Lecture 13: User Studies

Information Visualization
CPSC 533C, Fall 2007

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Readings Covered

Ware, Appendix C: The Perceptual Evaluation of Visualization Techniques and Systems

Snap-Together Visualization: Can Users Construct and Operate Coordinated Views? Chris North, B. Shneiderman. Intl. Journal of Human-Computer Studies, Academic Press, 53(5), pg. 715-739, (November 2000).

The Perceptual Scalability of Visualization. Beth Yost and Chris North. Proc. InfoVis 06, published as IEEE TVCG 12(5), Sep 2006, p 837-844.

Navigating Hierarchically Clustered Networks through Fisheye and Full-Zoom Methods. Doug Schaffer, Zhengping Zuo, Saul Greenberg, Lyn Bartram, John C. Dill, Shelli Dubs, and Mark Roseman. ACM Trans. Computer-Human Interaction (ToCHI), 3(2) p 162-188, 1996.

Turning Pictures into Numbers: Extracting and Generating Information from Complex Visualizations. J. Gregory Trafton, Susan S. Kirschenbaum, Ted L. Tsui, Robert T. Miyamoto, James A. Ballas, and Paula D. Raymond. Intl Journ. Human Computer Studies 53(5), 827-850.

Further Readings

Task-Centered User Interface Design, Clayton Lewis and John Rieman, Chapters 0-5.

The challenge of information visualization evaluation Catherine Plaisant. Proc. Advanced Visual Interfaces (AVI) 2004

Ware: Evaluation Appendix

- perceptual evaluation of infovis techniques and systems
  - empirical research methods applied to vis
  - difficult to isolate evaluation to perception
- research method depends on research question and object under study

[Ware, Appendix C: The Perceptual Evaluation of Visualization Techniques and Systems. Information Visualization: Perception for Design.]

Psychophysics

- method of limits
  - find limitations of human perceptions
- error detection methods
  - find threshold of performance degradation
  - staircase procedure to find threshold faster
- method of adjustment
  - find optimal level of stimuli by letting subjects control the level

Cognitive Psychology

- repeating simple, but important tasks, and measure reaction time or error
  - Miller's 7+/- 2 short-term memory experiments
  - Fitts' Law (target selection)
  - Hick's Law (decision making given n choices)
- interference between channels
- multi-modal studies
  - MacLean, "Perceiving Ordinal Data Haptically Under Workload (2005)
  - using haptic feedback for interruption when the participants were visually (and cognitively) busy

Structural Analysis

- requirement analysis, task analysis
- structured interviews
  - can be used almost anywhere, for open-ended questions and answers
- rating/Likert scales
  - commonly used to solicit subjective feedback
  - ex: NASA-TLX (Task Load Index) to assess mental workload
    - "it is frustrating to use the interface"
    - Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree

Comparative User Studies

- hypothesis testing
- hypothesis: a precise problem statement
  - ex from Snap: Participants will be faster with a coordinated overview+detail display than with an uncoordinated display or a detail-only display with the task requires reading details
  - measurement: faster
  - objects of comparison:
    - coordinated O+D display
    - uncoordinated O display
    - uncoordinated D display
  - condition of comparison: task requires reading details

Comparative User Studies

- study design: factors and levels
- factors
  - independent variables
  - ex: interface, task, participant demographics
- levels
  - number of variables in each factor
  - limited by length of study and number of participants

Comparative User Studies

- study design: within, or between?
- within
  - everybody does all the conditions
  - can lead to ordering effects
  - can account for individual differences and reduce noise
  - thus can be more powerful and require fewer participants
  - combinatorial explosion
    - severe limits on number of conditions
  - possible workaround is multiple sessions
- between
  - divide participants into groups
  - each group does only some conditions

Comparative User Studies

- measurements (dependent variables)
  - performance indicators: task completion time, error rates, mouse movement
  - subjective participant feedback: satisfaction ratings, closed-ended questions, interview
  - observations: behaviors, signs of frustration
- number of participants
  - depends on effect size and study design: power of experiment
- possible confounds?
  - learning effect: did everybody use interfaces in a certain order?
  - if so, are people faster because they are more practiced, or because of true interface effect?

Comparative User Studies

- result analysis
  - should know how to analyze the main results/hypotheses BEFORE study
  - hypothesis testing analysis (using ANOVA or t-tests) tests how likely observed differences between groups are due to chance alone
  - ex: a p-value of 0.05 means there is a 5% probability the difference occurred by chance
    - usually good enough for HCI studies
- pilots!
  - should know the main results of the study BEFORE actual study

Evalation Throughout Design Cycle

- user/task centered design cycle
  - initial assessments
  - iterative design process
  - benchmarking
  - deployment
- identify problems, go back to previous step

Task-Centered User Interface Design, Clayton Lewis and John Rieman, Chapters 0-5.

Initial Assessments

- what kind of problems are the system aiming to address?
  - analyze a large and complex dataset
- who are your target users?
  - data analysts
- what are the tasks? what are the goals?
  - find trends and patterns in the data via exploratory analysis
- what are their current practices
  - statistical analysis
- why and how can visualization be useful?
  - visual spotting of trends and patterns

- talk to the users, and observe what they do
- task analysis

Iterative Design Process

- does your design address the users' needs?
- can they use it?
- where are the usability problems?

- evaluate without users
  - cognitive walkthrough
  - action analysis
  - heuristics analysis
- evaluate with users
  - usability evaluations (think-aloud)
  - bottom-line measurements
  - example: snap paper experiment 1

Benchmarking

- how does your system compare to existing ones?
  - snap paper experiment 2
- empirical, comparative studies
  - ask specific questions
  - compare an aspect of the system with specific tasks
    - Amar/Stasko task taxonomy paper
  - quantitative, but limited
    - The Challenge of Information Visualization Evaluation, Catherine Plaisant, Proc. AVI 2004

Deployment

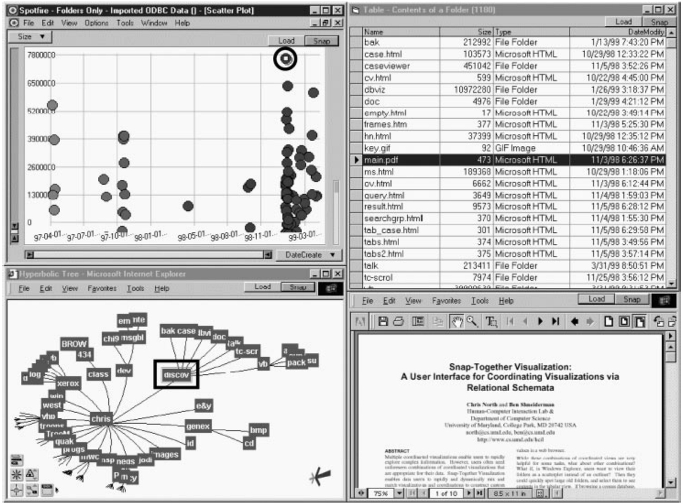
- how is the system used in the wild?
- how are people using it?
- does the system fit into existing work flow? environment?

- contextual studies, field studies

Comparing Systems vs. Characterizing Usage

- user/task centered design cycle:
  - initial assessments
  - iterative design process
  - benchmarking: head-to-head comparison
  - deployment
  - (identify problems, go back to previous step)
- understanding/characterizing techniques
  - tease apart factors
  - when and how is technique appropriate
- line is blurry: intent

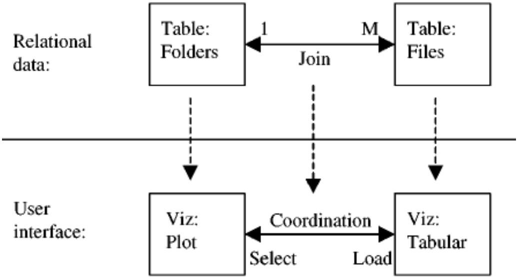
Snap-Together Visualization: CMV



[Snap-Together Visualization: Can Users Construct and Operate Coordinated Views? North and Shneiderman. Intl. J. Human-Computer Studies, Academic Press, 53(5), pg. 715-739, Nov 2000.]

Snap CMV Formalism

- relation :: visualization
- tuple :: item
- primary key :: item ID
- join :: coordination



[Snap-Together Visualization: Can Users Construct and Operate Coordinated Views? North and Shneiderman. Intl. J. Human-Computer Studies, Academic Press, 53(5), pg. 715-739, Nov 2000.]

Snap CMV Formalism

- one-to-one
  - linked selection across views
  - overview select $\longrightarrow$ detail scroll
  - linked scrolling across views
- one-to-many
  - parent select $\longrightarrow$ child load
- architecture
  - independent modules linked via API
  - versus tightly coupled Improvise approach

Snap Usability Evaluation

- 6 participants: 3 data analysts, 3 programmers
  - census bureau: analysts + 1 programmer (expert?)
  - CS students: 2 programmers (novice?)
- 3 tasks
  - 2 construct to spec
  - 1 open ended, “abstract thinking about coordination”
- measurements
  - survey of background knowledge (data, tools)
  - success at task
  - learning time, time to completion

Snap Usability Results

- success, enthusiasm
  - possible confound from please-the-creator effect
- analyst/programmer differences
  - interface building as exploration vs. construction
  - analysts performed better
- snap usability problems
  - explicit overview of coordination setup may help
  - provide attribute lists instead of requiring access queries
  - window rearrangement timesink

Snap User Study

- hypothesis
  - participants will be faster with a coordinated overview+detail display than with an uncoordinated display or a detail-only display with the task requires reading details
- factors and levels
  - interface: 3 levels
    - detail-only
    - uncoordinated overview+detail
    - coordinated overview+detail
  - task: 9 levels
    - many browsing tasks, not grouped prior to study
    - closed-ended, with obvious correct answers
    - ex: "which state has the highest college degree
    - compare with open-ended usability task: "Please create a user-interface that will support users in efficiently performing the following task: to be able to quickly discover which states have high population and high Per Capita Income, and examine their counties with the most employees"

Snap User Study Design

- within-subject
  - everybody worked on all interfaces/task combos
- counterbalanced between interfaces
  - 6 permutations to avoid ordering / learning effects
  - 3 groups x 6 permutations = 18 particip
- need one task set (9) for each interface
  - tasks in each set need to be isomorphic
- 27 tasks per study per participant
  - 3 interfaces x 9 tasks

Snap User Study Design

- measurements
  - task completion time to obtain answer
    - no errors
  - subjective ratings using rated scale (1-9)
- participants
  - 18 students (novice)

Snap User Study

- time result analysis: hypothesis testing with ANOVA
  - 3 (interface) x 9 (task) within-subjects ANOVA to check for main effects of interface, or task, or interface/task interaction
- ANOVA
  - (ANalysis Of VAriance between groups)
  - commonly used statistics for factorial designs
  - tests difference between means of two or more groups
    - example use: two-way ANOVA to see if there is an effect of interface and task, or interaction between them

Snap User Study

- time result analysis: descriptive statistics
  - on average, coordination achieves an 80% speedup over detail-only for all tasks
  - good for discoveries based on results
  - example: 3 task groups
  - example: explain quantitative data with observed participant behaviours
- subjective satisfaction analysis: hypothesis testing with ANOVA
  - 3 (interface) x 4 (question category) within-subjects ANOVA

Critique

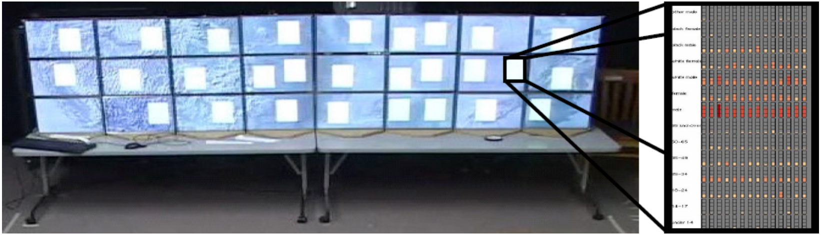
- good example of usability vs. comparative study

	Usability testing	User study
Aim	Improve product design •Is the prototype usable?	• Discover knowledge (how are interfaces used?) • Prove concepts (Is your novel technique *actually* useful?)
Participants	Few, domain expert or target users	More, novices, general human behaviours
Expt conditions	Partially controlled, could be contextual, and could be realistic, more open-ended tasks ◊More ecologically valid?	Strongly controlled, unrealistic laboratory environment with predefined, simplistic tasks ◊Less ecologically valid?
Reproducibility	Not perfectly replicable, too many uncontrolled / uncontrollable factors	Should be replicable (but, limited generalizbility?)
Report to...	Developers	Scientific community
Bottom-line	Identify usability problems	Hypothesis testing (yes, need those *p*-values to be less than .05!)

[Heidi Lam. http://www.cs.ubc.ca/ tmm/courses/cpsc533c-06-fall/#lect10]

Perceptual Scalability

- what are perceptual/cognitive limits when screen-space constraints lifted?
  - 2 vs. 32 Mpixel display
  - macro/micro views
- perceptually scalable
  - no increase in task completion times when normalize to amount of data

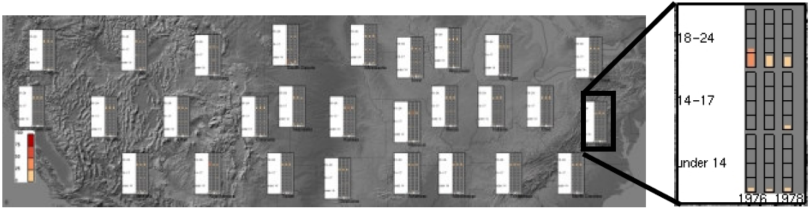


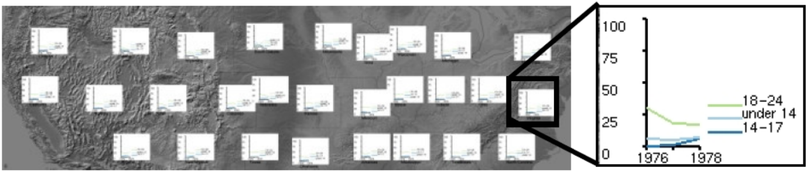
[The Perceptual Scalability of Visualization. Beth Yost and Chris North. IEEE TVCG 12(5) (Proc. InfoVis 06), Sep 2006, p 837-844.]

Perceptual Scalability

- design
  - 2 display sizes, between-subjects
    - (data size also increased proportionally)
  - 3 visualization designs, within
    - small multiples: bars
    - embedded graphs
    - embedded bars
  - 7 tasks, within
  - 42 tasks per participant
    - 3 vis x 7 tasks x 2 trials

Embedded Visualizations





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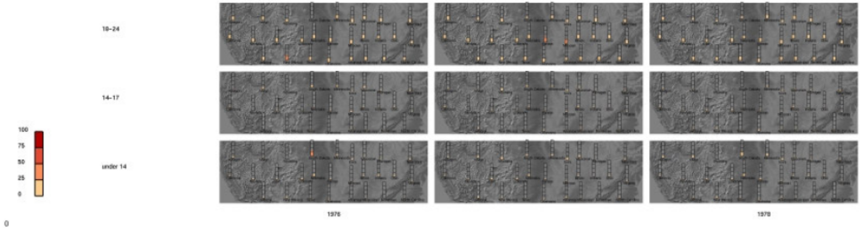
Small Multiples Visualizations

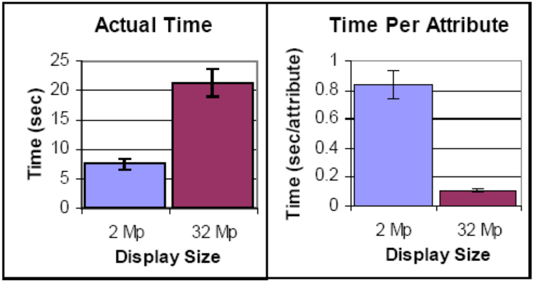
- attribute-centric instead of space-centric



[The Perceptual Scalability of Visualization. Beth Yost and Chris North. IEEE TVCG 12(5) (Proc. InfoVis 06), Sep 2006, p 837-844.]

Results

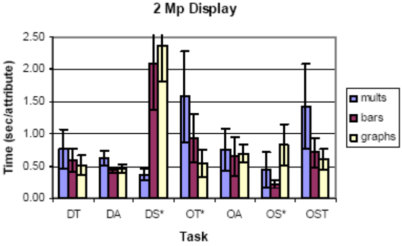
- 20x increase in data, but only 3x increase in absolute task times

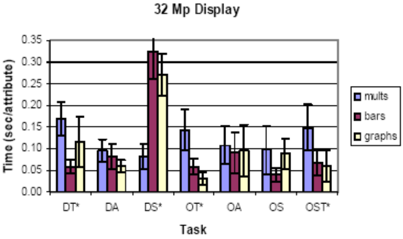


[The Perceptual Scalability of Visualization. Beth Yost and Chris North. IEEE TVCG 12(5) (Proc. InfoVis 06), Sep 2006, p 837-844.]

Results

- significant 3-way interaction
  - between display, size, task





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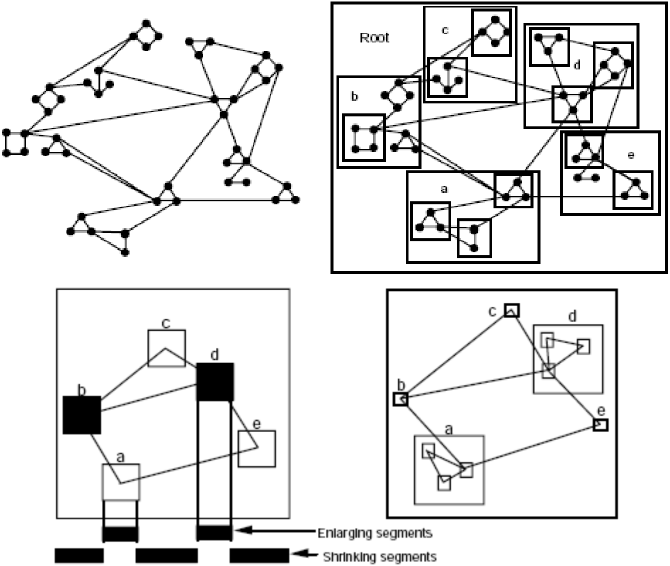
Results

- visual encoding important on small displays
  - DS: mults sig slower than graphs on small
  - DS: mults sig slower than embedded on large
  - OS: bars sig faster than graphs for small
  - OS: no sig difference bars/graphs for large
- spatial grouping important on large displays
  - embedded sig faster+preferred over small mult
  - no bar/graph differences

Critique

- first study of macro/micro effects
  - breaking new ground
- many possible followups
  - physical navigation vs. virtual navigation

Fisheye Multilevel Networks



[Navigating Hierarchically Clustered Networks through Fisheye and Full-Zoom Methods. Schaffer et al. ACM ToCHI 3(2) p 162-188, 1996.]

Lab Experiment

- 2 interfaces (fisheye, zoom)
- 2 tasks (isomorphic)
  - stages: find and repair
- within subjects, counterbalanced order
- 20 participants
- data: 154 nodes, 39 clusters
- measurements
  - completion time
  - number of zooms
  - success

Results

- sig effect of interface: fisheye faster
- but no differences with find subtask
  - information visible in both displays
- solution quality differed: fisheye better
  - local rerouting difficult in full-zoom

Field Experiment

- 2 real control room operators
- response times similar
  - no statistical analysis, too few subjects
- expressed preference for fisheye over full-zoom
  - (experimenter effect?)
- concerns about fisheye: missing details

Critique

- nicely designed study
- useful discussion of qualitative observations
- very good to do field followup with real operators

Pictures Into Numbers

- field study
- participants: professional meterologists
  - two people: forecaster, technician
- interfaces: multiple programs used
- protocol
  - talkaloud
  - videotaped sessions with 3 cameras

[Turning Pictures into Numbers: Extracting and Generating Information from Complex Visualizations. Trafton et al. Intl J. Human Computer Studies 53(5), 827-850.]

Cognitive Task Analysis

- initialize understanding of large scale weather
- build qualitative mental model (QMM)
- verify and adjust QMM
- write the brief

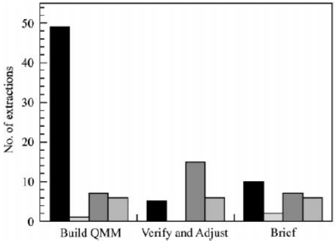
- task breakdown part of paper contribution

Coding Methodology

- interface
  - which interface used
  - whether picture/chart/graph
- usage (every utterance!)
  - goal
  - extract
    - quant/qual
    - goal-oriented/opportunistic
    - integrated/unintegrated
  - brief-writing
    - quant/qual
    - QMM/vis/notes

Results

- sig difference between vis used at CTA stages
  - charts to build QMM
  - images to verify/adjust QMM
  - all kinds during brief-writing
- many others...



The relation between the stage of the CTA and the type of visualization used by the forecasters: ■, chart; ■, graph; ■, picture; ■, text.

[Turning Pictures into Numbers: Extracting and Generating Information from Complex Visualizations. Trafton et al. Intl J. Human Computer Studies 53(5), 827-850.]

Critique

- video coding is huge amount of work, but very illuminating
  - untangling complex story of real tool use
- methodology of CTA construction not discussed here
  - often bottomup/topdown mix

Credits

- Heidi Lam guest lecture

http://www.cs.ubc.ca/ tmm/courses/cpsc533c-06-fall/#lect10