Lecture 2: The human vision system
Bottom line

• Use GIS or other mapping software to create map form, layout and to handle data
• Pass result to editing tools to use the design loop
• Better maps through:
  • knowledge
  • skill
  • experience
  • creativity
  • esthetics
  • understanding human vision

We’ll start here!
Human vision elements

• Physical
  • Stereo vision
  • Color/textured/shape
  • Granularity and resolution
  • Field of view

• Perceptual

• Cognitive/behavioral
The human eye

Optic nerve is at fovea
Eye can open/close and move
Eye lens is adjustable
Eyeball shape can adjust
Aperture also adjustable (dilates)
Camera model

Aperture
Brightness
Depth of field
2 Types of photoreceptors in the human retina, rods and cones.

- **Rods** are responsible for vision at low light levels. Do not mediate color vision, and have a low spatial acuity.
- **Cones** are active at higher light levels, are capable of color vision and are responsible for high spatial acuity.
- The central fovea is populated exclusively by cones. There are 3 types of cones: short-wavelength sensitive cones, the middle-wavelength sensitive cones and the long-wavelength sensitive cones or S-cone, M-cones, and L-cones for short.
- Broadly corresponds to Red, Green and Blue
Distribution of rods and cones
Eye/Brain combination: Visual cortex
Homo sapiens vision evolution

- Visible light = 400-800 nm wavelengths
- Search—food, shelter
- Face recognition
- Identification in vegetation--green
- Threat recognition—fight or flight—1000 yard stare
- Motion detection—reaction
- Sense integration (sight, taste, touch, hearing, smell)
- Visual memory is particularly intense, and mostly unconscious
Field of View: Total about $120^\circ$
Figure 11.17  Vertical Field of View
Overall
But, unequal qualities

At center
Max focus
2 retina holes
Stereo

Center to edge
Color
Contrast
Focus
Monocular
Motion sense
Depth perception

- **depth cues**
  - occlusion (strongest cue)
  - shadowing (light occlusion)
  - lighting (illumination)
  - perspective
  - texturing
  - **stereopsis**
  - depth of field/focus
  - motion and movement

- perceptual factors can be exploited for a 3D viewing experience or an ‘illusion’ of depth
Depth perception

**LOD Management**

In computer graphics

• Remove details not needed/cannot be rendered (e.g. culling), cannot be perceived
• Distance
• Size
• Priority
• Hysteresis (time)
• Environmental Conditions
• Perceptual factors, e.g. Eccentricity, Velocity, DoF
Depth perception

“virtual street reality”

Julian Beever
Depth perception

Julian Beever
Depth perception
Size depth cues

Depth perception
Stereo vision

• Input from 2 eyes only in part of vision
• Overlap processed in visual cortex
• Processing is perceptual, unconscious
• High speed (30 ms)
• Uses depth cues
• About 2° separation (low)
Stereoscopic depth perception

Differs from camera model
Image is rectangular, suffers from barrel distortion
Sensitive to separation
Stereoscopic viewing

This is a stereogram, hiding the text GEOG183 created using www.flash-gear.com/stereo/
Stereoscopic viewing

Examples of stereoscopic visualization for terrain and topography

For the 3D effect, you need to use red/blue glasses and view it in color (i.e. black and white print will not work)
Texture

Pattern
Color
Contrast
Shadow
Depth
Material
Repetition
Orientation
Granularity
Regularity
Abstraction
Contrast

Figure vs. ground
Range
Quantification
Granularity

- Human eye can resolve objects that are at least 0.1mm in size
- The size of a fine pencil dot
- 10 dots per millimeter equals 25.4 dots per inch
- At any given representative fraction, a scaled object transforms to a particular size
- Unless a decision is made on how to symbolize a feature, at some scale it will literally disappear from view! (Drop out)
- Relation between granularity and extent
Simplicity, Virginia at 150, 75, 37 and 18 dots per inch
Resolution

30 meters per pixel

10 meters per pixel
Human vision elements

• Physical

• Perceptual
  • Focus
  • Gaze
  • Head and shoulder motion
  • Body motion
  • Image motion
  • Depth perception
  • Foveation

• Cognitive/behavioral
Vision and perception

• Physical vision to human
  • Eye strain
  • Lighting
  • Color blindness
  • Vision correction
  • Attention

• Eye to brain
  • Training and experience
  • Differs by FOV, stereo, contrast, etc

• Brain to memory
  • Familiarity
Saliency

Things that *pop out*

- Color
- Orientation
- Size
- Motion

- Visual variables
Bertin’s six principal visual variables, as presented in “How to lie with maps” (Monmonier, 1991)

<table>
<thead>
<tr>
<th>Visual Variable</th>
<th>Point Symbols</th>
<th>Line Symbols</th>
<th>Area Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td><img src="image1" alt="Size Symbols" /></td>
<td><img src="image2" alt="Size Symbols" /></td>
<td><img src="image3" alt="Size Symbols" /></td>
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<tr>
<td>Shape</td>
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<td><img src="image6" alt="Shape Symbols" /></td>
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<tr>
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<tr>
<td>Hue</td>
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<td><img src="image17" alt="Hue Symbols" /></td>
<td><img src="image18" alt="Hue Symbols" /></td>
</tr>
</tbody>
</table>

FIGURE 2.11. The six principal visual variables.
<table>
<thead>
<tr>
<th>What People With Regular Vision See</th>
<th>What Red-Green Color Blind People See</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Regular Vision Image]</td>
<td>![Red-Green Blind Vision Image]</td>
</tr>
<tr>
<td>![Regular Vision Image]</td>
<td>![Red-Green Blind Vision Image]</td>
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<tr>
<td>![Regular Vision Image]</td>
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</tbody>
</table>
Perception

Context matters: The ‘white’ letters are actually darker than the ‘black’ letters (above), as is clear when surroundings are removed (inset).
Watercolor effect, in which the lighter of two colors seems to spread, shows how important color can be in delineating the extent and shape of a figure. The map of the Mediterranean Sea emerges at once when the tint that at first seems to cover the sea (top) spreads to the land area.
Vision by movement

• Eyes in socket and refocus
• Head movement, rotation
• Aids to vision e.g. telescope
• Body movement
• Aids to movement, e.g. google street view
• Movement by vehicle, travel etc.
• Multiple views from one (or more) locations, e.g. panorama (e.g. http://indiain360.in/view/taj-mahal/)
Fastest participant: 
~11 seconds, 25 fixations
Slowest participant: ~521 seconds, 1181 fixations
Foveation (angling the eyes to focus on an object).

Visual acuity directly related to human fovea

Around the fixation point only four to five letters are seen with 100% acuity.

Human Visual System’s level of detail management
Structure from Motion: Photogrammetry

- Need many images from different angles
- Overlap creates stereo model
- Agisoft Photoscan then extracts model and assigns point cloud with color
- Can process with Meshlab, CloudCompare, other software
- Our answer: Drone (Quadcopter)
Phantom 4 with collision avoidance

- Scans height by IR sensor
- Position using GPS
- Fully gimbaled camera
- Can be programmed to collect video or interval images
- 20 minutes of flight with rechargeable batteries
- Flight planning software, smartphone or tablet piloting
Image capture
This is not a photograph
A 3D model from scratch
Human vision elements

- Physical
- Perceptual

- Cognitive/behavioral
  - Detection, extraction and identification
  - Learning and recognition
  - Anticipation
  - Attention

selective attention: https://www.youtube.com/watch?v=qhF_baBVIOs
Cognitive load

• Learning and intellectual performance
  • Visual analytics, spatial thinking

• Types
  • Intrinsic e.g. simultaneous tasks
  • Extraneous e.g. distraction
  • Device/medium

• Biological and experimental measures
  • Task completion, performance, heart rate, blood pressure, pupil size ..
Visual Complexity

“The system that holds about three objects in attention at one time is called visual working memory.” Ware, 2008
Maps play two cognitive functions: Show and store.
Usability Engineering

First Principles

(Johnson 2008)

Introduction

Basic Principle 1: Focus on the users and their tasks, not on the technology
Basic Principle 2: Consider function first, presentation later
Basic Principle 3: Conform to the users’ view of the task
Basic Principle 4: Design for the common case
Basic Principle 5: Don’t complicate the users’ task
Basic Principle 6: Facilitate learning
Basic Principle 7: Deliver information, not just data
Basic Principle 8: Design for responsiveness
Basic Principle 9: Try it out on users, then fix it!

“Users are not designers, designers are not users”
Nielsen, 1993
Summary

• Vision Factors
  • Physical
  • Perceptual
  • Cognitive/behavioral

• Cognitive engineering studies how cognition impacts design

• Maps must be readable (simple) but also store information

• Use these ideas in working on your GEOG 183 assignments and project