Comp/Phys/APSc 715

Patterns, Gestalt, Perceived contours, Transparency, Motion, Uncertainty

Example Videos

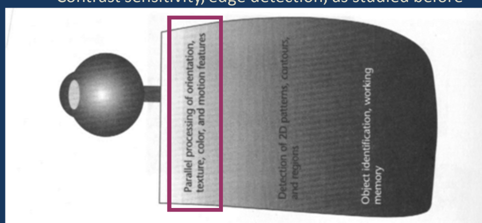
- Vis 2012: Barakat: ttg2012122392s.mov
  - Surface-based Structures in Flow Vis
- Vis2012: Gasteiger: FinalVersion.mov
  - Several views of flow in cerebral aneurysm

Patterns

- Investigation is often about finding patterns
  - That were previously unknown, or
  - That depart from the norm.
- Finding such patterns can lead to key insights
  - One of the most compelling reasons for visualization
- Today we look at
  - What does it take for us to see a group?
  - How is 2D space divided into distinct regions?
  - When are patterns recognized as similar?
  - When do different display elements appear related?

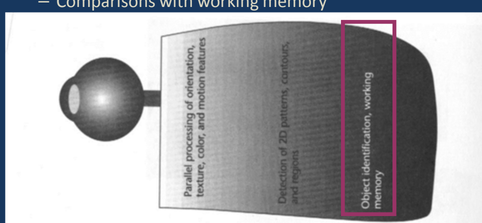
Object Perception Stages

- Stage 1: Parallel, fast extraction
  - Form, motion, texture, color, stereo depth
  - Contrast sensitivity, edge detection, as studied before



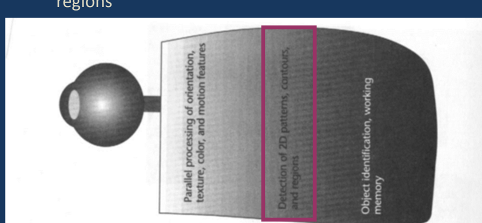
Object Perception Stages

- Stage 3: Object Identification
  - Slower, serial identification of objects within the scene
  - Comparisons with working memory



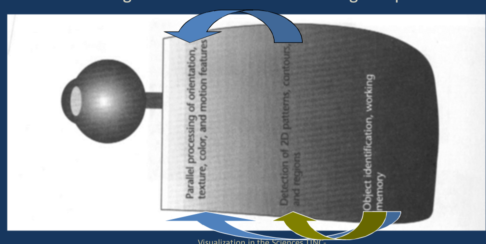
Object Perception Stages

- Stage 2: Pattern Perception
  - Contours and boundaries form perceptually distinct regions



Object Perception Stages

- There is feedback!
  - Linear model is a simplification
  - Later stage intentions affect earlier stage responses



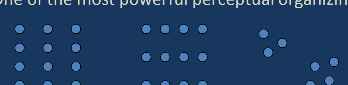
Pattern Perception: Gestalt "Laws"

- Gestalt = "pattern"
  - School formed by Max Westheimer, Kurt Koffka, and Wolfgang Kohler
- Robust rules easily translate into design principles
  - * Proximity
  - * Symmetry
  - * Continuity (and Connectedness)
  - * Closure
  - Similarity
  - Relative Size
  - Figure and Ground

* = stronger cues

Proximity

- Things that are close are grouped together
  - One of the most powerful perceptual organizing principles

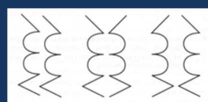


- We perceptually group regions of similar density

- Design Principle: Place related entities nearby

Symmetry (1/2)

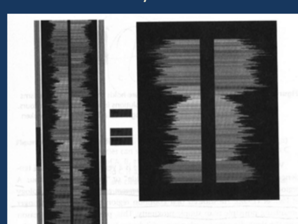
- Bilateral symmetry stronger than parallelism



- Symmetric shapes seen as more likely

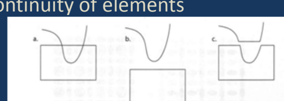
Symmetry (2/2)

- Design principle: Make use of symmetry to enable user to extract similarity

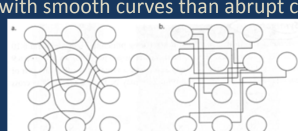


Continuity

- Good continuity of elements



- Easier with smooth curves than abrupt changes



- Design Principle: Connector and crossing linear elements should be smooth, without sharp bends

Connectedness

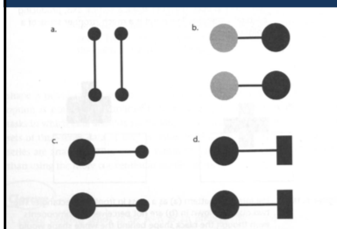
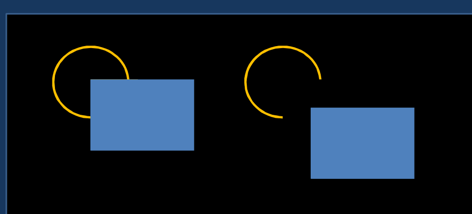


Figure 6.8 Connectedness is a powerful grouping principle that is stronger than (a) proximity, (b) color, (c) size, and (d) shape.

- Palmer and Rock (1994) argue that this is more fundamental than continuity
- Design principle: Positive and negative statement:
  - Connecting two objects can group them even when they are not otherwise similar.
  - Unrelated objects should not be connected, or they will appear to be grouped no matter what.

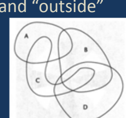
Closure (1/2)

- A closed contour is seen as an object
- Perceptual system will close gaps in contours

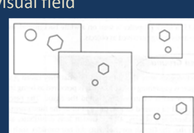


Closure (2/2)

- Contour separates world into “inside” and “outside”
  - Stronger than proximity
  - Venn diagrams from set theory
  - Closure and continuity both help



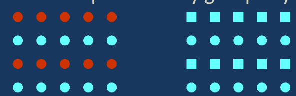
- Closed rectangles strongly segment visual field
  - Provide frames of reference



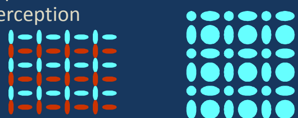
- Design Principle:
  - Partial obscuration may be okay
  - Especially for symmetric objects

Similarity

- Color or shape similarity groups by row



- Separable dimensions enable alternate perception



Integral dimensions form stronger pattern

- Design Principle: Items to be grouped should share similar characteristics

Relative Size

- The smaller components of a pattern tend to be perceived as the object
  - Black propeller on white background
- Horizontal and vertical tend to be seen as objects
- Plays into figure/ground principle
- Design principle
  - Make dots the object rather than “cheese grater”

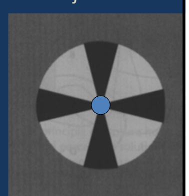
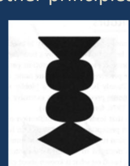
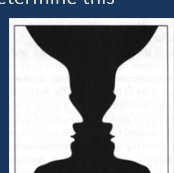


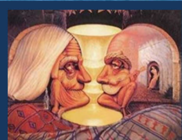
Figure and Ground

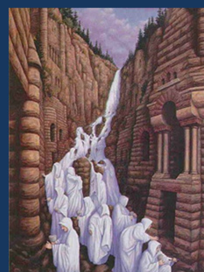
- The fundamental perceptual act in object identification according to Gestalt school
- What is foreground, what is background?
- All other principles help determine this





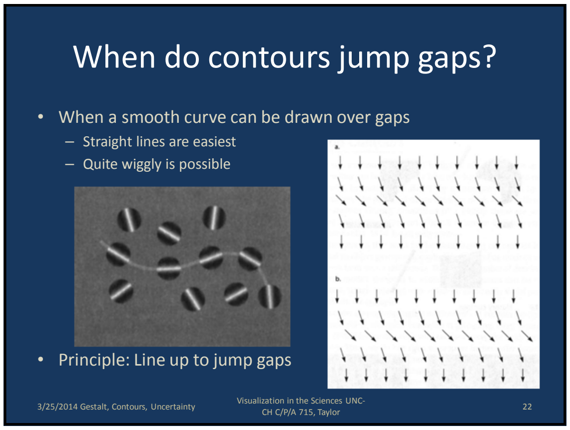
Figure/Ground Illusions from SPAM





Contours

- Perceived continuous boundary between regions
  - Line (sharp change on both sides in intensity)
  - Boundary between regions of two colors
  - Stereoscopic depth
  - Patterns of motion
  - Texture
  - Illusory (continuity & closure):


When do contours jump gaps?
• When a smooth curve can be drawn over gaps
– Straight lines are easiest
– Quite wiggly is possible
• Principle: Line up to jump gaps
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Visualization in the Sciences UNC-CH C/P/A 715, Taylor
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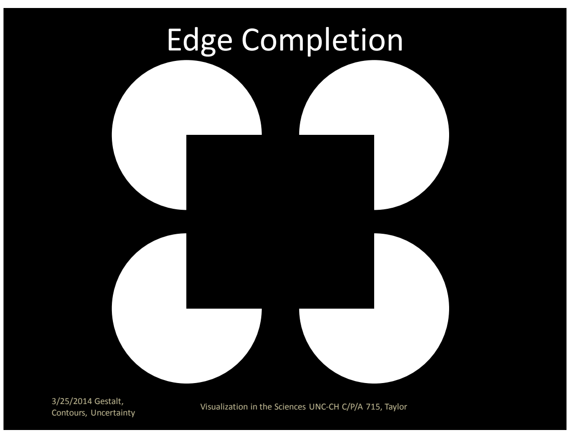
Edge Completion
3/25/2014 Gestalt, Contours, Uncertainty
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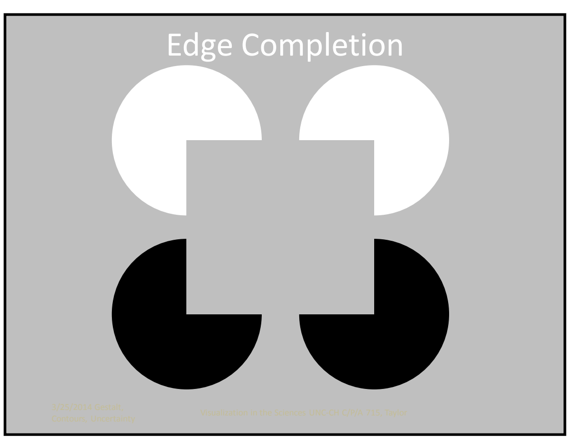
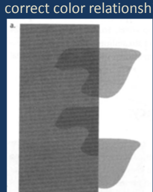

Edge Completion

Transparency (1/2)

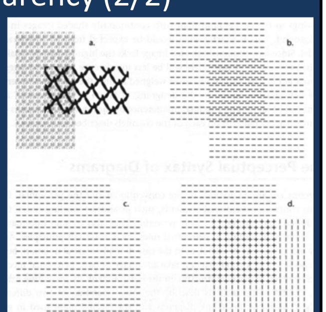
- Attempting to present multiple data layers
- Many perceptual pitfalls
  - "WARNING, WARNING, DANGER Will Robinson!"
  - Different layers interfere with each other to some extent
  - Sometimes layers will fuse perceptually into one
  - Patterns similar in color, frequency, motion, etc. interfere more
- Design principle:
  - Make layers differ in at least one significant dimension
  - Try before you buy

Transparency (2/2)

- Need good continuity and correct color relationship



- Switch to sparse, distinguishable patterns



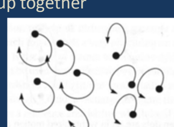
Visual Grammar of Maps

- Well-known grammar
- Developed over time
- Does it fit your problem?
  - Use wholesale if so
  - Consider adding animation

Graphical Code	Visual Instantiation	Semantics
1. Closed contour.		Geographic region.
2. Colored region.		Geographic region.
3. Textured region.		Geographic region.
4. Line.		Linear map features such as rivers, roads, etc. Depends on scale.
5. Dot.		Point features such as town, building. Depends on scale.
6. Dot on line.		Point feature such as town on linear feature such as road.
7. Dot in closed contour.		Point feature such as town located within a geographic region.
8. Line crosses closed-contour region.		Linear feature such as river crossing geographic region.
9. Line exits closed-contour region.		A linear feature such as a river terminates in a geographic region.
10. Overlapping contour, colored regions, textured regions.		Overlapping geographically defined areas.

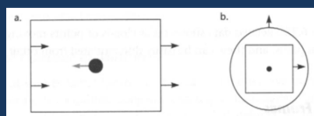
Form and Contour in Motion

- Contours can be seen in moving dot fields by motion alone
  - Rivals static contour detection
- Phase of the motion seems most salient
  - Compared to frequency and amplitude
- Patterns of dots moving in synchrony group together
- Click for app →
- Design Principle:
  - Consider animation for association of groups
  - Works *great* for data-driven spots (even linear motion)!

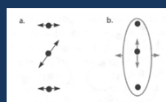


Frames in Motion

- Rectangular frame forms strong context



- Groups of dots moving together form frame

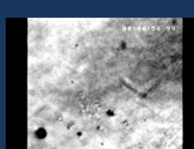


Motion Design Principles

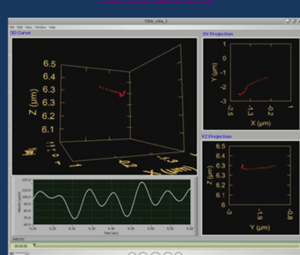
- Use motion as strong cue for grouping
- Add frame around group of related particles
- Speed around a few cm per second
  - Speed up things that are much slower than this
    (Show video of beads, use arrows and hide left then play)
  - Slow down things that are much faster
    (See next slide)

Slow Down Fast Objects

Link



Play with Quicktime



Other Motion Information

- Motion can express causality
  - Launching
  - Delayed Launching
  - Triggering
- Motion of dots on human limbs is immediately recognizable as such
- Motion patterns can express emotion or behavior
  - Happy triangle, excited square, sad circle

Comp/Phys/Mtsc 715

Visualizing Uncertainty

Sources of Uncertainty

- Wittenbrink et al., TVCG 2(3), 1996

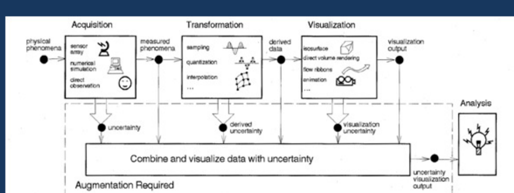


Fig. 1. This augmented visualization pipeline shows measurement uncertainty, derived uncertainty, and visualization uncertainty. Our glyphs attempt to multiplex these uncertainties with the data sources from the visualization pipeline.

The Taxonomy of Uncertainty

- Evan Watkins, masters thesis, Air Force Institute of Technology, 2000

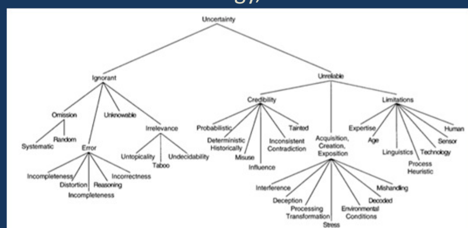


Figure 16. The Taxonomy of Uncertainty

Error Bars vs Ambiguation

- Olston and Mackinlay, InfoVis 2002
- There is a difference between statistical uncertainty and bounded uncertainty
  - Statistical: has an expected value and distribution extends to infinity
  - Bounded: no preferred value, just a range of possible values
- Use ambiguation for bounded uncertainty

Figure 1: Error bars and ambiguation applied to some common chart types.

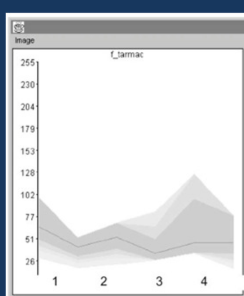
Three Views on Uncertainty Visualization

- View 1
  - Uncertainty is just another data set
  - Apply techniques for multivariate visualization
  - Show relationship between data and uncertainty
- View 2
  - Uncertain data may take on a range of values
  - Show possible range of data
- View 3
  - Uncertain data should intentionally be obscured
  - Actively prevent users from making judgments about uncertain data

Two Classes of Uncertainty Visualization Techniques

- Extrinsic
  - Additional visualization techniques to show uncertainty
  - Glyphs, annotations, volume rendering, animation
- Intrinsic
  - Vary visualization technique properties to show uncertainty
  - Transparency, Color maps, texture properties, etc.

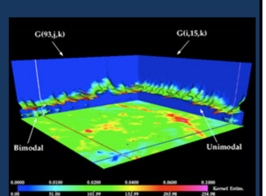
Fuzzy Spectral Signatures



- Bastin et al., Computers & Geosciences 28 (2002), pp. 337-350
- Showing fuzzy classifications of multi-spectral imagery
- Graph show thick lines of probability that a land cover type produces specific reflectivity in each band
- Mean reflectivity shown as dark line

Showing Uncertainty with Standard 2D Scalar Techniques

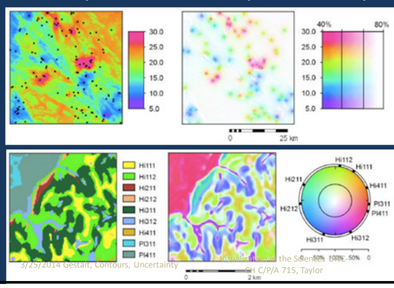
- Dungan et al., IGRSS 2002
- Use standard 2D scalar techniques for showing statistical information in remote sensing applications
- Shows uncertainty from different estimates of forest cover



Rainbow color map suboptimal

Saturation as an Indicator of Uncertainty

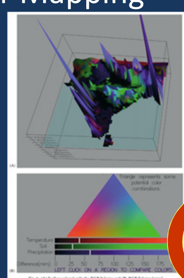
- Tomislav Hengl, GeoComputation, 2003
- Map data to color map, uncertainty to saturation



Rainbow color map suboptimal

RGB Color Mapping

- Cliburn et al., Computers & Graphics 26, 2002, pp. 931-949
- Temperature, soil, and precipitation encoded as intensities of red, green, and blue, respectively according to how much each contributes to uncertainty in water balance model



-Our sensitivities to RGB differ
-Unintuitive mapping

Isosurface Uncertainty

- Kindlmann et al., IEEE Vis 2003
- Color map shows uncertainty

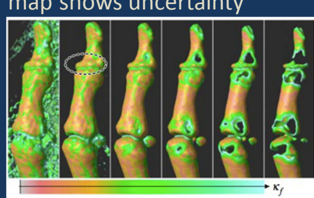
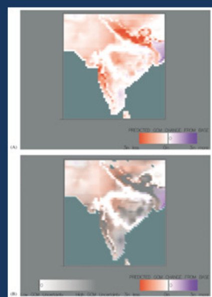


Figure 11: CT isosurfaces at values 1055, 1095, 1175, 1255, 1335, and 1405, colormapped by flowline curvature. Circle indicates site of high surface curvature and low flowline curvature.

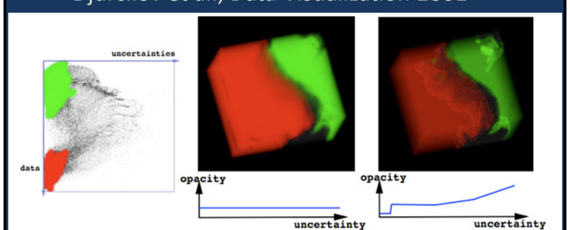
Transparency to Hide Uncertain Data

- Cliburn et al., Computers & Graphics 26, 2002, pp. 931-949
- Water balance model uncertainty
- Goals: don't want users to make decisions affecting locations where uncertainty is high
- Make uncertain regions transparent



Volume Rendering of Uncertainty Data

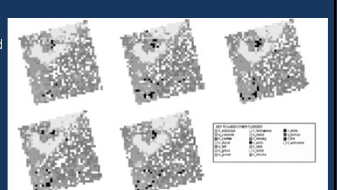
- Djurcilov et al., Data Visualization 2001



Animation Showing Uncertainty in Remotely Sensed Imagery

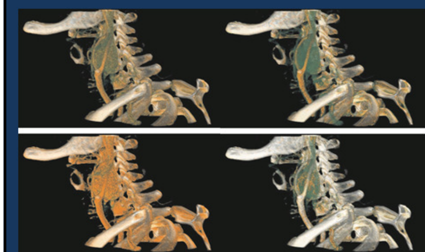
- Bastin et al., Computers & Geosciences 28 (2002), pp. 337-350
- Sources of uncertainty
  - Spectral confusion of land cover types
  - Spatial mis-registration
  - Topographic and atmospheric effects
  - Sensor biases

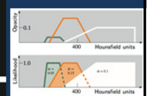
- Pixels randomly change between land cover types over time according to probability distribution



Probabilistic Animation in Volume Rendering

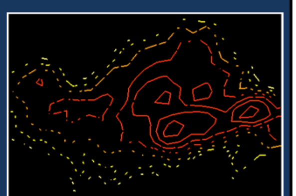
- Lundstrom et al., TVCG 13(6)





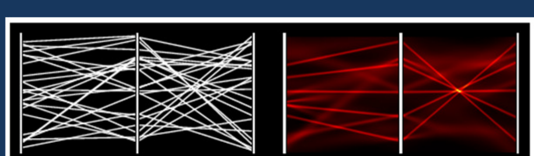
Broken Contour Lines

- Alex Pang, “Visualizing Uncertainty in Geo-spatial Data”, prepared for Computer Science and Telecommunications Board, 2001
- Broken-ness of lines indicates uncertainty in location of contours



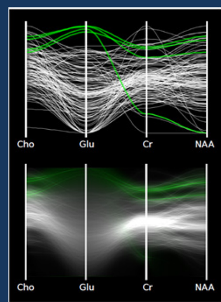
Kernel-Density Uncertainty

- Feng 2010
- Blurring lines by uncertainty removes false negative to indicate correlations



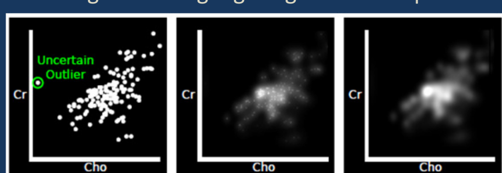
Kernel-Density Uncertainty (2)

- Feng 2010
- Blurring lines by uncertainty removes false positive to indicate no useful data in cluster



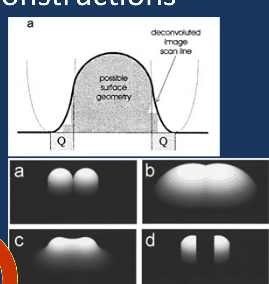
Kernel-Density Uncertainty (3)

- Feng 2010
- Blurring points by uncertainty removes false positive to indicate no outlier
- Adding center-highlighting shows samples



Uncertain Regions in AFM Surface Reconstructions

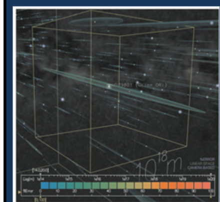
- Leung et al., J. Vac. Sci. Tech. B, 15(2), 1997
- Accounting for uncertain surface reconstruction in atomic force microscopy
- Shows uncertainty by making parts of reconstructed surface black (zero height)



Uncertainty displayed with same channel as data

Displaying Uncertainty in Astrophysical Data

- H. Li et al., IEEE Vis 2007



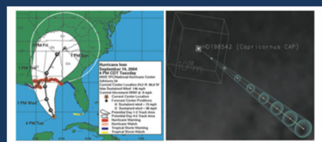


Fig. 5. Left: An example model showing trajectory uncertainty of a Hurricane. Right: The trajectory uncertainty of a star in 50,000 years; note: the color reveals the percentage error and the trajectory data of this star are 1) Radial component: $(2.87 \pm 0.41) \times 10^{11} m/yr$, 2) RA: $(-4.34 \pm 0.57) \times 10^{-8} rad/yr$, and 3) Dec: $(-1.23 \pm 0.40) \times 10^{-8} rad/yr$.

Where is Betelgeuse?

Where will a star be in 50,000 years?

Approaches to Visualizing Vector Uncertainty

- Wittenbrink et al., TVCG 2(3), 1996
- Table of glyphs potentially used for showing uncertainty
- Attempt to convey magnitude and angular uncertainty

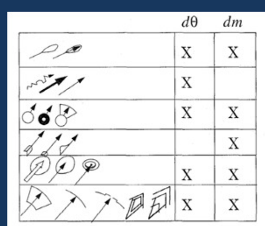


Fig. 5. Variety of glyphs considered for magnitude and angular uncertainty.

Wittenbrink Uncertainty Glyphs

- Wittenbrink et al., TVCG 2(3), 1996

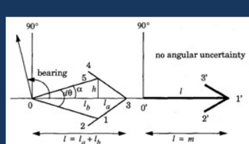


Fig. 7. Glyph parameters.

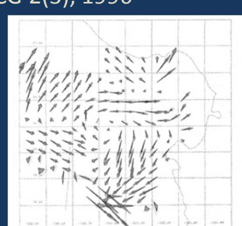
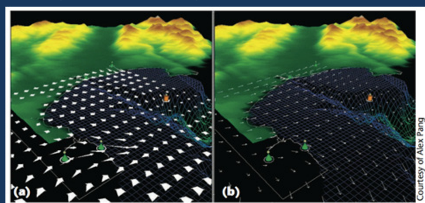


Fig. 16. Large version of Fig. 14, uncertainty glyphs, area scaled to magnitude, codar vector calculation Method II.

Display of Uncertainty with Glyphs

- Johnson and Sanderson, CG&A Sept/Oct 2003
  - Images from Alex Pang



2 Visualization of wind velocity (a) with and (b) without uncertainty using direction uncertainty glyphs and regular arrow glyphs, respectively.

2004 Sanderson, Johnson, Kirby

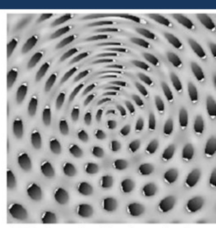
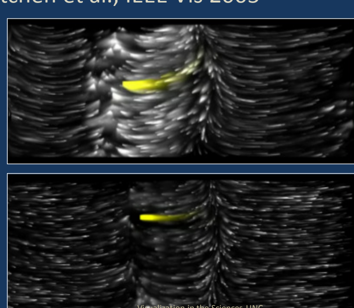


Figure 7: *Reaction-Diffusion visualization of orientation uncertainty. The orientation uncertainty is a function of the angular position.*

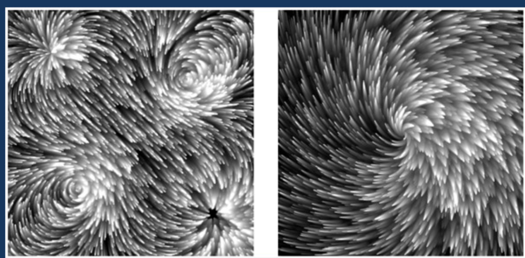
Error in Vector Fields

- Botchen et al., IEEE Vis 2005



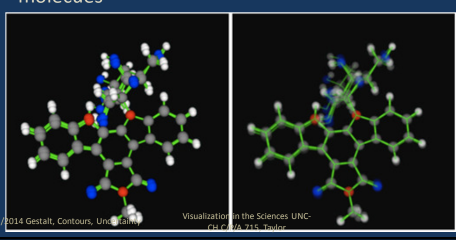
Error in Vector Fields

- Botchen et al., IEEE Vis 2005
  - Note: draws attention to uncertain regions!



Positional Uncertainty in Molecules

- Rheingans and Joshi, Data Visualization 1999
- Conveying uncertainty in atom positions in molecues



Metastable Molecular Visualization

- Schmidt-Ehrenberg, IEEE Vis 2002
- What is the space of possible molecular confirmations?
  - Shows confirmation density
  - Similar to notion of electron density

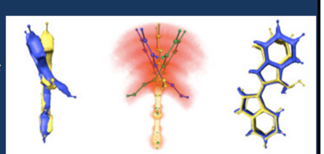
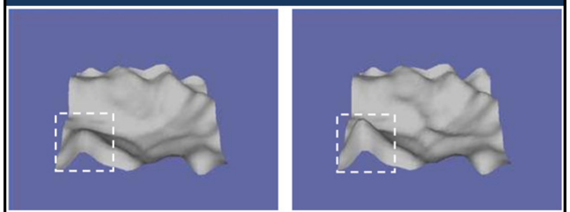


Figure 5: Metastable conformations of the molecule Indirubin. The image in the middle shows three conformations via representative geometries embedded in a direct volume rendering of their combined conformational densities. The left and right image show two of the conformations from different perspectives visualized with representative geometries and isosurfaces of their conformational densities. Alignment was done using the atoms of the lower double ring.

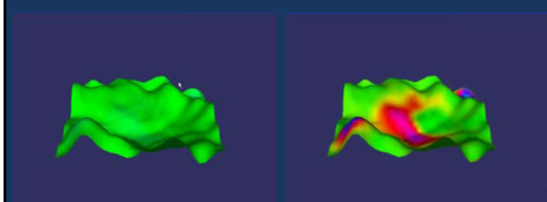
Left and right: 2 confirmations
Middle: volume rendering of density
Bottom two rings used for alignment

Vibrating Surfaces (3D)

- R. Brown, "Animated visual vibrations as an uncertainty visualization technique", 2004

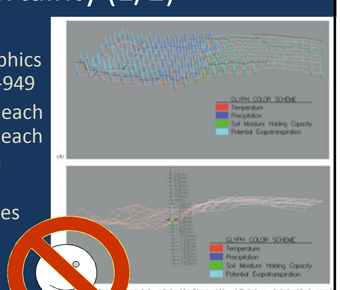


Vibrating Colors



Line Glyphs for Showing Uncertainty (1/2)

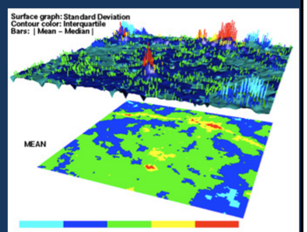
- Cliburn et al., Computers & Graphics 26, 2002, pp. 931-949
- Separate lines for each variable drawn at each sample point with different color
- Size of line indicates magnitude of uncertainty



Isoluminant lines with background, cluttered

Line Glyphs for Showing Uncertainty (2/2)

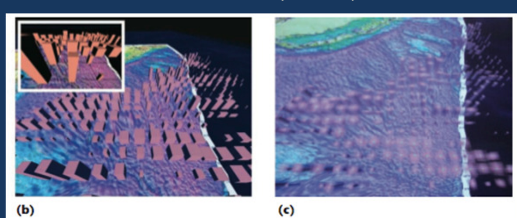
- Dungan et al., IGRSS 2002
- Four statistics summarizing variance in elevation data



Isoluminant lines with background, cluttered

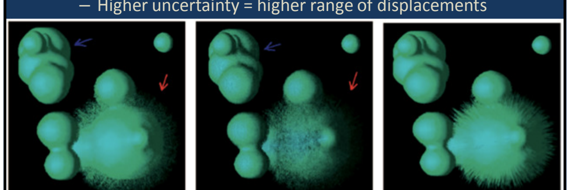
Box Glyphs for Showing Uncertainty

- Schmidt et al., Visual Analytics, Sept./Oct. 2004



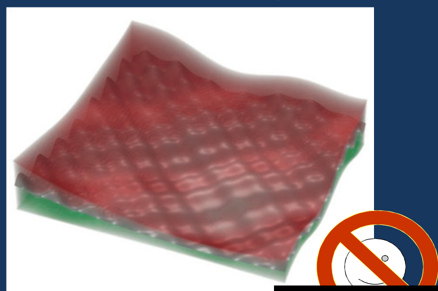
Point-based Surfaces

- Grigoryan and Rheingans, TVCG 10(5), 2004
- Render geometry as points
- Uncertainty conveyed by random displacement along normal
  - Higher uncertainty = higher range of displacements



Isosurface Uncertainty

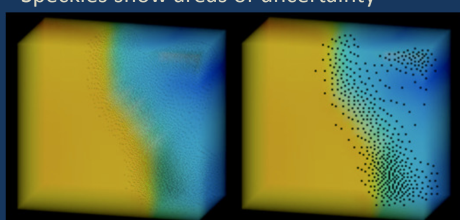
- Johnson and Sanderson, CG&A Sept/Oct 2003



Uniform transparency hides all surface shapes

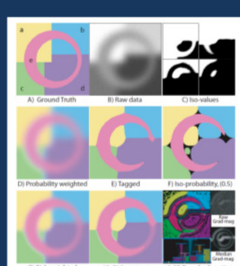
Adding Texture to Express Uncertainty

- Djurcilov et al., Data Visualization 2001
- Speckles show areas of uncertainty



Risk-based Classification (2D)

- Kniss et al., IEEE Vis 2005
- Delays material classification until rendering
- Importance is inversely proportional to penalty for misclassifying materials in volume



Risk-based Classification in Volume Rendering

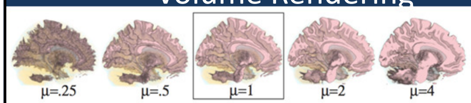
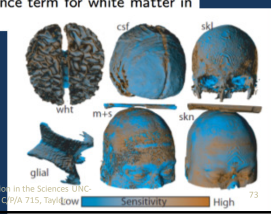


Figure 5: Effect of varying the importance term for white matter in a classified brain dataset visualization.



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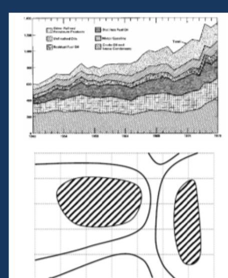
Vibrating Textures (2D)

- Draw attention to uncertain areas.
- Top: bad
- Bottom: good?



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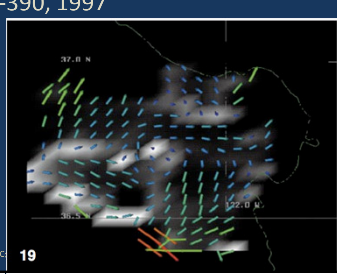
Color Maps Indicating Glyph Uncertainty

- Pang et al., The Visual Computer, 13, pp. 370-390, 1997



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Glyphs Glyphs Glyphs(1)

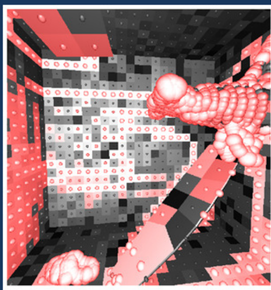


Figure 2: Spherical glyphs scaled to radiosity differences.

Glyphs Glyphs Glyphs(2)

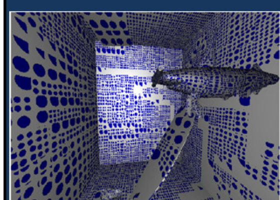


Figure 16: Radiosity differences mapped to 2D circular textures.

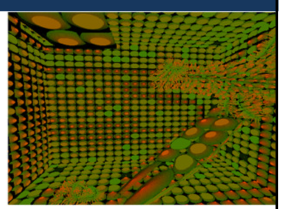


Figure 17: Radiosity differences mapped to 3D solid textures.

Glyphs Glyphs Glyphs(3)

Figure 10: Surfaces patches are translated in or out of their original positions to highlight differences.

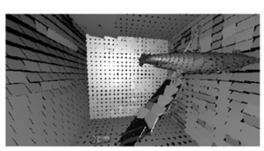
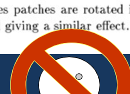


Figure 11: Surfaces patches are rotated instead of translated giving a similar effect.



Uncertainty displayed with same channel as data

Glyphs Glyphs Glyphs(4)

Figure 14: Altering diffuse coefficients according to difference.

Figure 15: Altering specular coefficients according to difference.

Uncertainty displayed with same channel as data

Uncertainty Annotations

- Cedilnik and Rheingans, IEEE Vis 2000
- Idea: overlay annotations on top of data and distort according to uncertainty

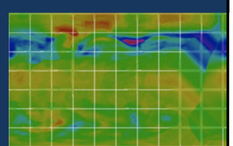


Figure 4: Width variation technique.

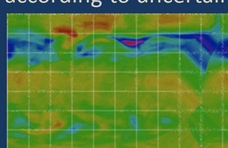


Figure 7: Noise technique.

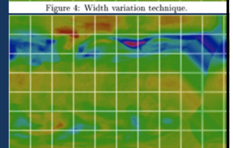
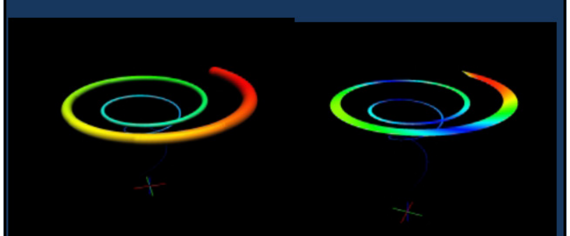


Figure 6: Exponential sharpness technique.

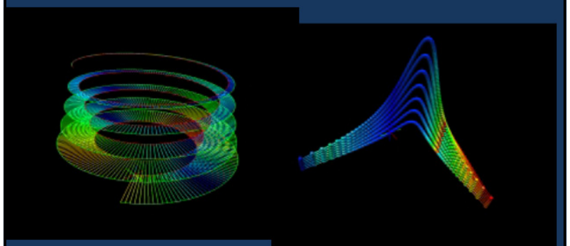
Uncertainty in Vector Fields(1)

- Lodha et al., UFLOW, 1996



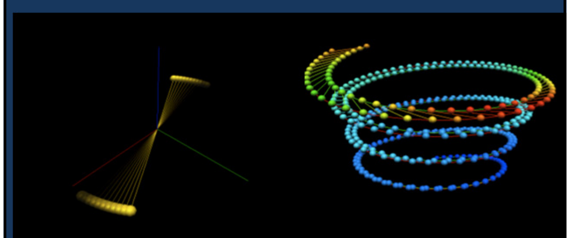
Uncertainty in Vector Fields(2)

- Lodha et al., UFLOW, 1996



Uncertainty in Vector Fields(3)

- Lodha et al., UFLOW, 1996

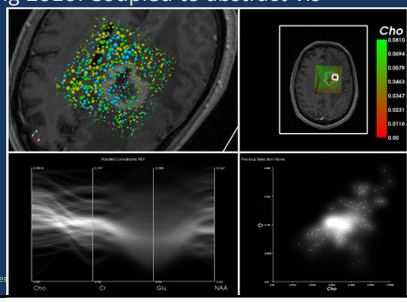


Sonification

- LISTEN library by Lodha et al., IEEE Vis 1996
- Use sound to express uncertainty
  - Use another perceptual channel besides visual
  - Uncertainty of data at probe mapped to pitch which can "show" more values than color map
  - Uses different timbres to display multiple variables
- Auditory perception and processing not understood well
- Good mappings to sound are unknown

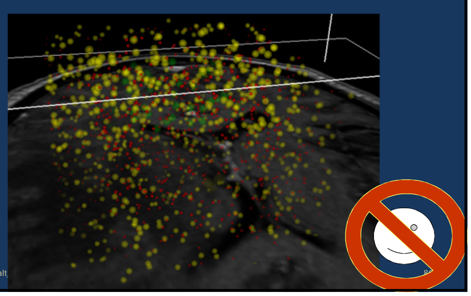
Multivariate 3D Uncertainty (1)

- Feng 2010: Coupled to abstract vis



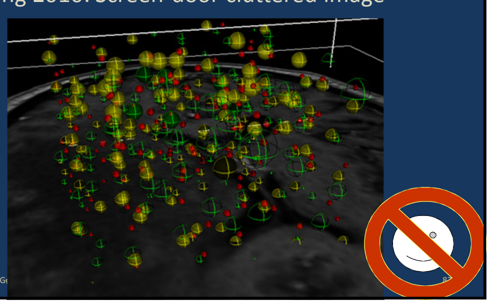
Multivariate 3D Uncertainty (2)

- Feng 2010: Transparency removed depth



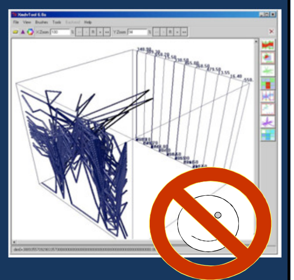
Multivariate 3D Uncertainty (3)

- Feng 2010: Screen-door cluttered image



Uncertainty + Parallel Coordinates

- Shiping Huang, master's thesis, Worcester Polytechnic Institute, 2005
- Show uncertainty by displacement in 3rd dimension
- Problems:
  - Occlusion
  - Parallel lines no longer parallel in projection
  - Non-parallel lines may become parallel in projection



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References:

- Edge completion, More perceptual illusions: Penny Rheingans
- The rest of the lecture: Colin Ware, "Information Visualization," chapter 6.

Extra readings

- Blinn, Jim, "Visualize Whirled 2x2 Matrices," IEEE Computer Graphics and Applications 22 (4), July/Aug 2002. pp. 98-102.

Credits

- User studies discussion: Robert Kosara, Christopher G. Healey, Victoria Interrante, David H. Laidlaw, and Colin Ware, "Visualization Viewpoints: User Studies: Why, How, and When?", IEEE CG&A July/August 2003. pp. 20-25.
- Annotation: Gitta Domik
- Protein Models: UNC GRIP project, F.P. Brooks, Jr. PI.

Credits
• Parallel Coordinates: Fua, InfoVis '99; Wong, Visualization '96
• ConeTree: Robertson, CHI '91; Card, InfoVis '97
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Credits
• Intrinsic/extrinsic discussion
– Gershon, CG&A, 8(4), pp. 43-45, 1998
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