Comp/Phys/Mtsc 715

Object recognition, Surface shape, Texture, Depth cues, Stereo, Combinations

Preview Videos

• Vis 2006: sreng.avi
  – Proximity and collision glyphs
• Digital Artforms Interface
  – Watch the video on the left side
• Video: Rendering text labels on visualizations

Administrative

• Questions about what you’re turning in tonight?
Discussion!

• When do we let the user choose?
• When don’t we let the user choose?

Surprised?

• What information from Ware chapter 7 surprised you?

What is an Object?

• Any identifiable, separate, and distinct part of the visual world
• A visual object cognitively groups visual attributes
• Lesson: Representing data values as visual features and grouping them into visual objects can be a powerful tool for organizing related data.
How are Objects Recognized?

• Image based?
  – The mind as a huge movie reel

• Structure based?
  – Breaking object into 3D parts

Image-Based Object Recognition

• Have I seen this before? (2560 images, 90%)
• Rapid serial presentation, with attentional blink
• Memory may be indexed by images (recognition), which then fire other related memories (recall).
• Selective Priming: Visual, not verbal
• Canonical views in monkey brains.

Uses of Image Display

• Icons in user interface can cause recognition and then recall of function.
• Priming can be helpful when the user is searching for a pattern or image.
• It may be faster to present images in a “burst” at up to 10 frames per second – like flipping through a book – rather than side-by-side thumbnails.
Hint for Image Display

• Biederman and Cooper (1992) showed that the optimal size for recognizing visual objects is 4-6 degrees of visual angle.

• Mona Lisa from afar

• Gremlin and Raven nearby

Structure-Based Object Recognition

• We recognize new orientations of novel objects
Geon Theory
- The whole is a sum of a set of basic primitive geometrical elements
- The way they are connected is also encoded

• Geon Man!

Silhouettes
- Especially important in object perception
  - Cave drawings based on this
  - Modern children draw this way
  - A clear diagram can be more effective than a photo
- Canonical silhouettes
  - Sideways Man!

• Concave sections break object into parts

Object-Based display of Data
- Grouping six variables into one object makes them more comprehensible
Object-Based display of Data

• Chernoff Faces

Object Display Characteristics

• Benefits
  – Can consolidate multiple related data sets into one object
  – Can map onto familiar objects

• Issues
  – Requires specific design for each application
  – Requires a meaningful metaphor
Surface Shape Perception

- Used for: digital elevation maps
  - Ocean floors
  - Molecular-scale surfaces
  - Mathematical functions
  - Other 2-dimensional scalar fields

- Important perceptual characteristics
  - Surface shading models and contours
  - Surface texture
  - (Stereo and Motion described more later)

Surface Shading

- Basic components (from before)
  - Lambertian shading: diffuse reflection
  - Specular shading: glossy highlights
  - Ambient: Hack to simulate radiosity
  - Low-contrast texture with linear elements
  - Cast shadows: On itself or another object

- Goal is revealing shape, not realism
  - Visual system assumes a single light source from above
  - Multiple light sources may be confusing
  - Cast shadows inform relative positions (more later)
Shading and Contours

- Shape from shading is inherently ambiguous
  - Assumes a lighting direction, for one thing
- Different contours with same shading ⇒ different perceived shapes
Shading and Internal Contours

• Internal contours also override shading information (apparent light direction shifts)

Shading and Internal Contours

• Equal-spaced lines enable gradient estimation

Surface Texture

• Gibson claims that a non-textured surface is just a patch of light

• Shape information comes from texture gradient
Surface Texture

- Kim, 2003
- a). 1st & 2nd PD
- b). 1st PD
- c). LIC on 1st PD
- d). No texture

Surface Texture and Stereo

- Untextured polygons produce no internal stereoscopic correspondences
- Stereo correspondences reveal surface shape

Surface Texture and Transparency

- Without texture, it is usually impossible to distinguish one curved transparent surface from another behind it
- How many times have we seen this?
Surface Display Guidelines

- One light at infinity, from above and to one side
- Lambertian + moderate specular lighting
  - Specular lighting is important to reveal details
  - Specular lighting is local, so enable control over light
- Surfaces should be textured with low-contrast textures that have linear features
- Cast shadows if they don’t interfere: soft edges on the shadows
- Rotation and stereo (and head tracking) helpful

Ambient Occlusion

- Tarini, Cignoni, Montani, IEEE TVCG 12(5), 2006

Image-based Relighting

- Akers et al., IEEE Vis. 2003
Living in a 3D World

- Recent hardware advances make it possible to view things in 3D easily and cheaply
- Early PowerPoint users taught us that "Just because you can do something doesn’t mean that you should!"
- It can be helpful when used appropriately

Depth Cues

- Monocular cues
  - Seen with one eye
  - Static
    - Picture not moving
    - Like a photo on the wall
  - Dynamic
    - Picture is moving
    - Like on TV or at the movies
- Binocular cues
  - Toy Story in 3D, Virtual Reality
- Artificial cues
  - Not like in the real world, but they work
Monocular Static Cues

- Occlusion: King of the depth cues!
- Linear Perspective
  - Size Gradient
- Texture Gradient
- Depth of Focus
- Cast Shadows
- Shape-from-Shading

Occlusion

- Strongest cue, but binary
- Don’t mess with occlusion →
- Occluding object looks closer

Linear Perspective

- 3rd person view
- 1st person view
Linear Perspective Characteristics

- Parallel lines converge to a single point
- Objects that are further away appear smaller
- Size constancy
  - Objects of known size (e.g., people) effectively scale the whole scene
- Can perceive objects in pictures even though perspective is incorrect for where we view from
  - Can perceive both “picture-plane” size and “3D” size of objects shown in pictures
  - Visual system overrides some aspects of perspective
  - Perhaps built-in assumption of objects as rigid bodies causes this
- Hint: Simulate long-focal-length lenses for extreme off-axis viewing (less perspective effect)

Texture Gradient

- Textures with uniform statistics show shape by their distortion
  - May be uniform on the surface
  - May be uniform in projection

Depth of Focus

- Objects at same plane as fixated objects in focus
  - Objects in front or behind are out of focus
    - Objects behind: sharp boundary with fixated object
    - Objects in front: blurry boundary with fixated object
  - Separates foreground object from background
- Hint: Can be used to highlight important parts by blurring non-critical portions of the display
Cast Shadows

• Show relative heights of objects above plane
• Even used in game consoles, where polygon count is the critical resource

Cast Shadows

• Strong cue for relative height, especially in motion

Cast Shadow Characteristics

• Potent at showing height above a plane
• Especially valuable in combination with motion
• In some cases can be stronger than texture, projection type, frames of reference, and motion

• Hints
  – Shadow shape does not have to be correct
  – Fuzzy-edged shadows lead to less confusion
Shape-From-Shading (Recap)

- Basic components
  - Lambertian shading: diffuse reflection
  - Specular shading: glossy highlights
  - Ambient: Hack to simulate radiosity
  - Low-contrast texture with linear elements
- Goal is revealing shape, not realism
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Monocular Dynamic Cues: Structure from Motion

- Motion Parallax
  - Sideways out a car window
  - Forwards out the car windshield
  - Head-Motion Parallax

- Kinetic Depth Effect
  - Objects in the environment moving or rotating

Motion Parallax

- Vehicle / linear motion

- Head-Motion Parallax (Virtual Reality)
  - Combination of directions coupled to head motion
  - Powerful effect if done with low latency
  - Especially powerful when combined with stereo

Kinetic Depth Effect

- Objects in the scene moving and/or rotating

- Kinetic Depth vs. Perspective
  - Rotating trapezoidal window
  - Appears to swing back and forth
  - www.exploratorium.edu
Binocular Cues

• Eye convergence
  – Not good at absolute judgment

• Stereoscopic depth
  – …

Nausea, Headache and Other Hazards of Stereoscopic Display

• Everything is in focus all the time
  – at a fixed distance that may not match fixated object distance
  – convergence and focus are out of alignment
• Objects cut off at the edge of the display
  – even if they are in front of it
• Stereo itself stops working after 30 meters

• Hint: Visual system is flexible about stereo cues
  – Enable user to adjust scaling and eye separation to suit
Integration of Cues

• All cues are useful (specular, lambertian, texture, stereo, motion parallax)
• Relative importance varies from person to person, and depends on the task
  – 2-4% of population is stereo blind
• Motion and Stereo reduced errors in combination with any of the others
• Lambertian shading with either stereo or motion was nearly the best for all subjects
• Others found that texture beat Lambertian or specular
• Stereo + head motion is much better than either alone

Artificial Spatial Cues

• Dropping a line to the ground plane
  – Directly shows height
  – A bit like shadows

• Proximity Luminance Covariance
  – Fades into background
  – A bit like fog
Depth Cues in Combination

- Quest for the relative values of cue combinations
  - It turns out to depend on the task (adding certain cues actually make some tasks harder)
- Quest for a small set of elementary tasks: here are some
  - Tracing data paths in 3D graphs
  - Judging the relative positions of objects in space
  - Judging the relative movement of self within the environment
  - Judging the “up” direction
  - Feeling a sense of “presence”
- We’ll focus on these two in this lecture
  - Judging the shape of surfaces
  - Finding patterns of points in 3D space
Task: Understand Surface Shape

- Rule of Thumb:
  - Use stereo, kinetic depth, shape-from-shading, and texture if you can
  - Test for yourself which matter most when you can't do them all

- Studies (sometimes conflicting)
  - Judging heights of cones:
    - Stereo >> structure-from-motion
  - Judging gradient of textured surface:
    - Structure-from-motion > stereo
  - How long have you been seeing spots?
    - Kinetic depth effect dominates for 4-6 seconds
    - Then stereoscopic depth became dominant

Task: Understanding Patterns of Points in 3D Space

- 3D scatter plot of points
  - Little perspective information available
  - Weak depth information from size gradient
  - Occlusion won't help for very small points
  - Cast shadows won’t work – which shadow for a point?
  - Shape-from-shading missing for unlit points

- What might work?
  - Stereoscopic depth
  - Structure-from-motion
  - Orient the points near boundaries, light the points to show cloud surface shape (based on gradient strength)
Immersive Display Systems Hints

• Head motion must change display naturally
  – Head-coupled perspective > stereo
  – HCP + stereo >> HCP

• Eye-hand relationship can vary
  – So long as there is not excessive lag
  – Think of the mouse (forward/back → up/down)

Credits

• This lecture is drawn from Chapters 7 and 8 of Colin Ware’s “Information Visualization” book.
• Cast Shadows: RPGFan.com.