Mini-Course Outline

Perception
Frameworks
Color
Space/Order
Depth/Occlusion
High Dimensionality
Interaction
Navigation/Zooming
Focus+Context
Graphs/Trees
Scalability
Task-Centered Design
### Finding the Right Order: Trellis

#### alphabetical

<table>
<thead>
<tr>
<th>Wisconsin No. 39</th>
<th>Fox</th>
<th>St Croix</th>
<th>Mississippi River</th>
<th>Minnesota</th>
<th>Wisconsin</th>
<th>1891</th>
<th>1892</th>
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</tbody>
</table>

#### main-effects: sort by median value

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Finding the Right Order: Table Lens

select column to sort
· user explores

[demo: www.tablelens.com]
Finding the Right Order: Rivet

Finding the Right Order: VisDB

each pixel represents database entry
  · color by query relevance
what order to sort?

spiral

2D

dimension j

dimension i

[www.dbs.informatik.uni-muenchen.de/db/project/papers/visdb.ps]
VisDB Windows

**group dimensions**

**separate dimensions**

one data item approximately fulfilling the query

one data item fulfilling the query
VisDB Results: Separate Dimensions

spiral

2D

[www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps]
VisDB Results: Grouped Dimensions
Derived Spaces: Slope

narrative of space and time
Marey train schedule, 1885
- horizontal line length: stop length
- slope: speed
- intersection: time/place of crossing

Slope: Banking to 45 Degrees

what size should a line graph be?

perceptual principle: most accurate slope judgement near 45 degrees

pick aspect ratio (height/width) to maximize amount of 45 degree slope
Space vs. Time: Showing Change

 literal
<------------------------->
| time for time          |
| abstract               |
| space for time         |

animation: show time using temporal change

- show process
- compare two things by blinking

bad

- directly compare between many things
  intermediate frames "overload mental buffer"

[www.geom.uiuc.edu/docs/outreach/oi/evert.mpg]  [www.astroshow.com/ccdpho/pluto.gif]
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

[Edward Tufte. The Visual Display of Quantitative Information, p 172]
More Reading

The Visual Design and Control of Trellis Display
R. A. Becker, W. S. Cleveland, and M. J. Shyu
http://cm.bell-labs.com/stat/doc/trellis.jcgs.col.ps

Chapter 4: Small Multiples, Chapter 6: Narratives of Space and Time


VisDB: Database Exploration using Multidimensional Visualization,
http://www.dbs.informatik.uni-muenchen.de/dbs/projekt/papers/visdb.ps

The Table Lens: Merging Graphical and Symbolic Representations in an Interactive Focus +
Context Visualization for Tabular Information
http://citeseer.ist.psu.edu/545353.html

Performance Analysis and Visualization of Parallel Systems Using SimOS and Rivet: A Case
Study. Robert Bosch, Chris Stolte, Gordon Stoll, Mendel Rosenblum, and Pat Hanrahan. In
http://graphics.stanford.edu/papers/rivet_argus/
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Layering And Separation
Visual Clutter
subtler background than foreground

[Tufte, Envisioning Information, Chap 3]
Visual Layering For Graphs

- edge crossing problem
- true attachments
- layers to avoid perception
- vs. spatial position

[Muñoz et al, Constellation, graphics.stanford.edu/papers/const]
3D Time-series Data

3D extrusion pretty but not useful
- daily, weekly patterns hard to see
- occlusion hides, perspective interferes
Time-series Data Analysis

data: N pairs of (value, time)
  - N large: 50K

tasks
  - find standard day patterns
  - find how patterns distributed over year, week, season
  - find outliers from standard daily patterns
  - want overview first, then detail on demand

possibilities
  - predictive mathematical models
    details lost, multiscale not addressed
  - scale-space approaches (wavelet, fourier, fractal)
    hard to interpret, known scales lost
  - 3D mountain: x hours, y value, z days
    occlusion hides, perspective interferes
Hierarchical Clustering

start with all M day patterns
  - compute mutual differences, merge most similar
  - continue up to 1 root cluster
result: binary hierarchy of clusters
  - choice of distance metrics

dendrogram display common
  - shows structure of hierarchy
  - does not solve pattern finding problem!
Link Clusters and Calendar

2D linked clusters—calendars shows patterns

- number of employees:
- office hours, fridays in/and summer, school break
- weekend/holidays, post-holiday, santa claus

[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, Figure 4, citeseer.ist.psu.edu/vanwijk99cluster.html]
Power Consumption

[van Wijk and van Selow, Cluster and Calendar based Visualization of Time Series Data, InfoVis99, Figure 5, citeeer.nj.nec.com/vanwijk99cluster.html]
van Wijk Lessons

derived space: clusters
visual representation of time: calendar
  • linked display
  • interactive exploration

clear task analysis guided choices
  • reject standard 3D extrusion
  • reject standard dendrogram

critique
  • pro: great design study, problem solved!
  • con: some chosen colors not discriminable
**3DPS**
1: 2D displace+magnify
2: 3D displace+magnify
3: 2D displace only
4: 3D displace only
5: visual access distortion

Extending Distortion Viewing Techniques from 2D to 3D Data
Carpendale et al 1997
Visual Access Distortion

naive 2D -> 3D extension yields occlusion
  · same problem as van Wijk

graph–based solution
  · move geometry according to viewpoint
  · magnify focus only
  · introduce curves into formerly straight lines

focus + context issues discussed later

[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]
Results

single, multiple foci

[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]
Results

randomly positioned nodes instead of grid
  · closer to real dataset

[pages.cpsc.ucalgary.ca/~sheelagh/personal/pubs/cga97.pdf]
Critique

sophisticated way to navigate 3D graphs

nice technique paper
  · not a design study

interesting discussion I'd like to see
  · more analysis of why 3D necessary
    cites Ware 3x improvement
  · occlusion workaround vs. occlusion avoidance

never shown on real data
  · hard to draw conclusions from toy datasets
EdgeLens

interactive control over edge occlusion

Figure 5a: Bubble approach
Figure 5b: Spline approach

user study: spline better than bubble

[EdgeLens: An Interactive Method for Managing Edge Congestion in Graphs
EdgeLens Final Algorithm

decide which edges affected
calculate displacements
calculate spline control points
draw curves
EdgeLens Techniques

transparency, color
EdgeLens Results


critique
  · very nice technique
  · compelling need
  · shown on real data
Cheops

compact

show paths through tree

extreme occlusion deliberately

browsing/exploration, not topological analysis

[Cheops, Beaudoin/Parent/Vroomen, www.istop.com/~maparent/paper.html]
Cheops Critique

pro
  · tiny footprint
    suitable when main user focus is other task
  · interaction techniques investigated
    informal usability

con
  · relatively hard to understand
  · singular nodes very salient, but not so important
More Reading


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Parallel Coordinates

only 2 orthogonal axes in the plane instead, use parallel axes!

point-line duality

[Parallel Coordinates: A Tool for Visualizing Multi-Dimensional Geometry.](https://www.stat.berkeley.edu/~berkman/research/pc.html)
Parallel Coords: Axis Ordering

geometric interpretations
  - hyperplane, hypersphere: points have intrinsic order

infovis
  - no intrinsic order, what to do?
  - indeterminate/arbitrary order
    weakness of many techniques
    downside: human–powered search
    upside: powerful interaction technique
  - most implementations
    user can interactively swap axes

Automated Multidimensional Detective
  - [Inselberg 99]
  - machine learning approach
Hierarchical Parallel Coords: LOD

[Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets. Eua, Ward, and Bundensteiner. IEEE Vis '99, davis.wpi.edu/~xmdv/docs/vis99_HPC.pdf]
Hierarchical Clustering

proximity-based coloring

[Hierarchical Parallel Coordinates for Visualizing Large Multivariate Data Sets
Fua, Ward, and Rundensteiner. IEEE Vis '99, davis.wpi.edu/~xmdv/docs/vis99_HPC.pdf]
Dimensionality Reduction

mapping
- Q high dims
- P low dims (2 or 3)
- n points
- map Q→P
- minimize error of low-dim distances wrt high-dim dist

distance measures
- pairwise distance matrix between points
- metric between points in space

methods
- MDS (multidimensional scaling)
- LLE (locally linear embedding)
- IsoMap, charting
- PCA, SOM

complexity
- naive $O(n^3)$, many $O(n^2)$,
- best $O(n \sqrt{n})$
True Dimensionality: Linear

how many dimensions is enough? > 2 or 3?
  · knee in error curve
example: measured materials from graphics
linear PCA: 25
  · can get physically impossible intermediate points

True Dimensionality: Nonlinear

nonlinear MDS: 10–15
  - all intermediate points possible  
categorizable by people
    - red, green, blue, specular, diffuse, glossy, metallic,  
    - plastic-y, roughness, rubbery, greasiness, dustiness...

[A Data–Driven Reflectance Model, SIGGRAPH 2003, W Matusik, H. Pfister
W. Freeman, L. McMillan]
Themescapes/Galaxies

MDS output: beyond just drawing points
  - galaxies: aggregation
  - themescapes: terrain/landscapes
Cluster Stability

display
  · also terrain metaphor

underlying computation
  · energy minimization (springs) vs. MDS
  · weighted edges

do same clusters form with different random start points?

"ordination"
  · spatial layout of graph nodes
Approach

- normalize within each column

- similarity metric
  - discussion: Pearson's correlation coefficient

- threshold value for marking as similar
  - discussion: finding critical value
Graph Layout

criteria
  · distance in layout matching graph-theoretic distance
  · vertices one hop away close
  · vertices many hops away far
  · insensitive to random starting positions
  · major problem with previous work!
  · tractable computation

force-directed placement
  · discussion: energy minimization
  · others: gradient descent, etc
  · discussion: termination criteria
Barrier Jumping

same idea as simulated annealing
  · but compute directly
  · just ignore repulsion for fraction of vertices
solves start position sensitivity problem
Results

efficiency
  · naive approach: $O(V^2)$
  · approximate density field: $O(V)$

good stability
  · rotation/reflection can occur

different random start    adding noise

Control

Original  Noise std .001  Noise std .010

Noise std .050  Noise std .100
Critique

real data
  · suggest check against subsequent publication!

give criteria, then discuss why solution fits

visual + numerical results
  · convincing images plus benchmark graphs

detailed discussion of alternatives at each stage

specific prescriptive advice in conclusion
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Dynamic Queries

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahlberg and Shneiderman, Proc SIGCHI '94. citeseer.ist.psu.edu/ahlberg94visual.html]
Dynamic Queries

Ahilberg & Shneiderman, Color plate 2. Categories have been selected, the displayed is zoomed

[Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. Ahilberg and Shneiderman, Proc SIGCHI '94, citeseer.ist.psu.edu/ahilberg94visual.html]
Toolglass and Magic Lens

- see-through
- two-handed

symmetry glass

(a)  (b)  (c)

curvature lens

[citeseer.nj.nec.com/bier93toolglass.html]
**Linked Views**

linked highlighting/brushing/
- extremely powerful technique

- Brushing Scatterplots, Becker and Cleveland, Technometrics 1987 vol 29, pp 127–142

**coordinated views**

- linked navigation

- CMV: International Conference on Coordinated & Multiple Views in Exploratory Visualization

**example: Exploratory Data Visualizer**

Highlighting (Focusing)

Focus user attention on a subset of the data within one graph (from Wills 95)
Link different types of graphs: Scatterplots and histograms and bars
(from Wills 95)

[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]
Baseball data: Scatterplots and histograms and bars (from Wills 95)

- How long in majors
- Select high salaries
- Avg assists vs avg putouts (fielding ability)
- Avg career HRs vs avg career hits (batting ability)
- Distribution of positions played

[www.sims.berkeley.edu/courses/is247/s02/lectures/Lecture3.ppt]
Linking types of assist behavior to position played (from Wills 95)
More Reading


Toolglass and magic lenses: the see-through interface

Brushing Scatterplots, Becker and Cleveland