Chapter 1: Visualization Design


Nested Model

- separating design into four levels
- validate against the right threat based on level

Problem: you misunderstood their needs

Abstraction: you're showing them the wrong thing

Encoding: the way you show it doesn't work

Algorithm: your code is too slow

- you = visualization designer
- they = target user
Characterizing Domain Problem

- identify a problem amenable to vis
  - provide novel capabilities
  - speed up existing workflow
- validation
  - immediate: interview and observe target users
  - downstream: notice adoption rates
Abstracting Data/Tasks

- abstract from domain-specific to generic operations/tasks
  - sorting, filtering, browsing, comparing, finding trend/outlier, characterizing distributions, finding correlation
- data types
  - tables of numbers, relational networks, spatial data
  - transform into useful configuration: derived data
- more next time
- validation
  - deploy in the field and observe usage
Designing Encoding and Interaction

- visual encoding: drawings they are shown
- interaction: how they manipulate drawings
- validation
  - immediate: careful justification wrt known principles
  - downstream: qualitative or quantitative analysis of results
  - downstream: lab study measuring time/error on given task
Creating Algorithms

- carry out specification efficiently
- validation
  - immediate: complexity analysis
  - downstream: benchmarks for system time, memory
### Upstream and Downstream Validation

- **humans in the loop for outer three levels**

<table>
<thead>
<tr>
<th>Threat</th>
<th>Validate</th>
</tr>
</thead>
<tbody>
<tr>
<td>wrong problem</td>
<td>observe and interview target users</td>
</tr>
<tr>
<td>bad data/operation abstraction</td>
<td>justify encoding/interaction design</td>
</tr>
<tr>
<td>ineffective encoding/interaction technique</td>
<td>analyze computational complexity</td>
</tr>
<tr>
<td>slow algorithm</td>
<td>measure system time/memory</td>
</tr>
<tr>
<td></td>
<td>qualitative/quantitative result image analysis</td>
</tr>
<tr>
<td></td>
<td>lab study, measure human time/errors for operation</td>
</tr>
<tr>
<td></td>
<td>field study, document human usage of deployed system</td>
</tr>
<tr>
<td></td>
<td>collect anecdotes about tool utility from target users</td>
</tr>
<tr>
<td></td>
<td>observe adoption rates</td>
</tr>
</tbody>
</table>

[informal usability study]
Validation Mismatch Danger

- cannot show encoding good with system timings
- cannot show abstraction good with lab study

- problem validate: observe target users
- encoding validate: justify design wrt alternatives
- algorithm validate: measure system time
- encoding validate: lab study, qualitative analysis
- abstraction validate: observe real usage in field
Genealogical Graphs

Genealogical Graphs: Validation

- justify encoding/interaction design
- qualitative result image analysis
- test on target users, collect anecdotal evidence of utility
MatrixExplorer

- domain: social network analysis
  - early: participatory design to generate requirements
  - later: qualitative observations of tool use by target users

- techniques
  - interactively map attributes to visual variables
    - user can change visual encoding on the fly (like Polaris)
  - filtering
  - selection
  - sorting by attribute

Requirements

- use multiple representations
- handle multiple connected components
- provide overviews
- display general dataset info
- use attributes to create multiple views
- display basic and derived attributes
- minimize parameter tuning
- allow manual finetuning of automatic layout
- provide visible reminders of filtered-out data
- support multiple clusterings, including manual
- support outlier discovery
- find where consensus between different clusterings
- aggregate, but provide full detail on demand
Techniques: Dual Views

- show both matrix and node-link representations

MatrixExplorer Views

- overviews: matrix, node-link, connected components
- details: matrix, node-link
- controls

Automatic Clustering/Reordering

- automatic clustering as good starting point
- then manually refine

Comparing Clusters

- relayout, check if clusters conserved
- encode clusters with different visual variables
- colorcode common elements between clusters

MatrixExplorer: Validation

- Observe and interview target users
- Justify encoding/interaction design
- Measure system time/memory
- Qualitative result image analysis
algorithm goals

- move nodes to make room, but maintain relative positions
- minimize edge crossings

[Fig 1c, 10. Phan, Yeh, Hanrahan, Winograd. Flow Map Layout. Proc InfoVis 2005, p 219-224.]
Flow Maps: Validation

justify encoding/interaction design
computational complexity analysis
measure system time/memory
qualitative result image analysis
LiveRAC

- domain: large-scale sysadmin
- data: time series of system status from devices
  ( 10 Aug 2007 9:52:47, CPU, 95% )

- tasks
  - interpret network environment status
  - capacity planning
  - event investigation (forensics)
  - coordinate: customers, engineering, operations

- techniques
  - semantic zooming
  - stretch and squish navigation
Time-Series Challenges

CPU utilization over time

Total CPU utilization vs. Time
Time-Series Challenges

CPU utilization over time

![CPU utilization graph](image-url)
Time-Series Challenges

CPU utilization over time

Total CPU utilization

Time

05:00:00 05:30:00 06:00:00 06:30:00 07:00:00 07:30:00 08:00:00
Time-Series Challenges

CPU utilization over time

![Graph showing CPU utilization over time](image-url)
Time-Series Challenges

CPU utilization over time

Total CPU utilization

Time
Design Approach

- time series challenges
  - not safe to just cluster/aggregate
  - need overview and details

- design principles
  - spatial position is strongest perceptual cue
  - side by side comparison easier than remembering previous views
  - multiple views should be explicitly linked
  - show several scales at once for high information density in context
  - preserve familiar representations when appropriate
  - overview first, zoom and filter, details on demand
  - avoid abrupt visual change
  - provide immediate feedback for user actions
Phased Design

- target users hard to access: high-level corporate approval
- phase 1
  - external experts
  - simulated data
  - result: visenc/interaction proof of concept
- phase 2
  - internal engineers, managers
  - real data
  - result: hi-fi prototype
- phase 3
  - 4 internal technical directors
  - result: deployment-ready robust prototype
- phase 4
  - field test: 4 directors, 7 network engineers
  - prototype deployed for 4 months
observe and interview target users

justify encoding/interaction design

qualitative result image analysis

field study, document usage of deployed system
LinLog

- energy model to show cluster structure
  - reject metric of uniform edge length
  - refine: two sets for length, within vs between clusters
- validation: proofs of optimality
- level is visual encoding not algorithm
  - energy model vs. algorithm using model for force-directed placement

LinLog: Validation

qualitative/quantitative result image analysis
Sizing the Horizon

- high data density displays
  - horizon charts, offset graphs

Experiment 1

- how many bands? mirrored or offset?
- design: within-subjects
  - 2 chart types: mirrored, offset
  - 3 band counts: 2, 3, 4
  - 16 trials per condition
  - 96 trials per subject
- results
  - surprise: offset no better than mirrored
  - more bands is harder (time, errors)
    - stick with just 2 bands
**Experiment 2**

- mirror/layer vs line charts? effect of size?
- design: within-subjects
  - 3 charts: line charts, mirror no banding, mirror 2 bands
  - 4 sizes
  - 10 trials per condition
  - 120 trials per subject

Results

- found crossover point where 2-band better: 24 pixels
  - virtual resolution: unmirrored unlayered height
  - line: 1x, 1band: 2x, 2band: 4x

- guidelines
  - mirroring is safe
  - layering (position) better than color alone
  - 24 pixels good for line charts, 1band mirrors
  - 12 or 16 pixels good for 2band
Sizing the Horizon: Characterization

lab study, measure human time/errors for operation
Key Ideas

- characterize methods using lab studies
  - more useful than A/B system comparison lab studies
  - finding thresholds
  - uncovering hidden variables
- controlled experiments
  - experimental design and statistical power
Critique

- Very well executed study
- Best paper award
- Finding crossover points is very useful
Critique

- strengths
  - very well executed study
    - best paper award
  - finding crossover points is very useful

- weaknesses
InfoVis Scope

- a human in the loop
InfoVis Scope

- a human in the loop
- visual perception
InfoVis Scope

- a human in the loop
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- external representation
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- a computer in the loop
InfoVis Scope

- a human in the loop
- visual perception
- external representation
- a computer in the loop
- show the data in detail

Identical statistics

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<tr>
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<td>x variance</td>
<td>10.0</td>
</tr>
<tr>
<td>y mean</td>
<td>7.50</td>
</tr>
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<td>y variance</td>
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[http://upload.wikimedia.org/wikipedia/commons/b/b6/Anscombe.svg]
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- a human in the loop
- visual perception
- external representation
- a computer in the loop
- show the data in detail
- driving task
InfoVis Scope

- a human in the loop
- visual perception
- external representation
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- driving task
- the meaning of better
Resource Limitations

- computational capacity
  - CPU time
  - computer memory: size, cache hierarchy
- human capacity
  - human memory: working, longterm recall
  - human attention: search, vigilance
- display capacity
  - information density
    - information encoded / total space used
    - show lots: minimize navigation/exploration
    - show less: minimize visual clutter