Comp/Phys/APSc 715

Multivariate & Ensemble Visualization Techniques

Preview Videos

- Vis '97: Visualization of Music (video)

Administrative

- HW2 due tonight
  - Private posts to the homework page
  - No peeking at image files for other users before turning yours in
- HW4 posting by tonight

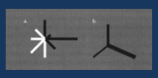
Team Dynamics

- Working in teams is…
  - Good, because you can do more work
  - Hard, because of scheduling, communication, expectation management
- Scheduling: Right After Class Find Partner
- Communications/Expectation Management
  - Default: Work together on this at the same time
  - Clearly split the work and provide hard deadlines
  - Everyone participates equally: one member is not supposed to be doing all the work

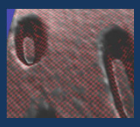
Multivariate Data Display

- At the frontier of data visualization
- More art than science
  - Several combinations can show 2-3 data sets
  - Attempting combinations beyond this is difficult
- Perceptual studies can help predict effectiveness
  - Avoiding interfering techniques gets you further
  - Still need to try it out and see
- Easier in 2D than 3D
- Several techniques shown today, some with characteristics listed

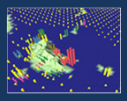
Multivariate Display Techniques



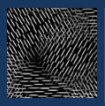
- Glyphs

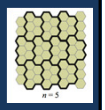


- Heterogeneous Techniques

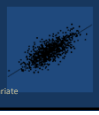


- Texture





- Layering/Subdividing



- Data Reduction

Glyphs

- Single graphical icon displaying multiple variables
  - Shape, color, other features
- Designed for discrete, non-spatial data
- Can be used to display fields
  - Scatter within 2D or 3D space
  - Display local characteristics

Classical Glyphs: Chernoff Faces

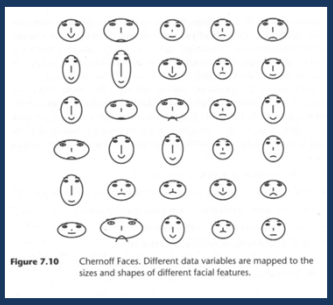


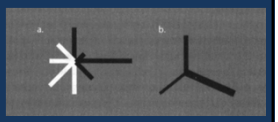
Figure 7.10 Chernoff Faces. Different data variables are mapped to the sizes and shapes of different facial features.

Glyph Techniques

Stick hard to use

- Paul Ferry, SKIGRAPH '99
  - Profile Icon, Star Icon, Stick figure Icon

- Ware
  - Probably only 3-4 distinguishable orientations
  - Don't use parallel ones (as the figure on the right above does)
  - Varying color polarity adds more
  - Varying line width adds more



Glyphs: Color + Size Vary

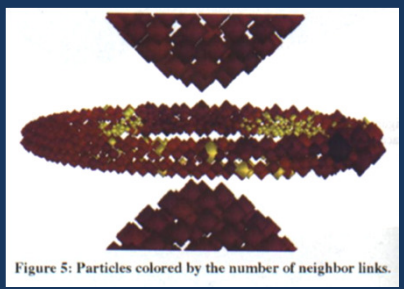
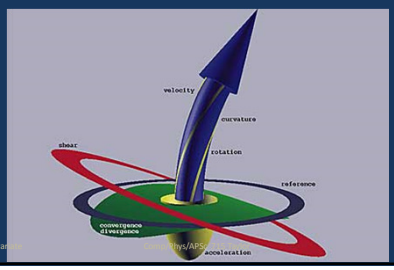


Figure 5: Particles colored by the number of neighbor links.

Glyph: Flow Probe

- Wijk, J.J. van, A.J.S. Hin, W.C. deLeeuw, F.H. Post, "Three Ways to Show 3D Fluid Flow." IEEE Computer Graphics and Applications, vol. 14, no. 5, p. 33-39, September 1994.



Characteristics of Glyphs

- Preattentive detection rules from before apply
  - size, orientation, and color coding
- Integral vs. Separable dimensions
  - Integral dimensions are perceived holistically (upper)
  - Separable dimensions perceived independently (lower)

red-green	yellow-blue
red-green	black-white
shape height	shape width
shape	size
color	size
direction of motion	shape
color	shape
color	direction of motion
x,y position	Size, shape, or color

- Attributes:
- Sirens' Song:

Visual variable	Dimensionality	Comment
Spatial position of glyph	3 dimensions: *X, Y, Z.*	
Color of glyph	3 dimensions: defined by color opponent theory.	Luminance contrast is needed to specify all other graphical attributes.
Shape	2–3? Dimensions unknown.	The dimensions of shape that can be rapidly processed are unknown. However, evidence suggests that size and degree of elongation are two primary ones.
Orientation	3 dimensions: corresponding to orientation about each of the primary axes.	Orientation is not independent of shape. One object can have rotation symmetry with another.
Surface texture	3 dimensions: orientation, size, and contrast.	Not independent of shape or orientation. Uses up one color dimension.
Motion coding	2–3? Dimensions largely unknown, but phase may be useful.	
Blink coding: The glyph blinks on and off at some rate.	1 dimension.	Motion and blink coding are highly interdependent.

Figure 5.26 Graphical attributes that may be used in glyph design.

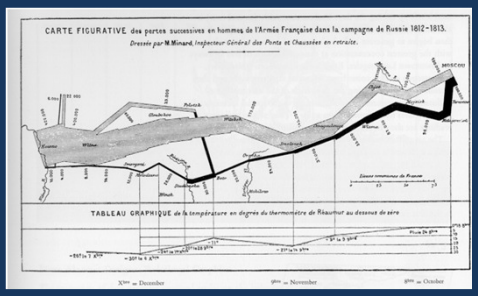
Number of Displayable Values

- Many dimensions not independent
  - Texture relies on at least one color difference
  - Blinking and motion coding will interfere
  - Fortunate if you can display 8-dimensional data with color, shape, spatial position (not for glyphs in space), and motion.
- Number of resolvable steps in each dimension
  - Maybe 4 values for each
  - Disallowing conjunction searches leaves 32 alternatives
- ~4 values for each of 8 channels – 6 in spatial data
  - We didn't see more than 3 work together at high density when doing combinations of different techniques

Heterogeneous Techniques

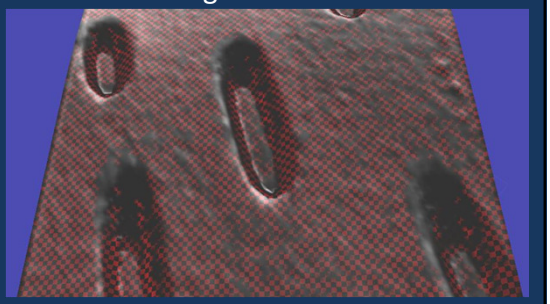
- "Wandering in the desert"
  - "Simpleton" ideas prove their worth
- Throw a bunch of techniques together
- Hope for the best
  - Works okay for a few data sets
  - We found it hopeless for large numbers of sets

Heterogeneous 2D: Location + Width + Color



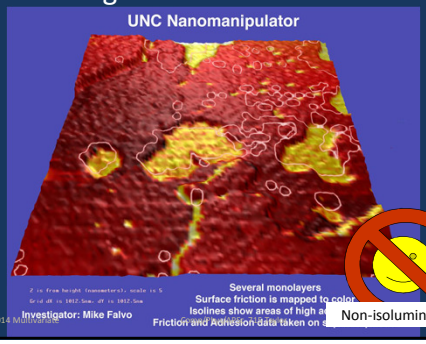
UNC Nanoscience

Heterogeneous 2D: Height + Texture



UNC Nanoscience

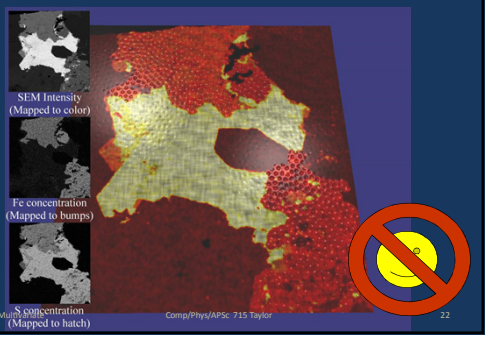
Heterogeneous 2D: Height + Color + Contour



Non-isoluminant color

UNC Nanoscience

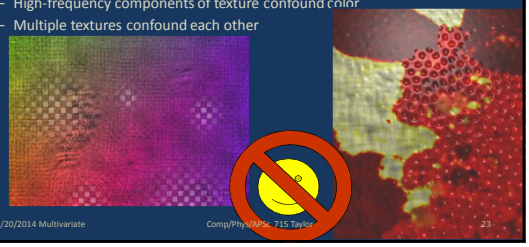
Heterogeneous 2D: Color + Texture + Bump Tex



UNC Nanoscience

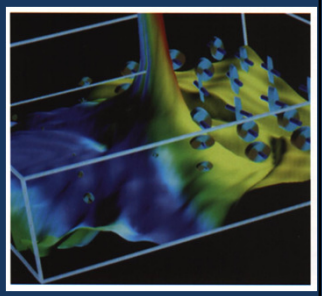
Heterogeneous 2D

- Promise
  - 1 Height dimension, 2 Color dimensions, 3+ Texture dimensions = 6+ perceptual dimensions
- Results
  - Luminance contrast in color confounds shape
  - High-frequency components of texture confound color
  - Multiple textures confound each other



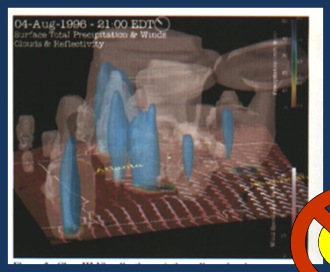
Heterogeneous 2D: Height + Color + Glyph

- Haber, Koh, Lee
  - UIUC
- Found in
  - Keller & Keller p. 62



Rainbow

Heterogeneous 3D: Slice + Contour + Color + Tex.



Heterogeneous 3D: Surface + Color + Texture

- Vis 2001: Severance, Lazos, Keefe, "Wind Tunnel Data Fusion and Immersive Visualization"

Rainbow

Color Plate 1. Texture mapped oil flow images colored by pressure on the front wheel. Flow direction is from lower left to upper right.

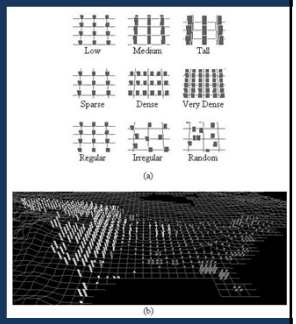
Color Plate 3. Final data fusion of oil flow images, surface pressures, and velocity measurements for the landing gear configuration. Flow direction is from left to right.

Texture-Based Multivariate 2D

- Varying several characteristics to display data
  - Adjusting size, density, and regularity
  - Adjusting size, orientation, and density
  - Adjusting scale, orientation, and contrast
  - Spot Noise: Adjusting orientation and hue/saturation
- Varying a single characteristic to differentiate between multiple layers, intensity in each layer (both texturing and layering technique)
  - Beyond four scalar fields in the same image
  - Oriented Slivers
  - Data-Driven Spots

Texture Dimensions

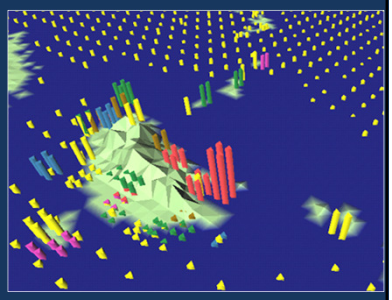
- Chris Healey
- Height = cultivation level
- Density = ground type
  - Sparse = alluvial
  - Dense = wetland
- Grayscale = vegetation
  - Dark = plains
  - Light = forest
  - White = woodland



Chris Healey: Size, Density, Regularity, Hue

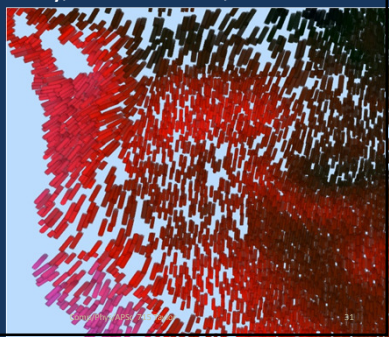
Sort of like glyphs + arrangement

Result is ~texture



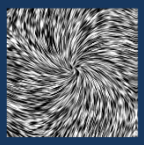
Chris Healey: Size, Density, Orientation, Color

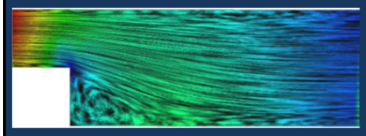
Dense glyphs form a texture



Texture: Spot Noise

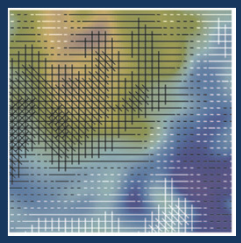
- Invented by JJ van Wijk, SIGGRAPH 1991
  - Spot orientation, spot size, hue
  - Can vary scale
  - Can vary shape
    - Affects texture

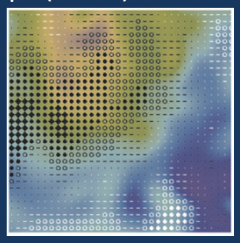




Rainbow

Quantitative Texton Sequences for Bivariate Maps (Ware)



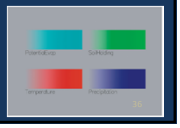


Layer-Based Multivariate 2D

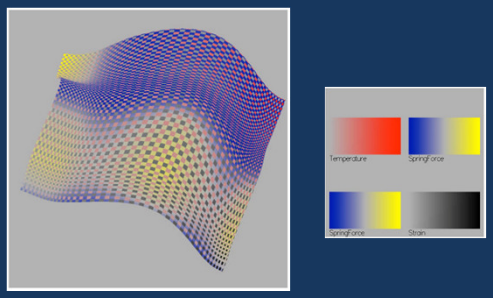
- Subdividing the surface
- Varying a single characteristic to differentiate between multiple layers, intensity in each layer (both texturing and layering technique)
  - Beyond four scalar fields in the same image
  - Oriented Slivers
  - Data-Driven Spots
  - Nested and intersecting surfaces
- Layering heterogeneous techniques
  - Crawfis
  - Laidlaw
  - Urness/Interrante

Attribute Blocks: Visualizing Multiple Continuously Defined Attributes (James Miller)

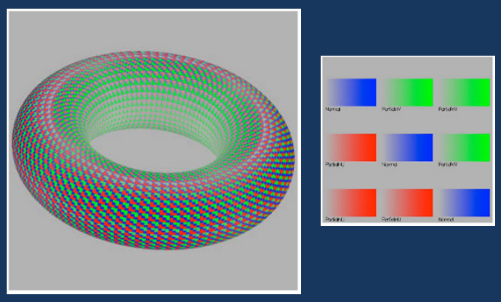
Cyan isoluminant with background



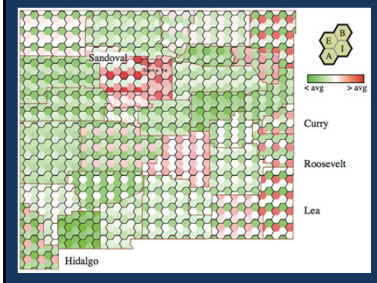
Multivariate Visualization on Parametric Surfaces (James Miller)



Multivariate Visualization on Parametric Surfaces (James Miller)



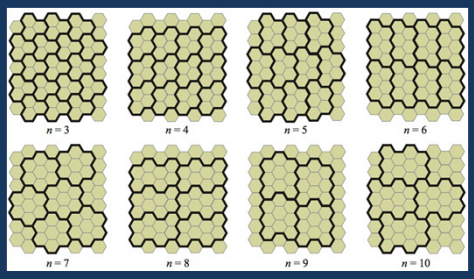
Visualizing Multidimensional Scalar Data Using Hexagonal Tiles (Ramachandran and Healey)



New Mexico State

Employment
Affluence
Bachelor's degree level
Income

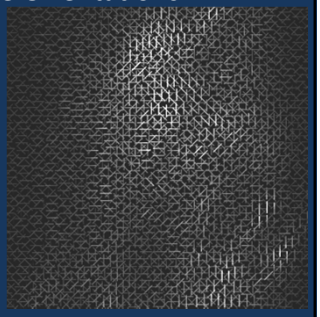
Visualizing Multidimensional Scalar Data Using Hexagonal Tiles
(Ramachandran and Healey)



Chris Weigle, UNC

Oriented Slivers: Four Tube Orientations

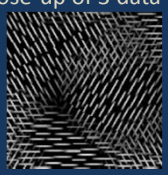
- Four scalar fields
  - Here, 4 orientations
  - Each mapped to displayed orientation
- Overall intensity shows total amount of material

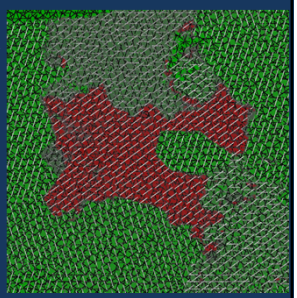


Chris Weigle, UNC

Oriented Slivers

- Background color shows another data set
  - Reveals dark slivers
  - Shows region boundary
- Close-up of 3 data sets





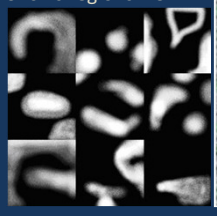
Oriented Sliver Characteristics

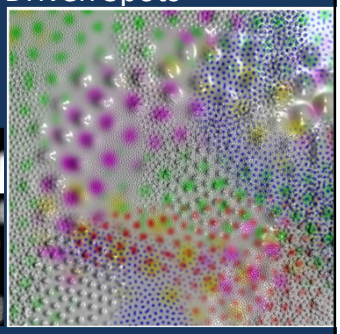
- User study shows that 15-degree orientation difference can be easily seen
  - Enables 7+ data sets to be displayed!
- Russ claims:
  - Enables relative value estimation for all data sets at a point
  - Difficult to see boundary of a region with a particular orientation
  - Easy to see where no data sets are present

Alexandra Bokinsky, UNC

Data-Driven Spots

- 9 Scalar fields
- Each mapped to color or bump size
- Shows regions well



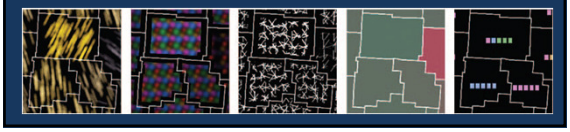


DDS Characteristics

- User studies show
  - At least 9 scalar fields can be shown!
  - Users can attend pairwise to data sets without interference
  - Boundaries of shapes can be seen as well as when they are drawn explicitly
- Animation of one or more data sets is *very* effective
  - Reveals areas with low values
  - Sweeps over entire region, showing boundaries at high resolution
  - Highlights data set(s) of interest
  - link to videos (show 3a)

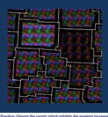
Evaluation of Trend Localization

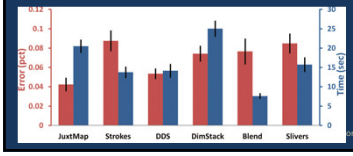
- Mark Livingston, Jonathan Decker; TVCG 2011
  - Strokes (intensity, hue, orientation, width, length); DDS; Oriented slivers; Color blend; Attribute blocks tested against each other
  - Asked for region with largest trend
  - Had to compare two of the five channels

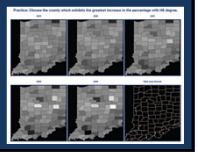


Evaluation of Trend Localization

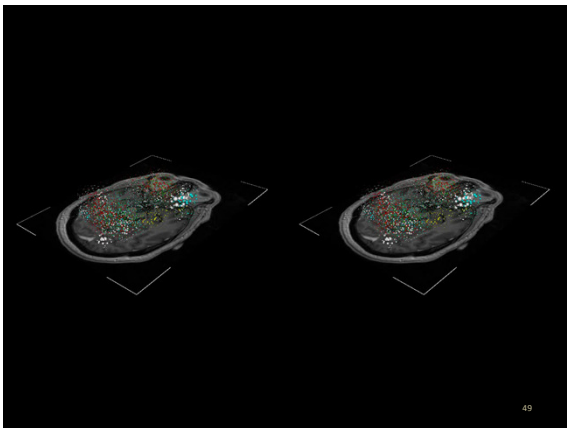
- Mark Livingston, Jonathan Decker; TVCG 2011
  - Also compared against side-by-side ("juxtmap")
  - County blocks provided local alignment cues





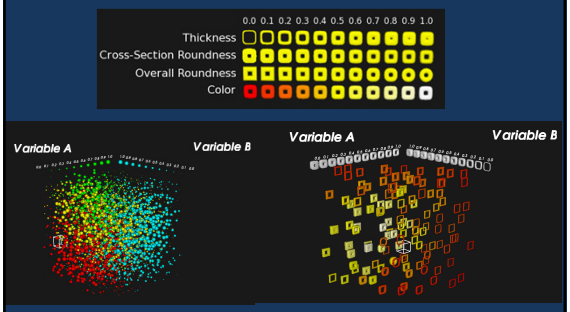


Scaled Data-Driven Spheres (David Feng, UNC)

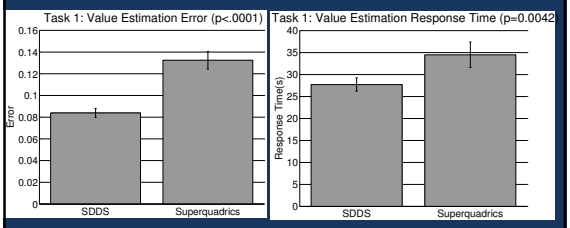


3D SDDS User Study

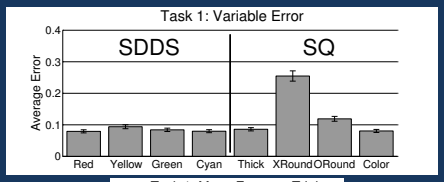
Value Estimation Task

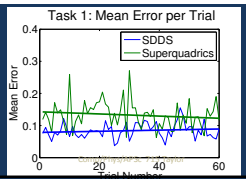


3D SDDS User Study



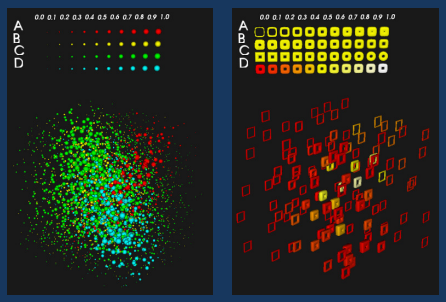
3D SDDS User Study



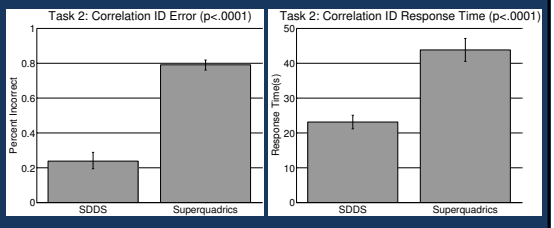


3D SDDS User Study

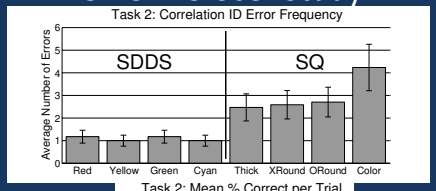
Correlation Detection Task

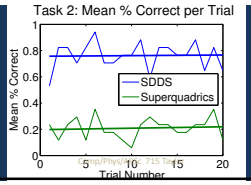


3D SDDS User Study



3D SDDS User Study





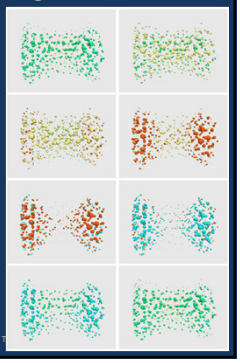
3D SDDS Conclusions

- Layered > Heterogeneous
- Value Estimation:
  - Spheres > Superquadrics
  - Error ~8% / ~13%
- Correlation Identification:
  - Sphere >> Superquadrics
  - Error ~20% / ~80%
- Motion seems to help

Madhura Phadke, NCSU/UNC

Motion SDDS

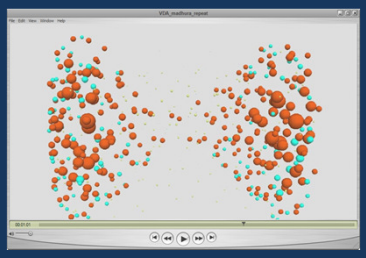
- VDA: Phadke 2012
  - Nominal color by ensemble
  - Sinusoidal scale over time
  - Compares regions pairwise



Madhura Phadke, NCSU/UNC

Motion SDDS Video

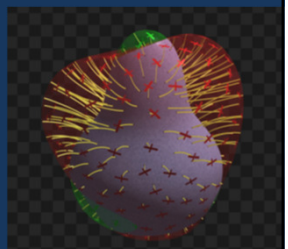
- Can also vary shape and/or color (click movie)



Chris Weigle, UNC

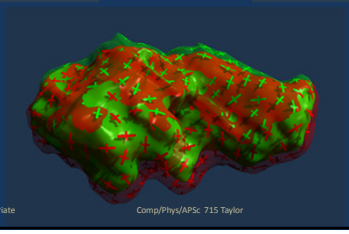
Nested/Intersecting Surfaces

- Chris Weigle (UNC) dissertation
  - Inner/outer factoring
  - Transparent outer
    - Colored
    - Surface glyphs
  - Drop lines
    - Follow heat transfer



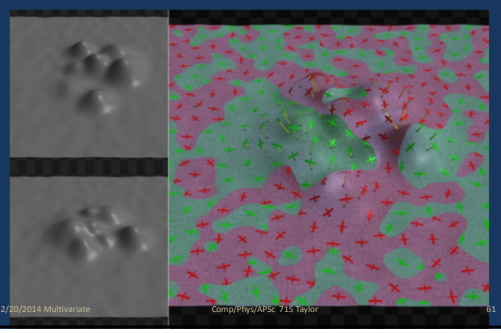
Chris Weigle, UNC

Intersecting-surface display



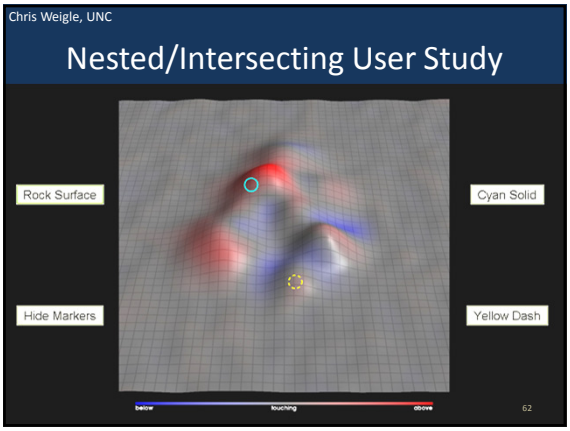
Chris Weigle, UNC

Nested/Intersecting Surfaces



Chris Weigle, UNC

Nested/Intersecting User Study

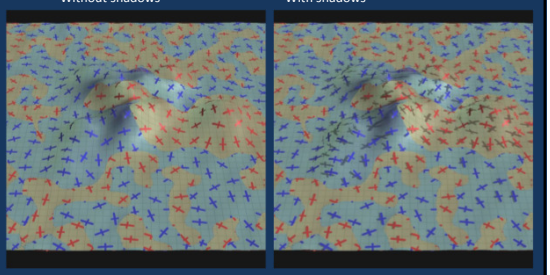


Chris Weigle, UNC

Nested/Intersecting User Study

Without shadows

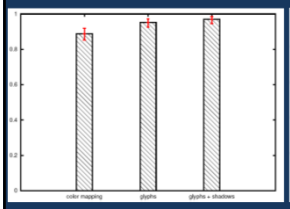
With shadows



Chris Weigle, UNC

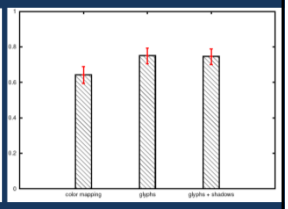
Nested/Intersecting User Study

Inter-surface Distance



Accuracy (more is better)

Surface Orientation

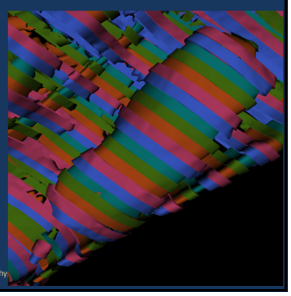


Accuracy (more is better)

Oluwafemi Alabi, UNC

Ensemble Display: ESS

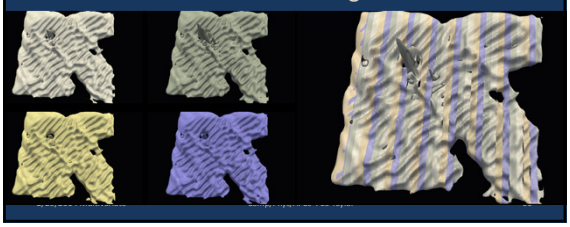
- Ensemble Surface Slicing: VDA Alabi 2012
  - Multiple sims
  - Slice into strips
  - Color nominally
  - Animate slicing



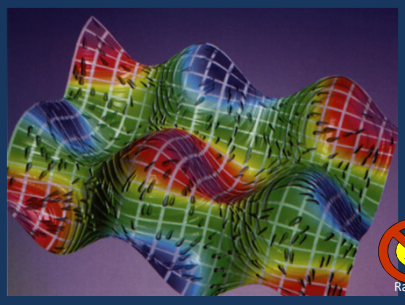
Oluwafemi Alabi, UNC

ESS wildfire example

- Four wildfire simulations
- Same in upper left, obviously different peak
- Subtle differences in lower right



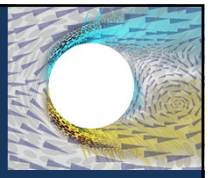
Layering 2D: Crawfis Height + Color + Textures

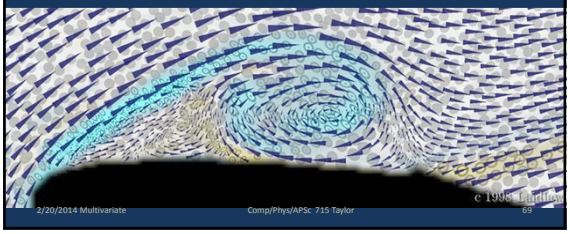


Rainbow

Layering 2D: Laidlaw Color + Sparse Glyphs

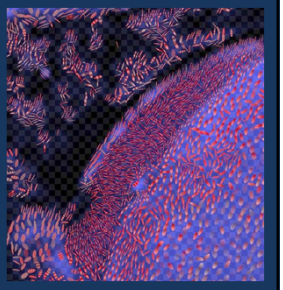
- Flow Visualization
- Black shadow of the geometry
- Color layer, ellipsoid layer, arrow layer





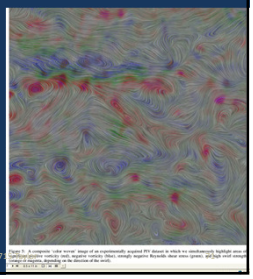
Layered 2D: Laidlaw
Color + Texture + Sparse Glyphs

- Mouse spinal cord
- Texture underlayer
- Color layer
- Glyphs
  - Ellipsoidal
  - Textured



Layered 2D: Texture + Color

- Urness & Interrante, "Effectively Visualizing Multi-Valued Flow Data using Color and Texture"
  - Color each LIC stroke
  - Saturation scale
  - Round-robin colors
  - Red, Blue, Green, Orange
  - Vis 2003



Urness & Interrante Vis 2003 Close-Up

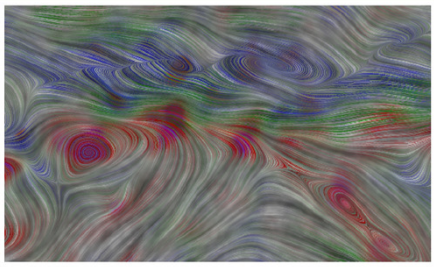
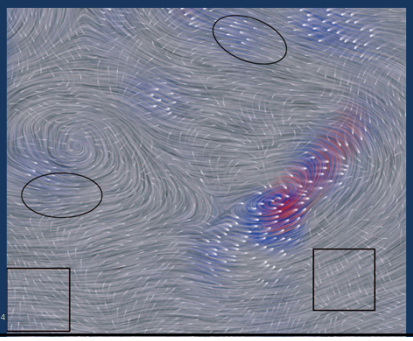
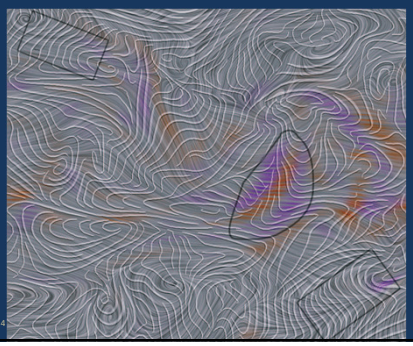


Figure 9: A close-up view of a portion of a color weave image created using a uniformly low frequency input pattern.

Urness & Interrante CGA 2006



Urness & Interrante CGA 2006



Urness & Interrante CGA 2006

- Similar styles interact
  - UL: Two textures
  - ML: Two glyphs
  - LL: Two line-based
- Different styles separate
  - UR: Glyph + texture
  - MR: Line + glyph
  - LR: Line + texture

Layering Summary

- Layering >> Heterogeneous
- Layering >> Varying texture parameters

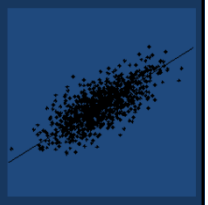
- Use sparse layers
- Use distinct display technique for each layer
  - Similar: discs of different color
  - Similar: Slivers of different orientation
  - Different: Ellipses, arrows
  - Different: Texture vs. line vs. glyph

Problem Reduction Techniques

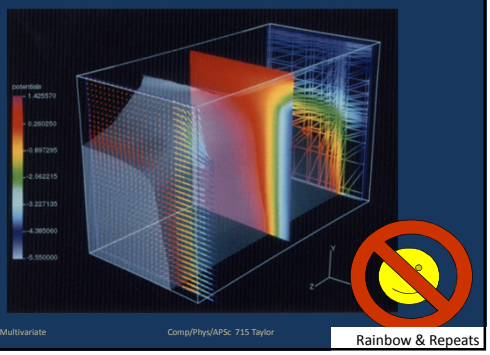
- Dimensional reduction / projection
- Time and space multiplexing
  - Multiple views with different mappings
  - Mapping different fields over time
  - Dynamic Maps
  - Magic Lenses
- Adding computation
  - Smart Particles
  - Cluster analysis / Feature mapping

Dimension Reduction

- Principal-component analysis determines most significant dimensions
  - 2D to 1D shown here
- Project data onto 2D subspace of two largest principal components
  - Color or shape by others

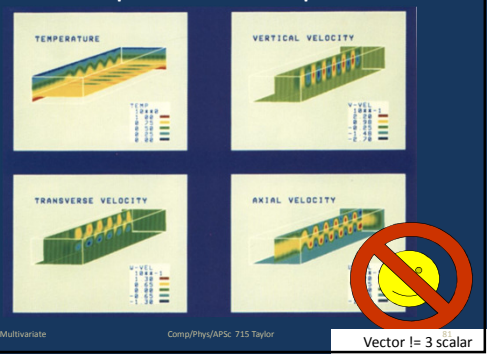


Multiple views in Space



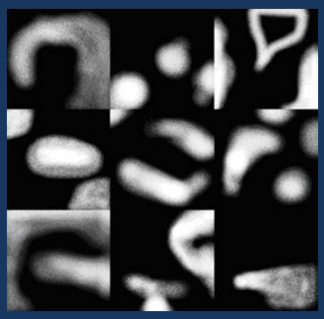
Rainbow & Repeats

Multiple views in Space



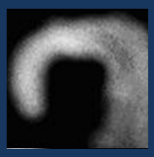
Vector != 3 scalar

Multiple views in Space



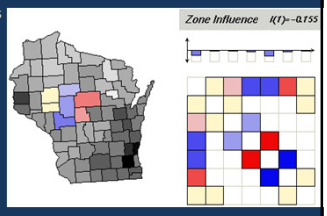
Multiple views in Time

- Cycle data sets through different representations
  - Animated
  - User controlled
- Overlaid on same spatial location



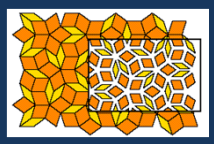
Dynamic Maps

- http://www.geog.le.ac.uk/argus/ICA/j.Dykes/
- Clicking on 2D (or ND) mapping highlights values
  - Column, row, or individual entries in covariance matrix show where on map
  - Map region highlights entries



Example Magic Lenses

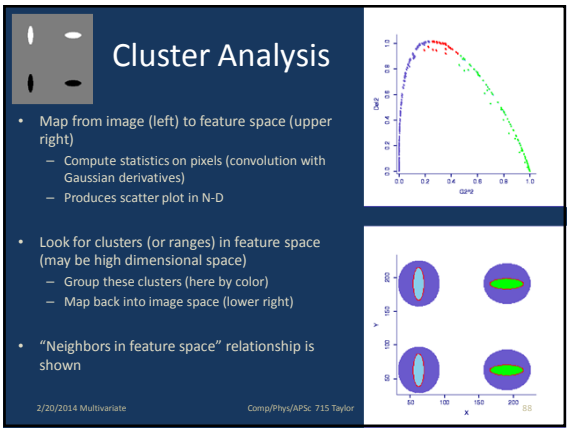
- Local Scaling Lens
  - Adjusts geometry
  - Also could be wireframe

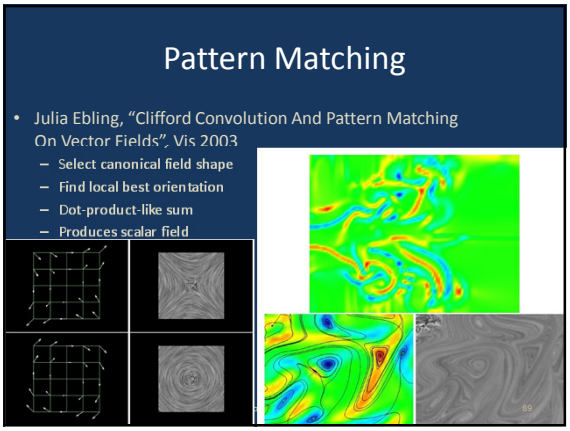


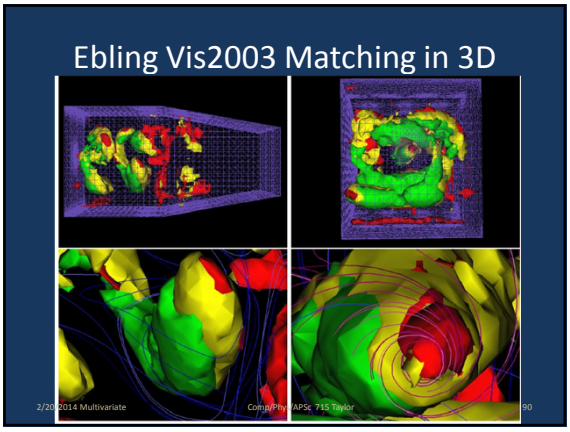
- Gaussian Curvature
  - Pseudo-color map
  - Numeric value overlay

Magic Lenses

- Enable viewing a subset of the data sets, and select others to be viewed in certain areas
  - Toolglass and Magic Lenses
    - Eric Bier, Maureen Stone, Ken Pier, William Buxton, Tony DeRose; Xerox Parc; SIGGRAPH 93
    - Filter the data
  - 3D magic lenses: X-ray vision

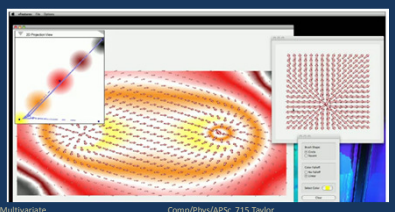

Cluster Analysis
• Map from image (left) to feature space (upper right)
– Compute statistics on pixels (convolution with Gaussian derivatives)
– Produces scatter plot in N-D
• Look for clusters (or ranges) in feature space (may be high dimensional space)
– Group these clusters (here by color)
– Map back into image space (lower right)
• "Neighbors in feature space" relationship is shown
2/20/2014 Multivariate
Comp/Phys/APSc 715 Taylor
88


Pattern Matching
• Julia Ebling, "Clifford Convolution And Pattern Matching On Vector Fields", Vis 2003
– Select canonical field shape
– Find local best orientation
– Dot-product-like sum
– Produces scalar field
89


Ebling Vis2003 Matching in 3D
2/20/2014 Multivariate
Comp/Phys/APSc 715 Taylor
90

Interactive Vector Field Feature Identification

- Joel Haniels II, Arik W. Anderson, Luis Gustavo Nonato, Claudio Silva, Utah
- Link to movie



Conclusions

- Several example techniques
- Perceptual analysis of some of them
- Characteristics known for some of them
- Still an open area of research

Run ScalarStack

- NSRG/CISMM Scalar Stack Viewer
- Load Census data
  - C:\Program Files (x86)\CISMM\...
- Show Colored Slivers
- Show DDS
- Show Oriented Slivers

References

- Texture Dimensions: Chris Healey (http://www.csc.ncsu.edu/faculty/healey/HTML_papers/plankton/plankton.html)
- Typhoon visualization: Chris Healey (http://www.csc.ncsu.edu/faculty/healey/download/tvcg.99.pdf)
- Dense Glyphs/Textons: Chris Healey
- Three Icons: Paul Ferry, SKIGRAPH 99: http://pages.cpsc.ucalgary.ca/~jungle/skigraph99/papers/ferry.pdf

References

- Spot noise image: Wim de Leeuw: http://www.cwi.nl/~wimc/SN_intro.html
- Glyph characteristics and use for multidimensional display: Colin Ware's book, "Information Visualization."
- Cluster Analysis: James Coggins, UNC-CH
- Oriented Slivers: Chris Weigle, UNC-CH
- Nested/Intersecting Surfaces: Chris Weigle, UNC.
- Data-Driven Spots: Alexandra Bokinsky, UNC-CH