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

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

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

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

- 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
- 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

Edge Completion

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

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

- 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
The Taxonomy of Uncertainty


![The Taxonomy of Uncertainty](image)

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

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., IGSS 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

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

Isosurface Uncertainty

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

Sources of uncertainty:
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Probabilistic Animation in Volume Rendering
• Lundstrom et al., TVCG 13(6)

Broken Contour Lines
• Alex Pang, "Visualizing Uncertainty in Geospatial 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

- 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

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

Wittenbrink Uncertainty Glyphs

• Wittenbrink et al., TVCG 2(3), 1996
Display of Uncertainty with Glyphs
• Johnson and Sanderson, CG&A Sept/Oct 2003
  – Images from Alex Pang

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!

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Positional Uncertainty in Molecules

• Rheingans and Joshi, Data Visualization 1999
• Conveying uncertainty in atom positions in molecules

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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

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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

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

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.

Vibrating Textures (2D)

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

Color Maps Indicating Glyph Uncertainty

- Pang et al., The Visual Computer, 13, pp. 370-390, 1997
Uncertainty displayed with same channel as data
Glyphs Glyphs Glyphs

Figure 14: Altering diffuse coefficients according to different.

Figure 15: Altering specular coefficients according to different.

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

Uncertainty in Vector Fields

• Lodha et al., UFLOW, 1996
Uncertainty in Vector Fields (2)

- 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
References:

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

Extra readings


Credits

• 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

Credits

• Intrinsic/extrinsic discussion