Analytical and Computer Cartography

Lecture 14:
Perceptual Issues for 3D Mapping

3D mapping

- Much cartography uses (x, y), but digital globes and 3D models us (x, y, z)
- Heights can be above a global or nominal datum
- In this and the next 2 lectures, we'll explore why 3D representation and viewing are a bit more complex
- First and most important is understanding the human vision system and the cognitive aspects of display
- Much credit to: Arzu *Çöltekin University of Zurich*

Arzu on Ted Europe

The Blue Marble

Developments in data collection methods

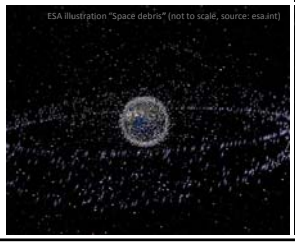
"We'd like to confirm, […], that the world is round."
-- Apollo 17 crew

earthobservatory.nasa.gov

1972. Recorded by Apollo 17

Top down

"A multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of geo-referenced data." – Al Gore



Bottom up

"Citizens as sensors .."
-- M. Goodchild

Example: Google Earth and Google Maps

The question

Today's question: How much detail does a digital earth require?

Part I: GeoVEs, HCI & LOD Management

modified image, photographer unknown

Part I Outline

- Virtual and Augmented Reality
  - Definitions
  - Displays
  - Human depth perception
- Usability Engineering and the HCI
  - Perception and cognition
  - Visual complexity and visual analytics
  - Level of Detail Management and Cartographic Generalization

Virtual and Augmented Reality

Definitions

jamstec.go.jp

"Cyberspace is real."
--Barak Obama (2009)

- Definitions of reality and "virtuality"
  - Physics vs. sensory experiences
- Virtual reality vs. virtual environments
- Virtual, augmented, real
  - Continuum
- **Geo**-VE

Milgram et al. 1994. Image: creative commons

Definitions: VR

"A chair displayed in such a room would be good enough to sit in." – Shuterland, 1965

Howard et al. 2009, Virtual Cocoon

- No consensus on definitions: "mimic real life"
- Some technology driven, some human-centered
- Gets philosophical quickly: what does **real** mean anyway?

Definitions: Virtual ..

- Ultimately all five senses should be stimulated

SMELLIT – smell printer Tokyo Institute of Tech

- Virtual Reality (VR)
  - Virtual: "existing in essence or effect though not in actual fact" (wordnetweb.princeton.edu)
  - Reality? Not always. Sometimes we simulate a scenario or add abstract information which does not exist in real world → hence the term:
- Virtual Environment (VE)

Definitions: Augment..


http://graphics.cs.columbia.edu

- Better than reality?
- Augmented reality?
  - Augmentation: to enlarge, to increase, to grow, to intensify
- Animation vs. VR/VE?
  - Interactivity is the key difference, i.e. user can change the course of action

Example: Augmented Reality

AR example

16 A view through a see-through HMD shows a 3D model of demolished building at its original location. (Courtesy T. Höllerer, S. Feiner, J. Pavlik, Columbia Univ.)

Definitions – Geographical VE

The "four I"s of VEs (MacEachrean et al. 1999)

- Immersion & (tele)presence
  - sense of presence, "being there"
- Interactivity
  - navigate, orient, request and change things
- Information intensity
  - **control level of detail**
- Intelligence of objects
  - e.g. avatars ("intelligent agent")


Image courtesy of West Virginia University
Photo: T. Kawai

Definitions – Geographical VE

Extending the map metaphor: Sensory GI?

A representation of **everything**

- Visual: clearly the most studied
- Audio: sound localization?
- Touch: haptic feedback
- Olfaction (sense of smell)
- Taste?

Odor Localization and Sniffing

Johannes Frasnelli[1,2], Genevieve Charbonneau[2], Olivier Collignon[2] and Franco Lepore[1,2]
[1]Centre hospitalier universitaire Sainte-Justine and [2]Centre de Recherche en Neuropsychologie et Cognition, Université de Montréal, Montréal, Québec, Canada

Applications

- Simulation and training
  - environmental scenarios, virtual tourism
  - training (flights, surgery), phobia treatments
- Visualization of complex, dynamic, multimedia information
  - make the 'invisible' visible
- Fun!
  - efficient science-society communication

Osaka University grad student project "Funbrella" simulates rain when under the umbrella

Definitions – Types of VE

- Semi-immersive
  - Desktop (Fishtank) VR, One-wall displays (e.g. Geowall)
- Fully immersive
  - Head mounted displays, CAVEs, body suits
- Physical world and virtual object mixtures
  - "Touch" holography, AR

Displays

"Technology is a word that describes something that doesn't work yet."
— Douglas Adams

- Some VEs use holographic displays
- Most current VEs use **stereoscopic displays**

Stereoscopic Displays

- Humans (and other predators) have two eyes

→ Stereoscopic displays are a result of this realization

Depth perception

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

Photo: A. Coltekin

- these perceptual factors are exploited for a 3D viewing experience or an 'illusion'

Depth perception

"virtual street reality"

Julian Beever

Depth perception

Julian Beever

Depth perception

wlu.ca

Virtual and Augmented Reality

Depth perception

wlu.ca

Stereoscopic depth perception

Two eyes, two views, and a lateral shift: why don't we see two pictures?

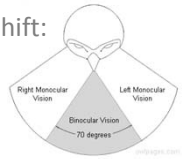
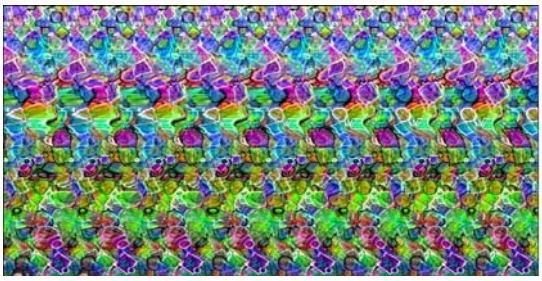


image source unknown

- Stereopsis & cyclopean eye
- The lateral shift causes retinal **disparity**
  - → 3D coordinates
  - → 3D displays (illusion)
- Parallax vs. disparity

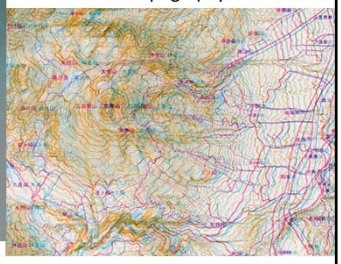
Stereoscopic viewing



This is a **stereogram**, hiding the text Florida 2010
created using www.flash-gear.com/stereo/

Stereoscopic viewing

Examples of stereoscopic visualization for terrain and topography

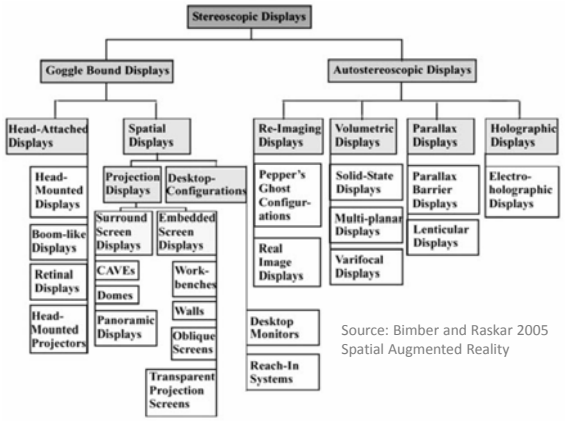


T. Sato and M. Nagaoka,
Geographical Survey Institute, Japan

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)

Stereoscopic viewing

- Cross eye or parallel focusing, magic eye (bare eyes)
- Anaglyphs: red-blue or red-green filtering (passive, with glasses)
- Polarization: light filtering (passive, with glasses)
- Shutter glasses: temporal, alternate frame sequencing (active, with glasses)
- Autostereo: lenticular, parallax barrier (no glasses)
- Holograms (made of 'real' light, not an illusion)



Source: Bimber and Raskar 2005 Spatial Augmented Reality

Acceptance of stereo viewing

"If we had virtual 3D environments that allowed us to reach and move things, then we would appreciate stereo technology more" – Colin Ware, 2008

"Heyday" of stereo
- Victorian era
- 1930s and 1940s
- Now

Why are the fluctuations?

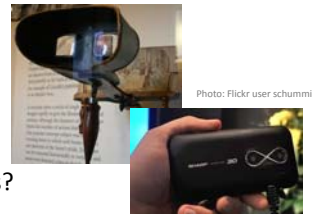
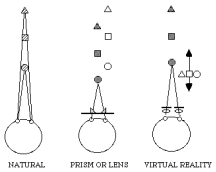


Photo: Flickr user schummi

Problems with stereo viewing

- Eyestrain
- The vergence-focus problem (a.k.a. accommodation convergence problem)
- Frame cancellation
- Disparity over distance



uq.edu.au

Future Display?

- Compact mobile projectors
- Foldable, wearable
- Extended virtual table
- Context aware


vuzix.com

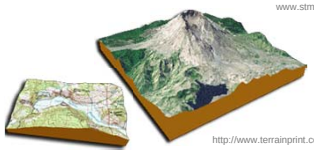

Sony's flexible OLED display


3M's compact mobile projector

3D Printing

- Print 'raised relief' hardcopies
- Developed through 'rapid prototyping', now 'solid terrain' possible


www.stm-usa.com


http://www.terrainprint.co.uk/

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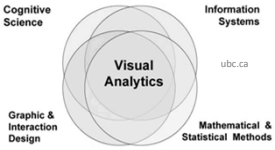
Visual Analytics

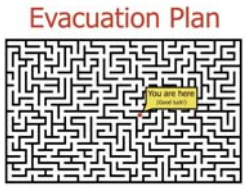


"…*Geoscope* would make it possible for humans to identify the true scale of themselves and their activities on this planet. Humans could thus **comprehend much more readily** that their personal survival problems related intimately to all humanity's survival."

— R. Buckminster Fuller, 1962

Visual Complexity

"The system that holds about three objects in attention at one time is called **visual working memory.**" Ware, 2008



Cognitive load

speakingaboutpresenting.com

- Learning and intellectual performance
  - Visual analytics, spatial thinking
- Types
  - Intrinsic
  - Extraneous
- Biological and experimental measures
  - Task completion, performance, heart rate, blood pressure, pupil size ..

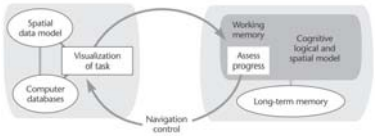
Visual Ergonomics

→ HCI and Usability studies

HCI: Human Computer Interaction

- Human factors
- Usability engineering

- Design principles
  - Perception
  - Mental models
  - Attention
  - Memory



"The navigation control loop" Ware 2008

Usability Engineering

First Principles

(Johnson 2008)

Jeffrey Veen

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!

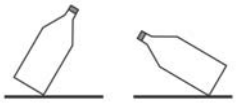
"Users are not designers, designers are not users"
Nielsen, 1993

Usability Engineering

- Individual and group differences
- User-centered design
  - Focus groups
  - Expert interviews
  - Task analysis/task modeling
  - Cognitive walkthrough
- SEE metrics
  - Satisfaction
  - Efficiency
  - Effectiveness

Evaluating visual stimuli

- Visual search
- Perception versus cognition
  - Bottom up (low level) vs. top down (high level)
- Saliency
- Water level test



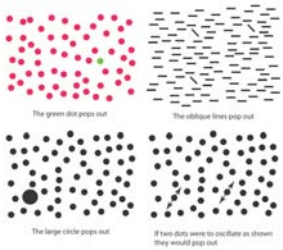
Lynn S. Liben

Saliency

Things that *pop out*

- Color
- Orientation
- Size
- Motion

- **Visual variables**



Ware 2008

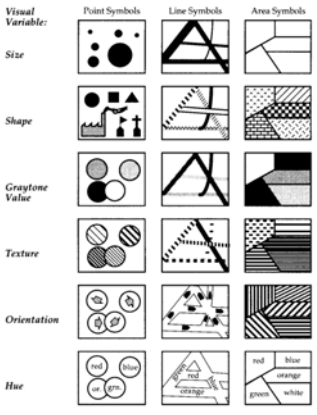


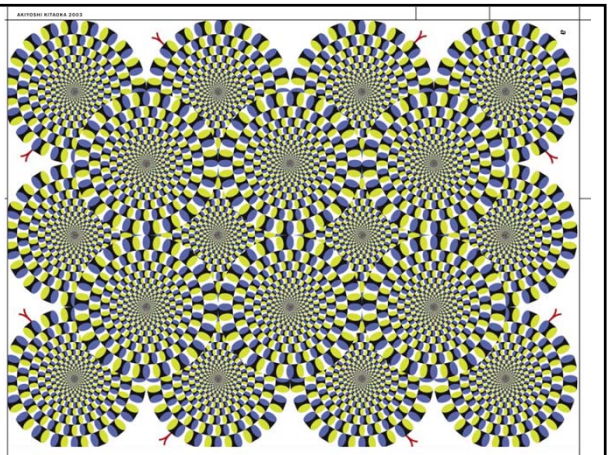
FIGURE 2.11. The six principal visual variables.

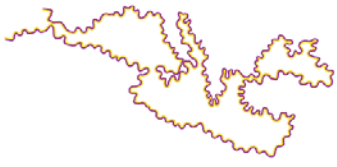
Bertin's six principal visual variables, as presented in "How to lie with maps" (Monmonier, 1991)

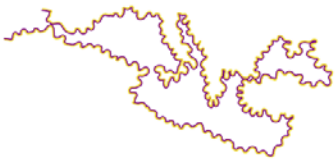
Perception

Context matters: The "white" letters are actually darker than the "black" letters (above), as is clear when surroundings are removed (inset).

Scientific American
Special Issue on Perception, 2008





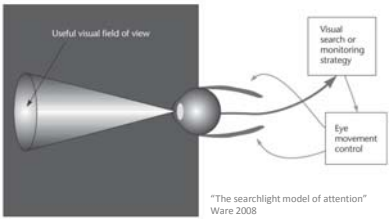


Scientific American
Special Issue on Perception, 2008

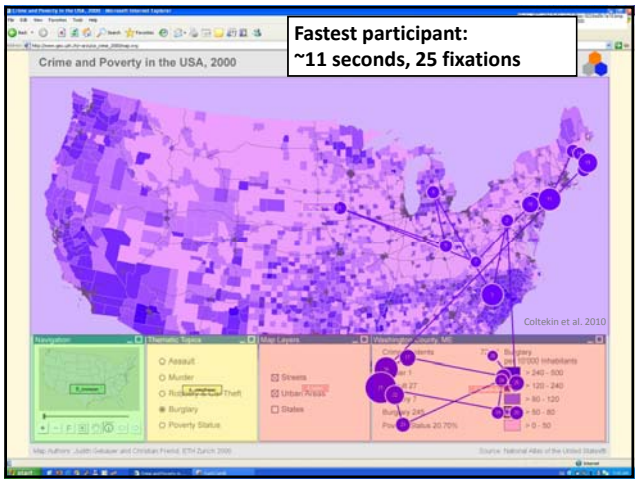
Watercolor effect, in which the lighter of two colors seems to spread, shows how important color can be in delineating the extent and shape of a figure. The map of the Mediterranean Sea emerges at once when the tint that at first seems to cover the sea (*top*) spreads to the land area.

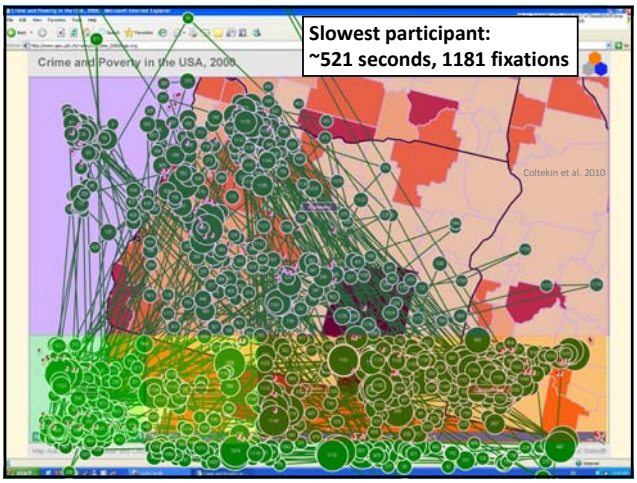
Eye tracking

- Reliable proxy to overt attention
- Metrics complement usability
- Measuring cognitive load?
- Lots of data



"The searchlight model of attention" Ware 2008

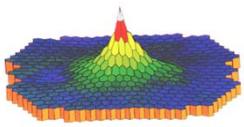




Virtual and Augmented Reality

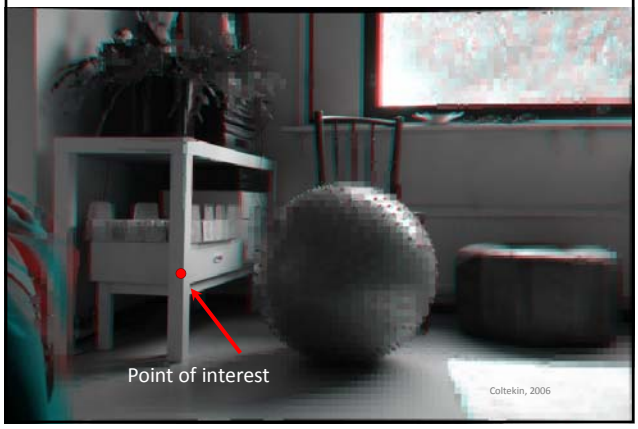
Foveation

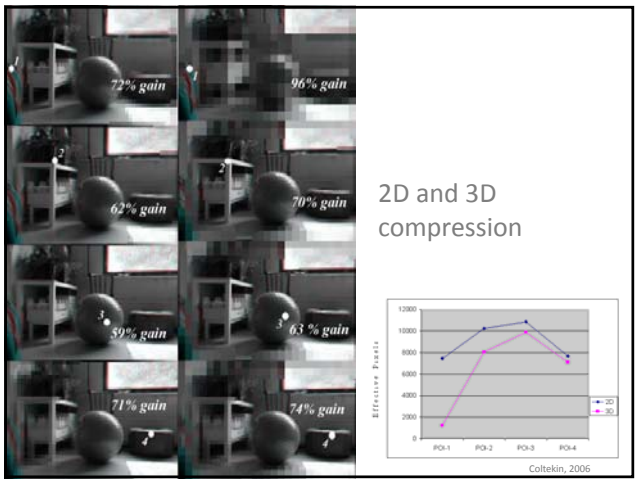
Visual acuity directly related to human fovea



Human Visual System's level of detail management

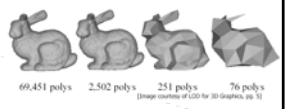
Gaze contingent displays





Virtual and Augmented Reality

LOD Management



In computer graphics

- Remove details not needed/cannot be rendered (e.g. culling), cannot be perceived

- Distance
- Size
- Priority
- Hysteresis
- Environments Conditions
- Perceptual factors, e.g. Eccentricity, Velocity, DoF

Virtual and Augmented Reality

Level of detail in GI

→ Generalization