Interactive Information Visualization
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Outline
- information visualization motivation
- designing for humans
- information visualization techniques
- future directions

Information visualization
- interactive visual representation of abstract data
  - help human perform some task more effectively

Interactivity
- static images
  - 10,000 years
  - art, graphic design
- moving images
  - 100 years
  - cinematography
- interactive graphics
  - 20 years
  - computer graphics, human-computer interaction

Information visualization
- interactive visual representation of abstract data
  - help human perform some task more effectively
- external representation
  - reduces load on working memory
- bridging many fields
  - graphics: interacting in realtime
  - cognitive psych: finding appropriate representation
  - HCI: using task to guide design and evaluation

Task-oriented design
- custom design for checking semantic networks
  - reading definition subgraph labels
Task-oriented design

previous general methods

Design tradeoffs

information density vs. visual salience

Scientific vs. information visualization

scivis: inherently spatial data
  - fluid flow over airplane wing
infovis: abstract data, choice of spatialization
  - FilmFinder

Example: node-link graphs

powerful abstraction
  - common in many domains

Why visualize graphs?

Example: book topic relationships
  - [Godel, Escher, Bach. Hofstadter 1979]

Why visualize graphs?

offload cognition to visual systems
minimal attention to read answer
Why draw graphs automatically?
manually: hours, days   automatically: seconds

Human perception
sensors/transducers
- psychophysics: determine characteristics
relative judgements: strong
absolute judgements: weak
different optimizations than most machines
- eyes are not cameras
- perceptual dimensions not nD array
- brains are not hard disks

Preattentive visual dimensions
color (hue) alone: preattentive
- attentional system not invoked
- search speed independent of distractor count

Preattentive visual dimensions
many preattentive dimensions of visual modality
- hue
- shape
- texture
- length
- width
- size
- orientation
- curvature
- intersection
- intensity
- flicker
- direction of motion
- stereoscopic depth
- lighting direction

Preattentive visual dimensions
color alone: preattentive
shape alone: preattentive
combined hue and shape: multimodal
- requires attention
- search speed linear with distractor count
Dimensional ranking

Data types
- continuous (quantitative): 10 inches, 17 inches, 23 inches
- ordered (ordinal): small, medium, large
- categorical (nominal): apples, oranges, bananas

Dimensional ranking varies by data type
spatial position best for all types

Nonlinear perception of magnitudes
sensory dimensions not equally discriminable
- Stevens power law

Integral vs. separable dimensions
- red-green, x-size, size, color, motion, location

Dimensional dynamic range
linewidth: limited discriminability

[Blackler, Automating the Design of Graphical Presentations of Relational Information, ACM TOG 5.2, 1986]
[Colin Ware, Information Visualization: Perception for Design. Morgan Kaufmann, 1999]
Foveal Vision
thumb at arm’s length
small high resolution area on retina

Equal Legibility
if fixated on center point

Eyes
saccades
- fovea: high-resolution samples
- brain makes collage
- vision perceived as entire simultaneous field
- fixation points: dwell 200–600ms
- moving: 20–100ms

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Coloring Categorical Data
22 colors, but only 8 distinguishable

Coloring Categorical Data
discrete small patches separated in space
limited distinguishability: around 8–14
- channel dynamic range: low
- maximally discriminable colors from Ware
- maximal saturation for small areas

choose bins explicitly for maximum mileage
Minimal Saturation for Large Areas

- avoid saturated color in large areas
  - "excessively exuberant"

![Map of the United States with color gradients](image)

[Edward Tufte, Envisioning Information, p.82]

Coloring Ordered Data

- innate visual order
  - greyscale/luminance
  - saturation
  - brightness
- unclear visual order
  - hue

Coloring Quantitative Data

- continuous field
  - side by side patches highly distinguishable
    - channel dynamic range: high
  - mediocre
    - hue (rainbow)
  - good
    - greyscale/luminance
    - saturation
    - brightness

Rainbow Colormap Advantages

- low-frequency segmentation
  - "the red part", "the orange part", "the green part"

Rainbow Colormap Disadvantages

- segmentation artifacts
  - popular interpolation perceptually nonlinear
  - solution
    - create perceptually isolinear map

Non-Rainbow Colormap Advantages

- High-frequency continuity
  - Interpolating between just two hues

Segmenting Colormaps

- Explicit rather than implicit segmentation

Color Deficiency

- Very low channel dynamic range for some!
  - Protanope: has red/green deficit (10% of males)
  - Deutanope: has yellow/blue deficit
  - Tritanope: has chromatic deficient

http://www.vischeck.com/vischeck
  - Test your images

Color Deficiency Examples: vischeck

- Original
- Protanope
- Deutanope
- Tritanope

Designing Around Deficiencies

- Red/green could have domain meaning then distinguish by more than hue alone
  - Redundantly encode with saturation, brightness

Overview + detail

- Problem:
  - Avoid user disorientation when inspecting detail
  - Hard for big datasets

Bad: one window, must remember position

- Global overview
- Local detail
Overview and detail
better: add linked overview window(s)

how to create overview?

Overview and detail
SeeSoft: software maintenance
(colormaps: segmented vs. continuous)
code age
platform dependencies

Overview+detail
Rivet: performance tuning
level of detail

Overview to detail to sorting

Focus+context
linked windows
still have cognitive load to correlate
good solution:
merge overview, detail into single window
fisheye views [Furnas 86], [Sarkar et al 94]

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nonlinear magnification [Keahey 96]
**Focus + context**
H3 [Munzner 97]
- task: browsing large quasi-hierarchical graphs
  - [demo]

**Global focus + context**
Treejuxtaposer: comparing trees
- linked highlighting
  - [demo]

**Space vs. Time: Showing Change**

- **literal**
  - time for time

- **abstract**
  - space for time

animation: show time using temporal change
- good: show process
- bad: compare by flipping between two things

[www.graphvue.cs.washington.edu](http://www.graphvue.cs.washington.edu)

**Space vs. Time: Showing Change**

- **literal**
  - time for time

- **abstract**
  - space for time

animation: show time using temporal change
- good: show process
- good: compare by flipping between two things
- bad: compare between many things
- interference from intermediate frames

[www.graphvue.cs.washington.edu](http://www.graphvue.cs.washington.edu)
**Space vs. Time: Showing Change**

- literal
- abstract

| time for time | space for time |

small multiples: show time using space
- overview: show each time step in array
- compare: side-by-side easier than temporal
- external cognition instead of internal memory
- general technique, not just for temporal changes

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**Minimizing occlusion**

- bad: Midwestern occlusion

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**Minimizing occlusion**

- good: show only start and end of lines

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**Minimizing occlusion: 3D vs. 2D**

- bad: 3D pretty but not useful
  - metacognitive gap: lose by adding dimension

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**Minimizing occlusion: 3D vs. 2D**

- good: 2D display of category clusters

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**Motion: clarify structure**

- navigation
  - rotate/translate/zoom

- object recognition
  - moving lights at joints
  - Johansson 1973

- animated transitions
  - avoid change blindness
  - jump increases cognitive load
  - smooth transition from one state to next
  - maintain object constancy
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Future: scaling to huge datasets
- data explosion
  - sensors
    - Human Genome Project
    - Sloan Digital Sky Survey
  - simulation
    - Accelerated Strategic Computing Initiative
    - microprocessor design
  - logging
    - long-distance telephony backbone
    - Web traffic

Future: dynamic data
- static
  - hyperlink structure of entire Web
- dynamic
  - entire Web changing through time (Internet Archive)
- open problem: incremental/online layout
  - minimal visual changes: maintain user's mental model
  - faithfully represent current state

Future: scaling display resolution
- always pixel-bound in past
- high-res displays now available
  - 4K x 2K: 9M pixels vs 1 Mpixel
  - pixel rich
- interactivity + resolution of paper
  - add physical navigation (walk closer) to virtual navigation

Project domains
- current
  - bioinformatics
  - data mining
  - environmental sustainability
- past
  - topology
  - networking
  - computational linguistics
  - web site design

More Information
- Term 1 course: 533C Visualization
- email me to schedule time to talk: tmmi@cs.ubc.ca
- FSC 2618
  - Term 1 office hours: 3:45-4:45 Wed
- http://www.cs.ubc.ca/~tmm