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

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

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”

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”
Pseudocolor for Maps: What to use?

• Single Scalar Fields
  – Nominal: Labeling up to 12 ranges
  – Based on these colors
  – Ordinal: Perceiving shape of maxima/minima areas
  – Increasing-luminance scales (especially Blackbody)
  – Opponent scales
  – Saturation scales

• Ordinal with Special Values
  – Double-ended scales (perhaps with middle zero)
  – 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 Surrounding
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

Height Field for 3D Shape

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

Non-isoluminant color

Coloration: blue is low, red high
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

See reasons above
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

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Texture Improves Surface Comp.
• Victoria Interrante

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

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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
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

Ozone Hole Development 1979 - 1988

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

[Image of a non-isoluminant map]

Height + Color + Contour

[Image of a topographic map of Food Network's fan base]

Color + Model

Height Field over Model


Height Field + Surface detail

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

Color + Enridge Contour Lines

- Van Wijk and Telea, IEEE Vis 2001
Color + Enridged Contour Lines

- Van Wijk and Telea, IEEE Vis 2001

![Contour Lines Image]

Color + Image Texture + Geometric Texture

- Bump and hash textures interfere with each other

![Texture Image]

Color + Image Textures (Yuck!)

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

![Texture Image]
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”