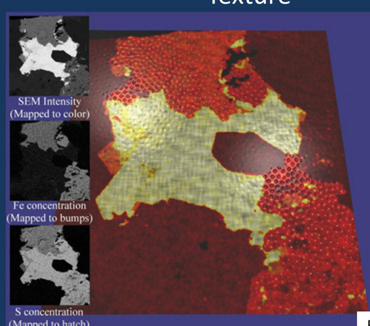


Figure 13: Average temperature (color) and precipitation (height) Alpes, July

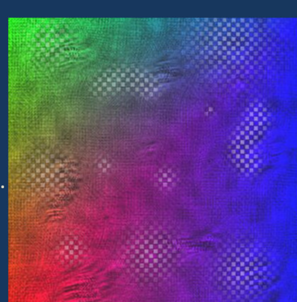
Color + Image Texture + Geometric Texture



Bump and hash textures interfere with each other

Color + Image Textures (Yuck!)

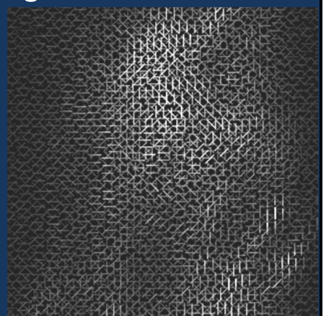
- Three data sets
  - Hue
  - Hatch presence
  - Texture orientation
- Hatch masks orient.
- Orient. not so good



See reasons above

Four Image Textures

- Chris Weigle (UNC)
- Four tex. orientations
  - One per tube orient.
  - Intensity for each
- Total int. = Total tubes



Color + Image Texture

- UNC: Oriented Slivers and Color Show Multiple SEM Data Sets [Weigle00]

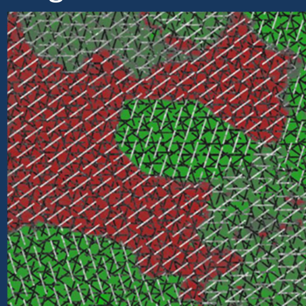
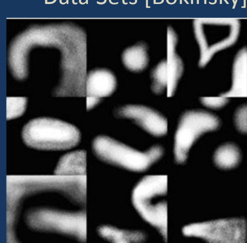
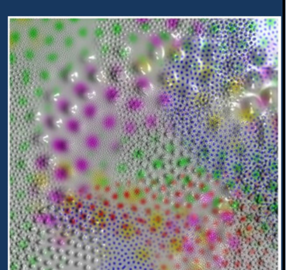


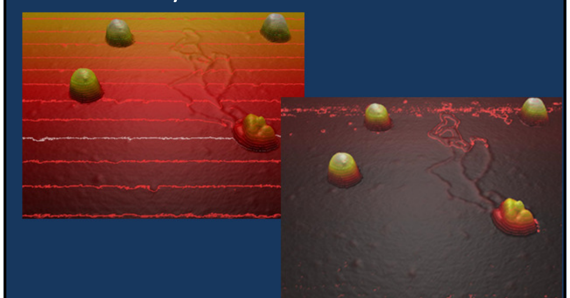
Image + Geometric Textures

- UNC: Data-Driven Spots Show Multiple Data Sets [Bokinsky]





2D Techniques Hint: You may need to flatten the data



2D Scalar Techniques: Summary

- Several available techniques for 2D scalars
  - Pseudocolor, contours and bands, height fields, textures, transparencies, glyphs
- Each is more appropriate for some data/task
  - Nominal, ordinal, interval, ratio
  - Finding extrema, understanding 3D shape, finding regions with similar values, quantitative measurements
- Can combine techniques
  - On the same data: improve perception
  - On different data sets: Multivariate display

Other 2D Scalar Techniques

- Others not described in detail
  - Animation (coming in later lecture)
    - To show time-series of data as it changes
    - Textures sweeping across surface
    - More motion in orbit with larger data value, or different phase
  - For multivariate display (later lecture)
    - Sequential presentation, toggling in place
    - Side-by-side presentation
    - Stacked 2D layers in 3D

References

- “Orientation”, “Four Image Textures”, “Color + Height Texture”: Chris Weigle’s Oriented Slivers
- “Other Texture Dimensions” and “Image + Geometric Textures”: Alexandra Bokinsky’s Data-Driven Spots
- “Height + Color + Intensity”: Adam Seeger’s combined SEM/AFM visualization with the nanoManipulator
- Others: Colin Ware, “Information Visualization”