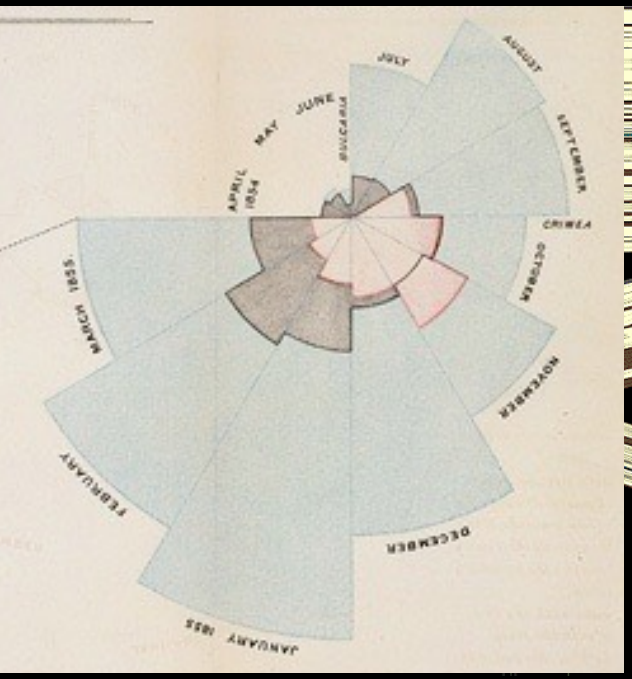
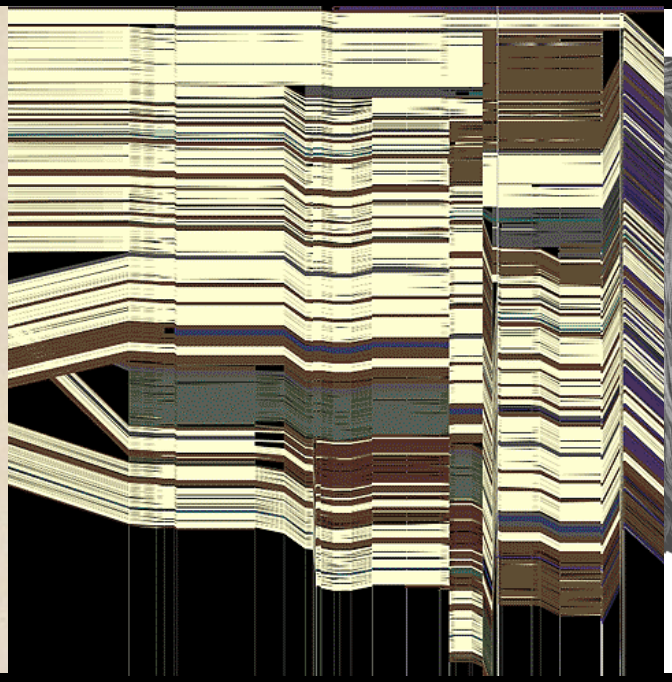
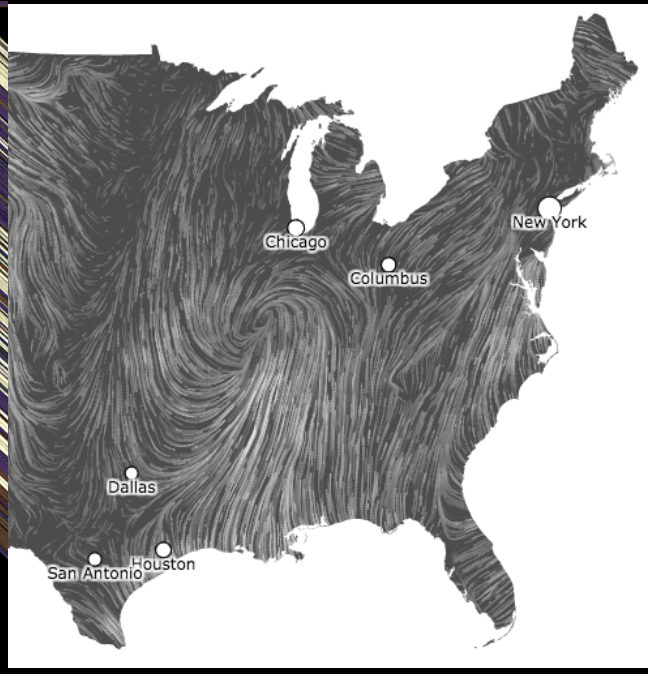
CSE 442 - Data Visualization

Evaluation



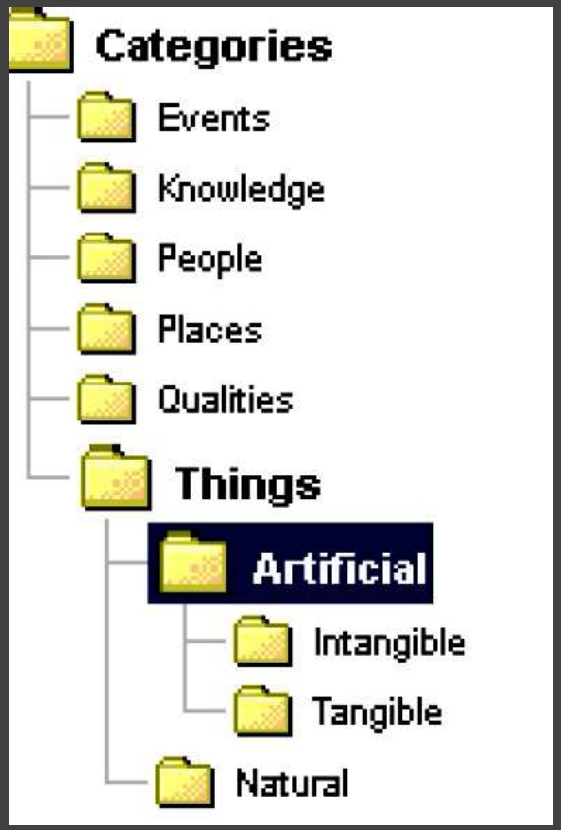




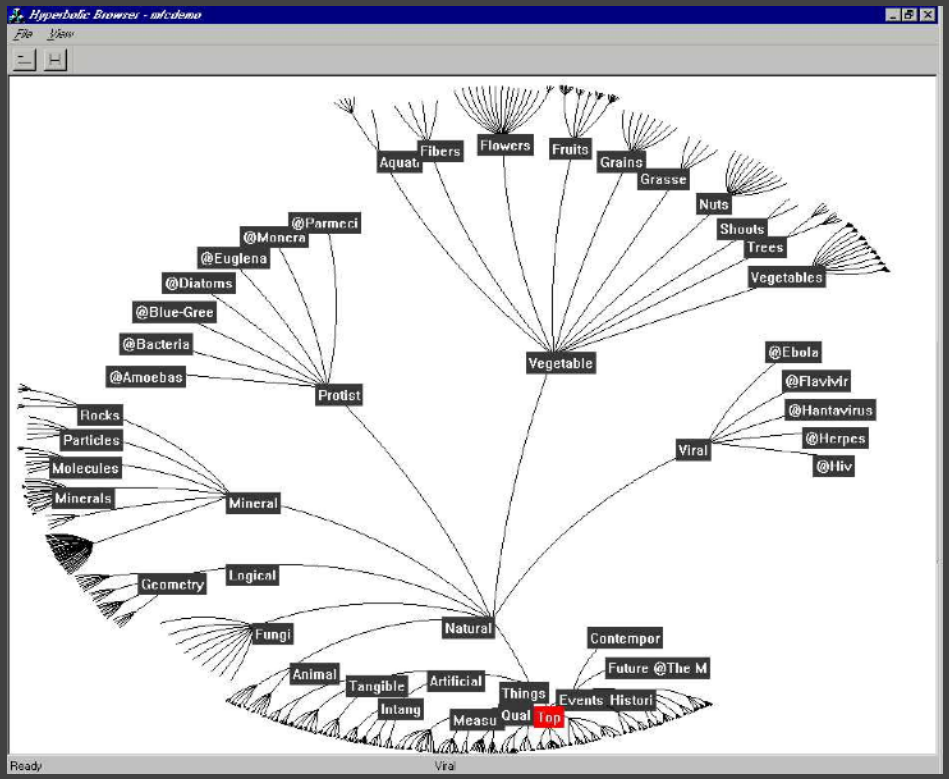
Jeffrey Heer University of Washington

How do we determine if a visualization is *effective*?

Example: Tree Browsers



vs.



Evaluation Methods

Inspection or Principled Rationale
Apply design heuristics, perceptual principles

Informal User Study
Have people use visualization, observe results

Controlled Experiment
Choose appropriate tasks / users to compare
Choose metrics (time, error, **what else?**)

Evaluation Methods

Field Deployment or Case Studies
Observation and Interview
Document effects on work practices

Theoretical Analysis
Algorithm time and space complexity

Benchmarks
Performance (e.g., interactive frame rates)
Scalability to larger data sets

Topics

Focus+Context (Trees, Spatial Navigation)

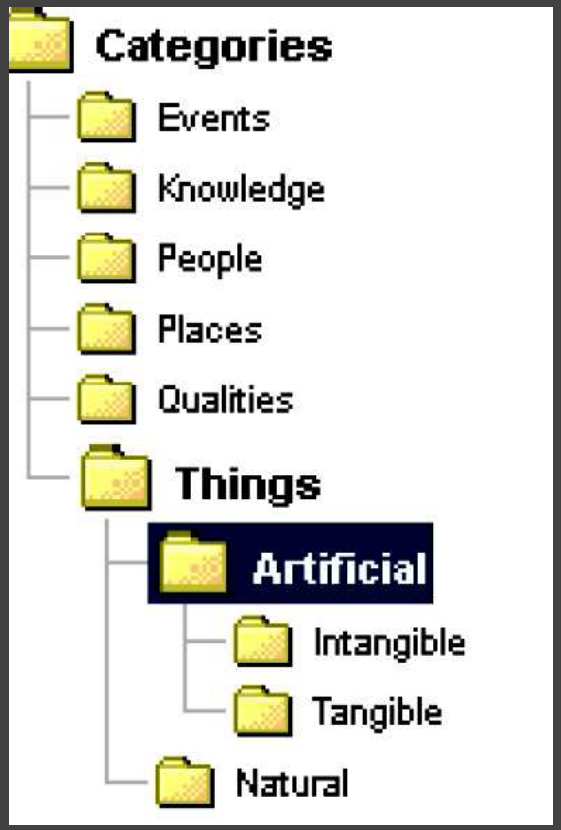
Data Density of Time Series

Perceptual Organization of Graphs

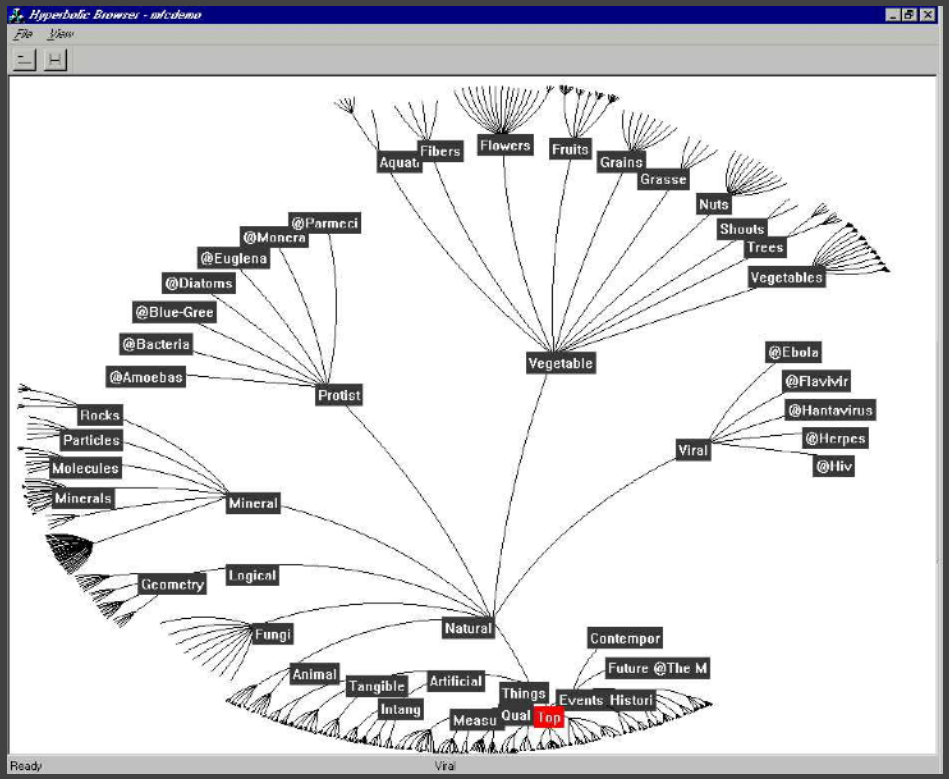
Discussion and Course Evaluation

Trees

The Great Browse-Off! [CHI 97]



vs.



Microsoft File Explorer

Xerox PARC Hyperbolic Tree

Which visualization is better?

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Xerox PARC researchers ran eye-tracking studies to investigate... [Pirolli et al 00]

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Subjects performed both retrieval and comparison tasks of varying complexity.

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Xerox PARC researchers ran eye-tracking studies to investigate... [Pirolli et al 00]

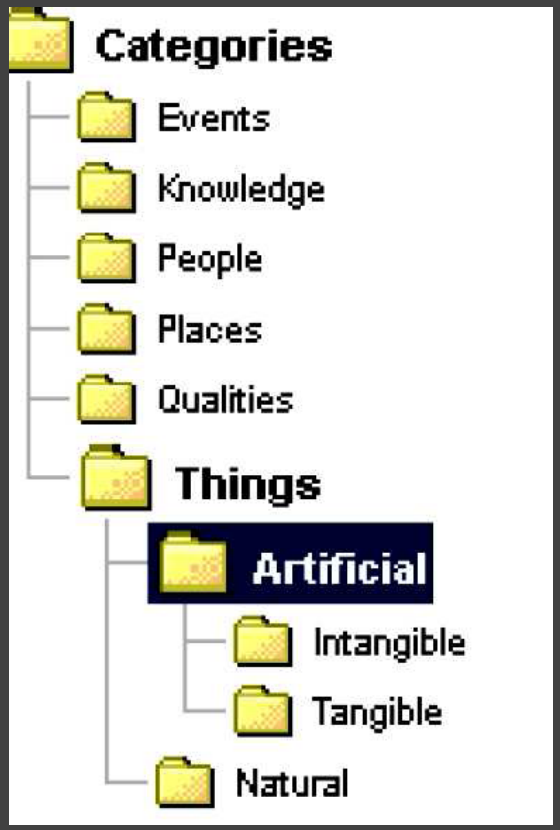
Subjects performed both retrieval and comparison tasks of varying complexity.

No significant performance differences were found across task conditions.

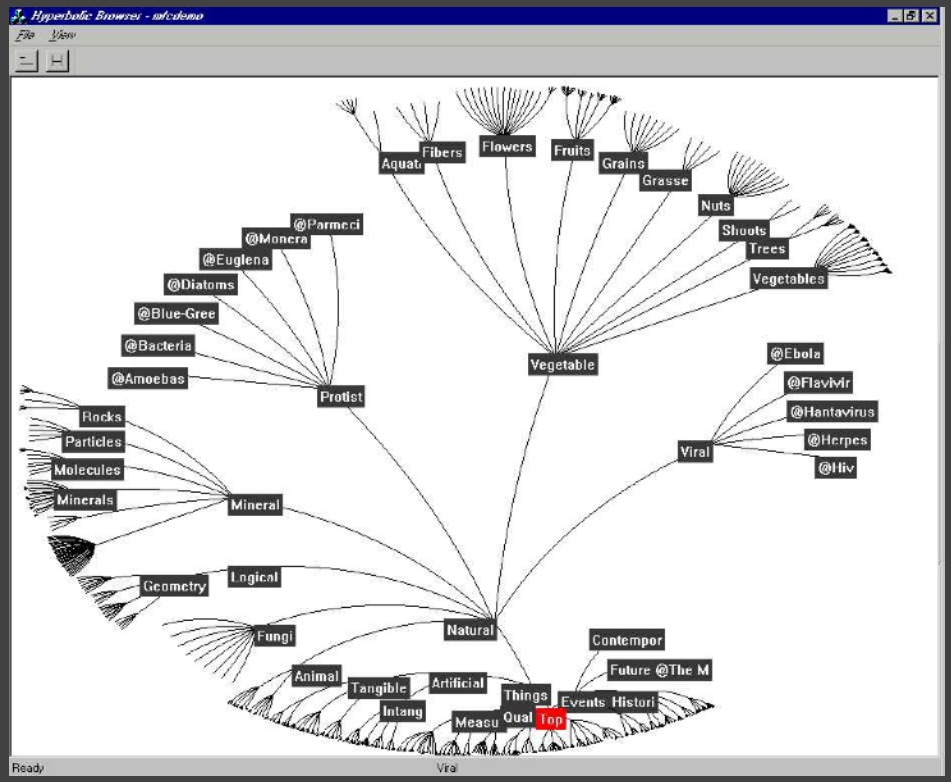
How do users navigate the tree?

How do users navigate the tree?

They read the labels!



vs.



Microsoft File Explorer

Xerox PARC Hyperbolic Tree

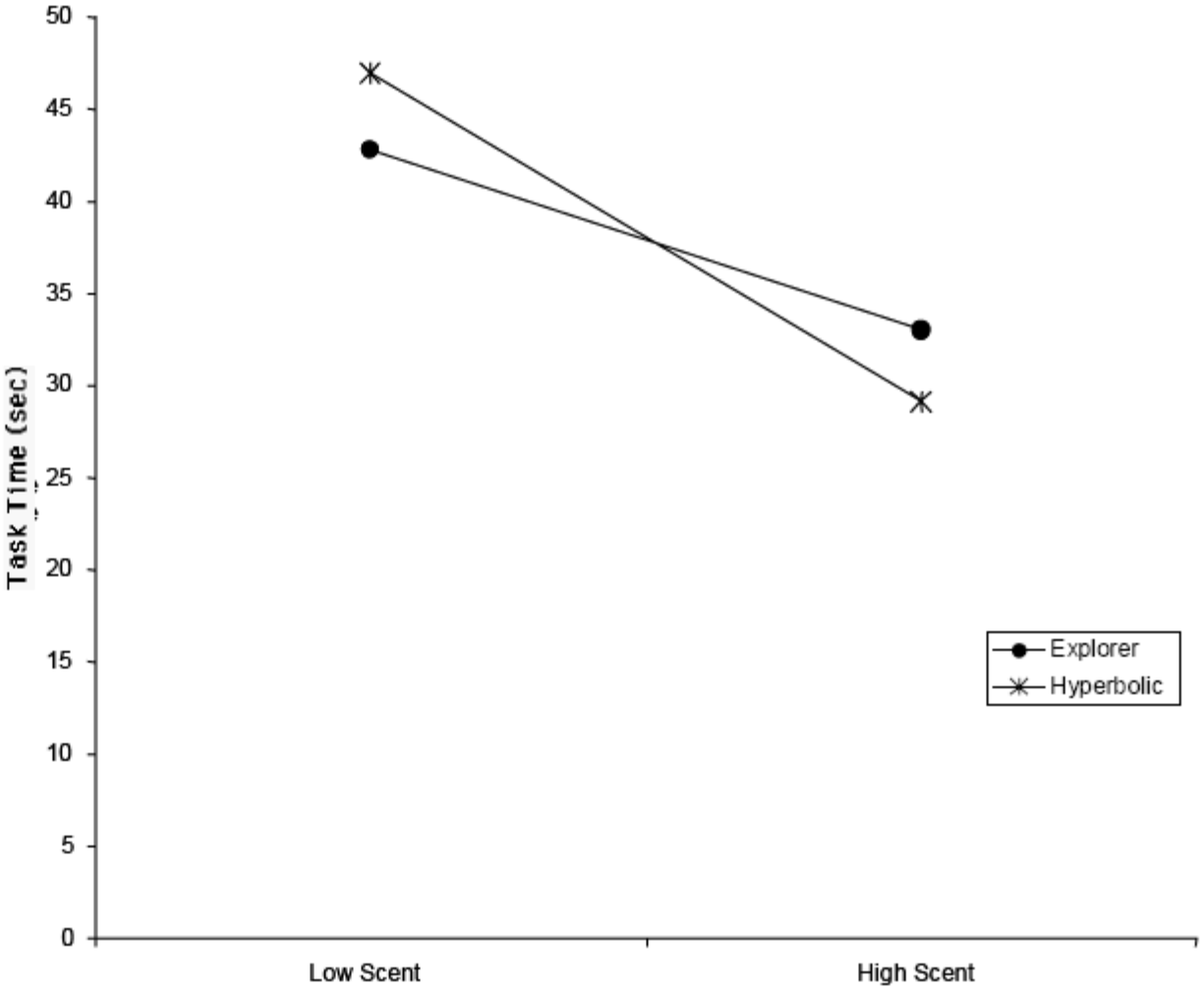
How do users navigate the tree?

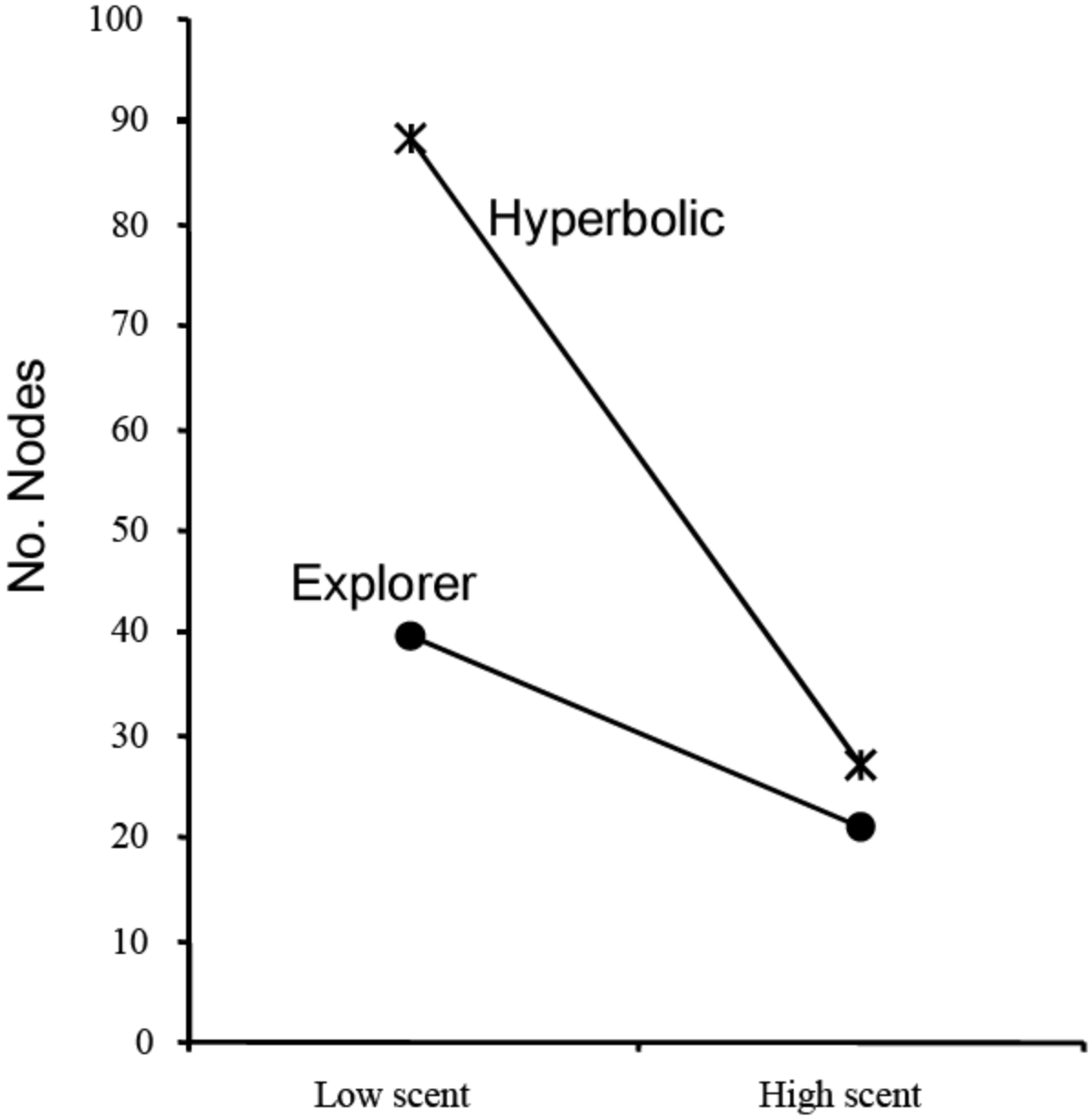
Information Scent: A user's (imperfect) perception of the value, cost, or access path of information sources obtained from proximal cues. [Pirolli & Card 99]

How do users navigate the tree?

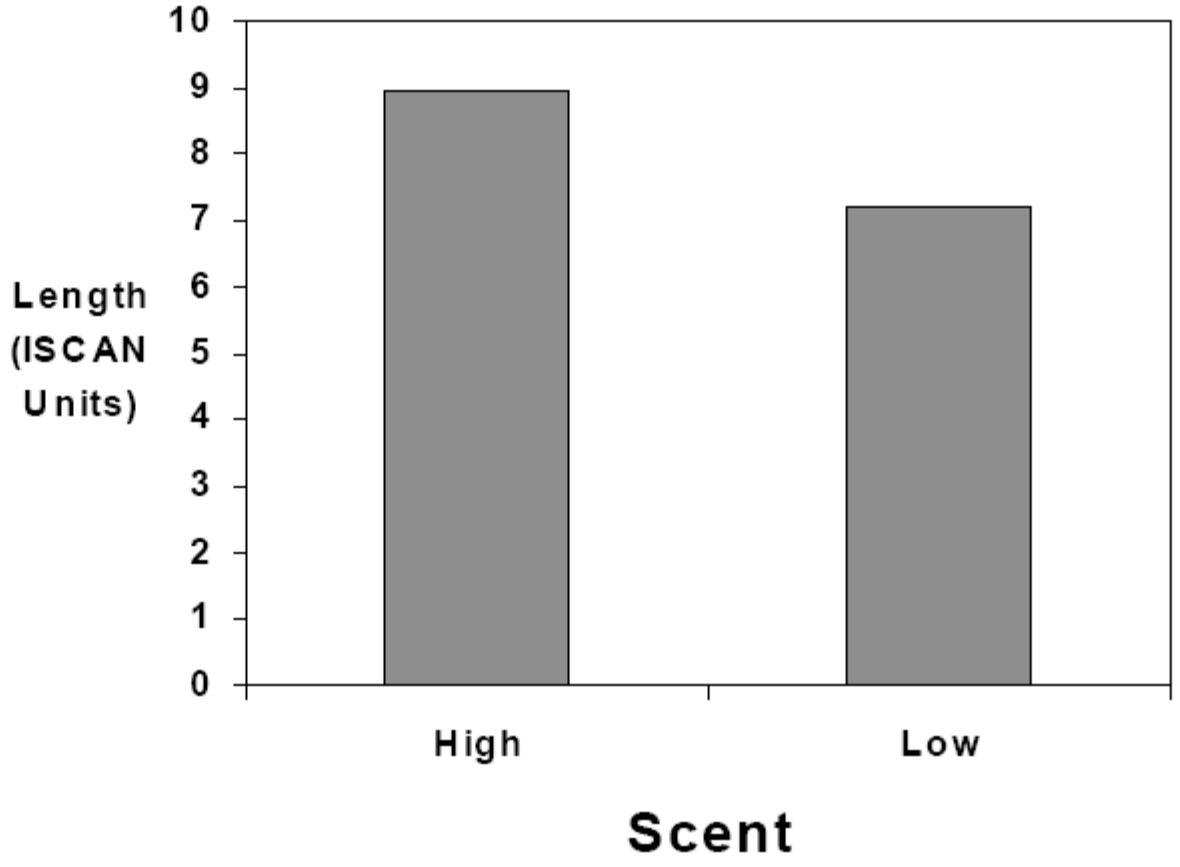
Information Scent: A user's (imperfect) perception of the value, cost, or access path of information sources obtained from proximal cues. [Pirolli & Card 99]

Operationalize as: the proportion of participants who correctly identified the location of the task answer from looking at upper branches in the tree.

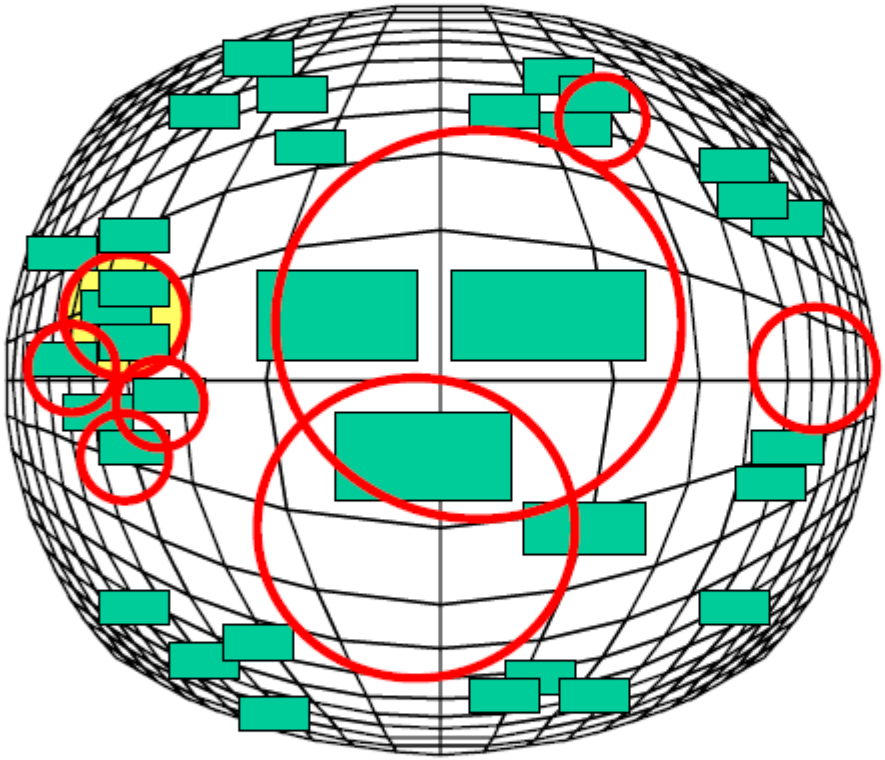

50
45
40
35
30
25
20
15
10
5
0
Task Time (sec)
Low Scent
High Scent
Explorer
Hyperbolic

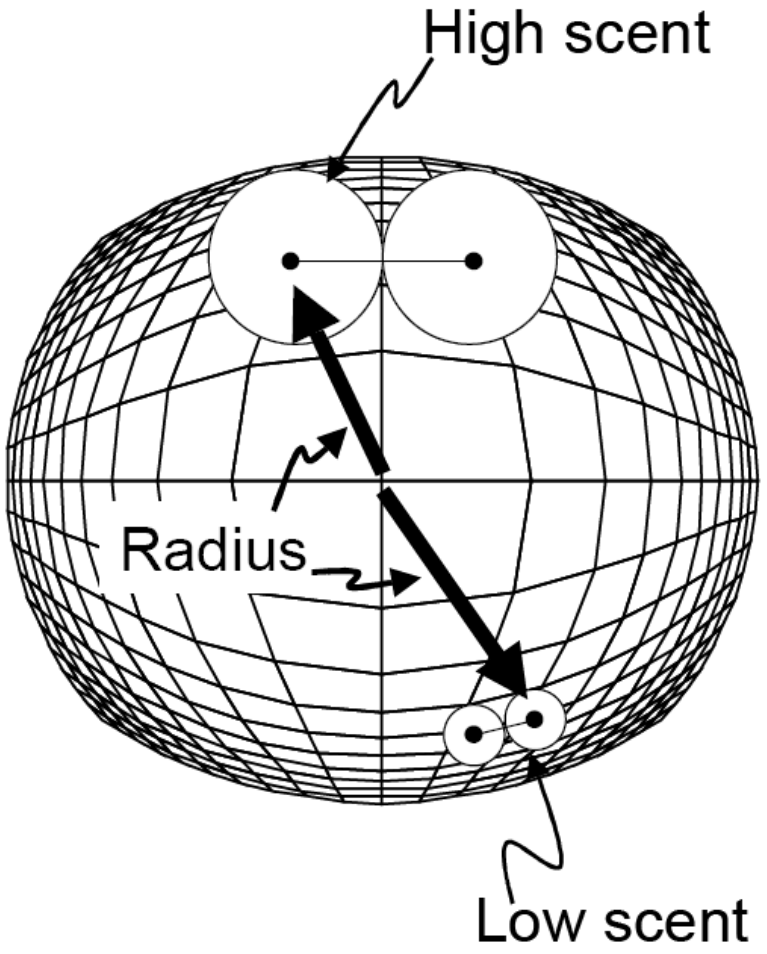

100
90
80
70
60
50
40
30
20
10
0
No. Nodes
Hyperbolic
Explorer
Low scent
High scent

Length of Eye Movements

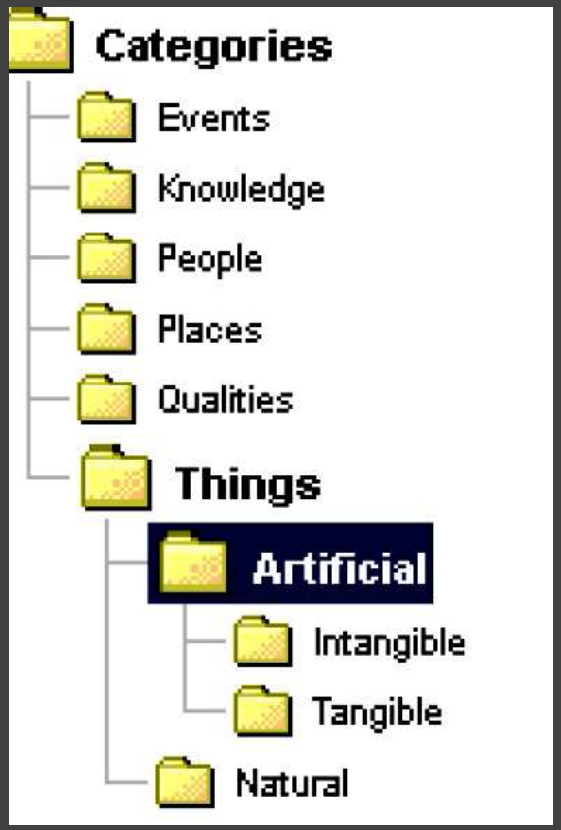


An Adaptive Field of View?

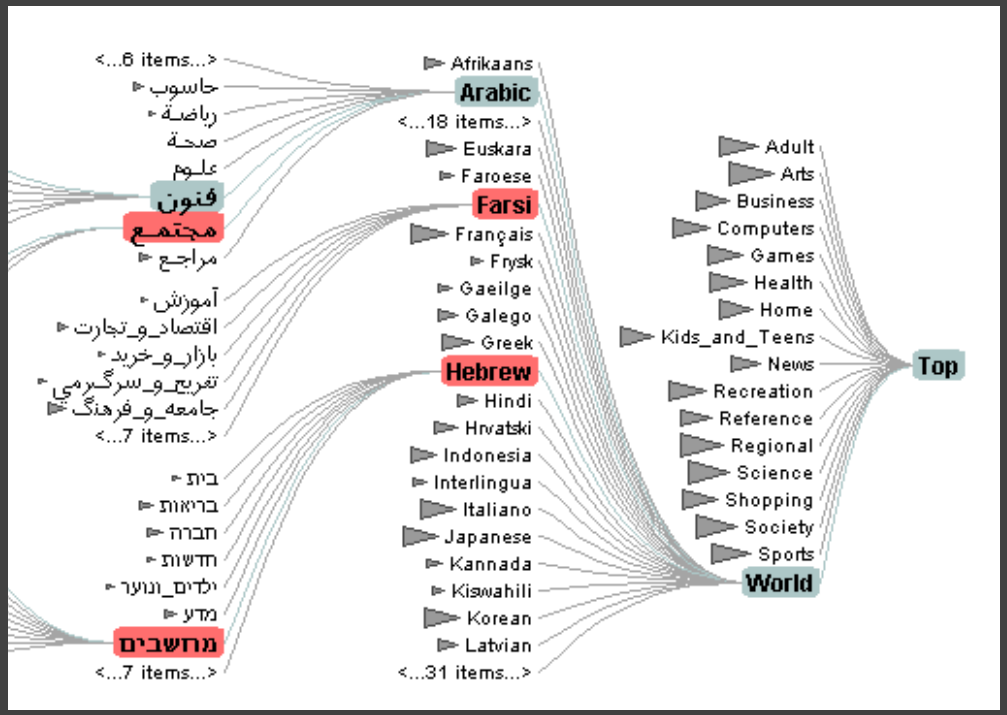




More Evaluations



vs.



Evaluation of DOI Trees

DOITree vs. Windows Explorer [Budiu, AVI 06]

Nodes visited (avg)	DOI:83	Exp:53	*p<.005*
Revisitation (avg)	DOI:6.6	Exp:8.2	*p<.005*
Divergence (avg)	DOI:4.6	Exp:3.9	*p<.001*

DOITree more forgiving to navigation errors
BUT no significant difference in task time

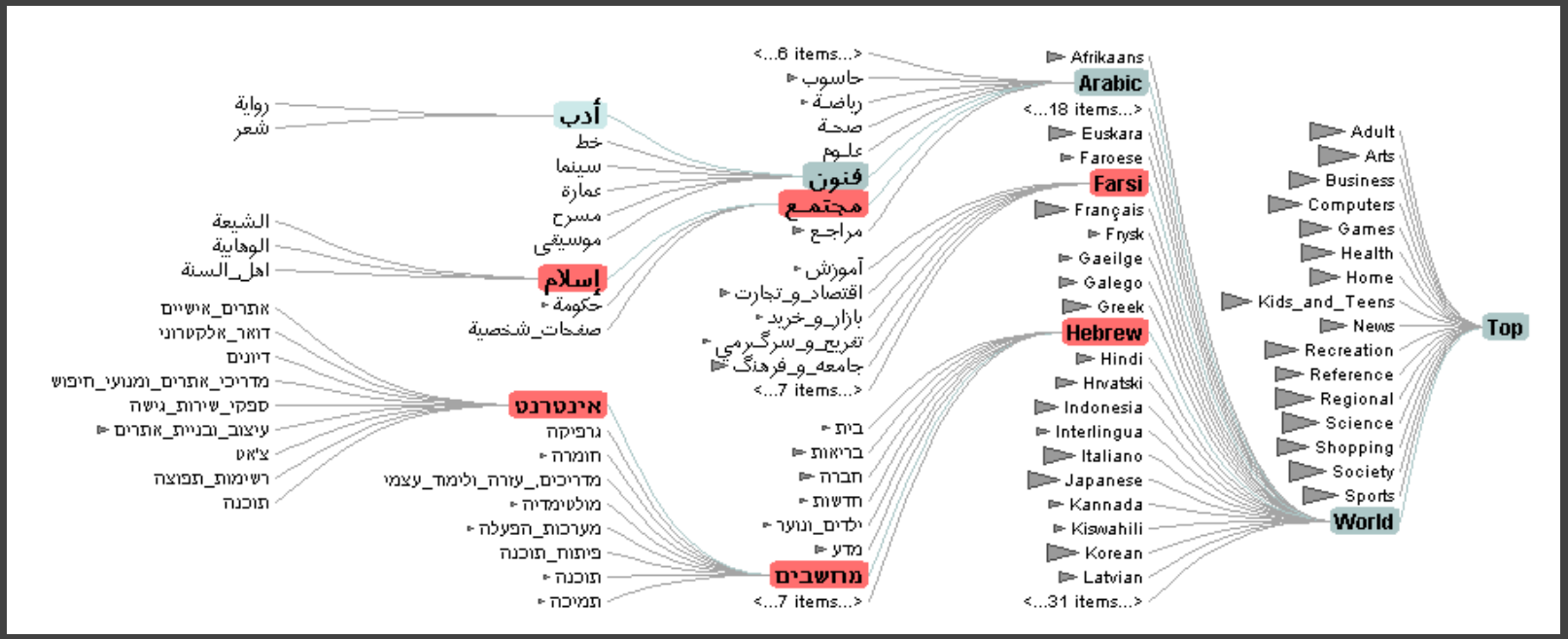
DOITree vs. Google Directory [Pirolli, CHI 06]
DOITree has superior task knowledge transfer

Design Guidelines

Design Guidelines

Support rapid visual scanning

Most people **don't read in circles!**



Degree of Interest Trees [Heer & Card 04]

Design Guidelines

People don’t read in circles!

Showing more is not always better

- **Distractors** can decrease task performance
- Interaction with quality of **information scent**

Design Guidelines

People don’t read in circles!

Showing more is not always better

Navigation cues critical to search

- **Informative labels** or landmarks needed
- Poor **information scent** undermines search

Lessons Learned

Both **task** and **data properties** (here, *information scent*) may interact with the visualization type in unexpected ways.

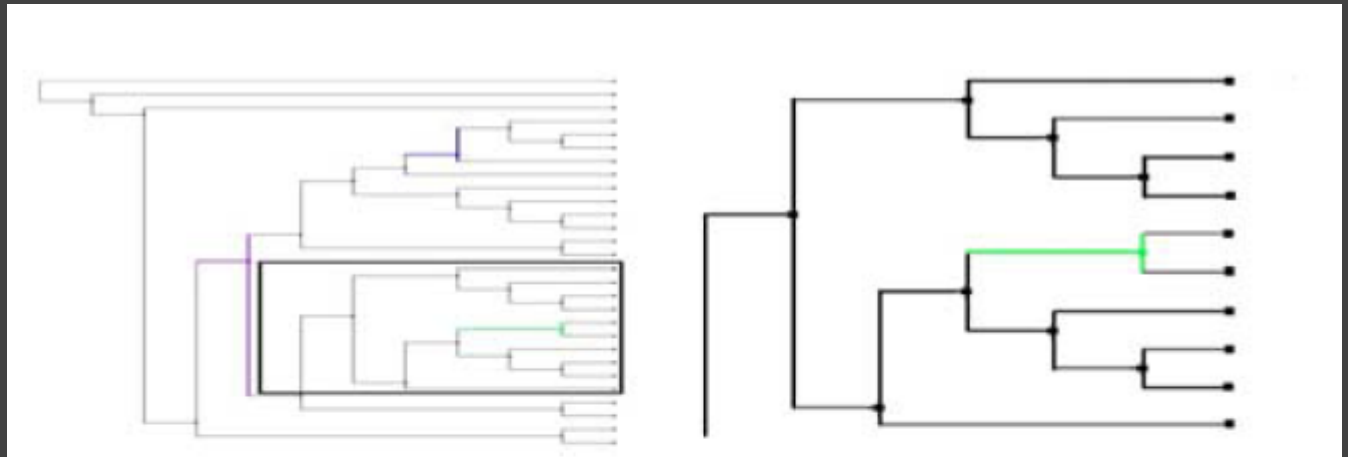
Equal **performance** in terms of accuracy or response time is **not the whole picture**. We often require more detailed study!

Spatial Navigation

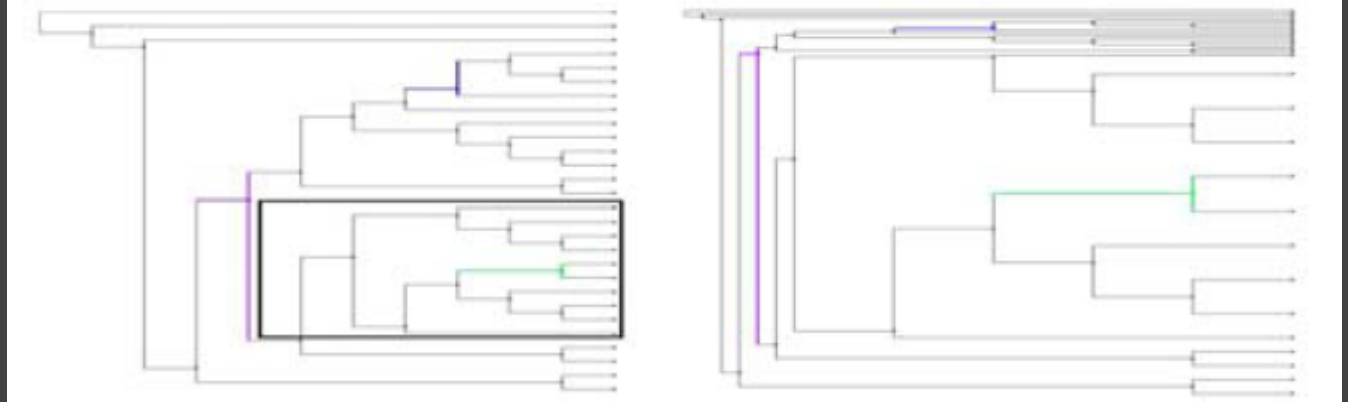
An Evaluation of Pan & Zoom and Rubber Sheet Navigation with and without an Overview

Dmitry Nekrasovski, Adam Bodnar, Joanna McGrenere,
François Guimbretière, Tamara Munzner

Pan & Zoom vs. Rubber Sheet



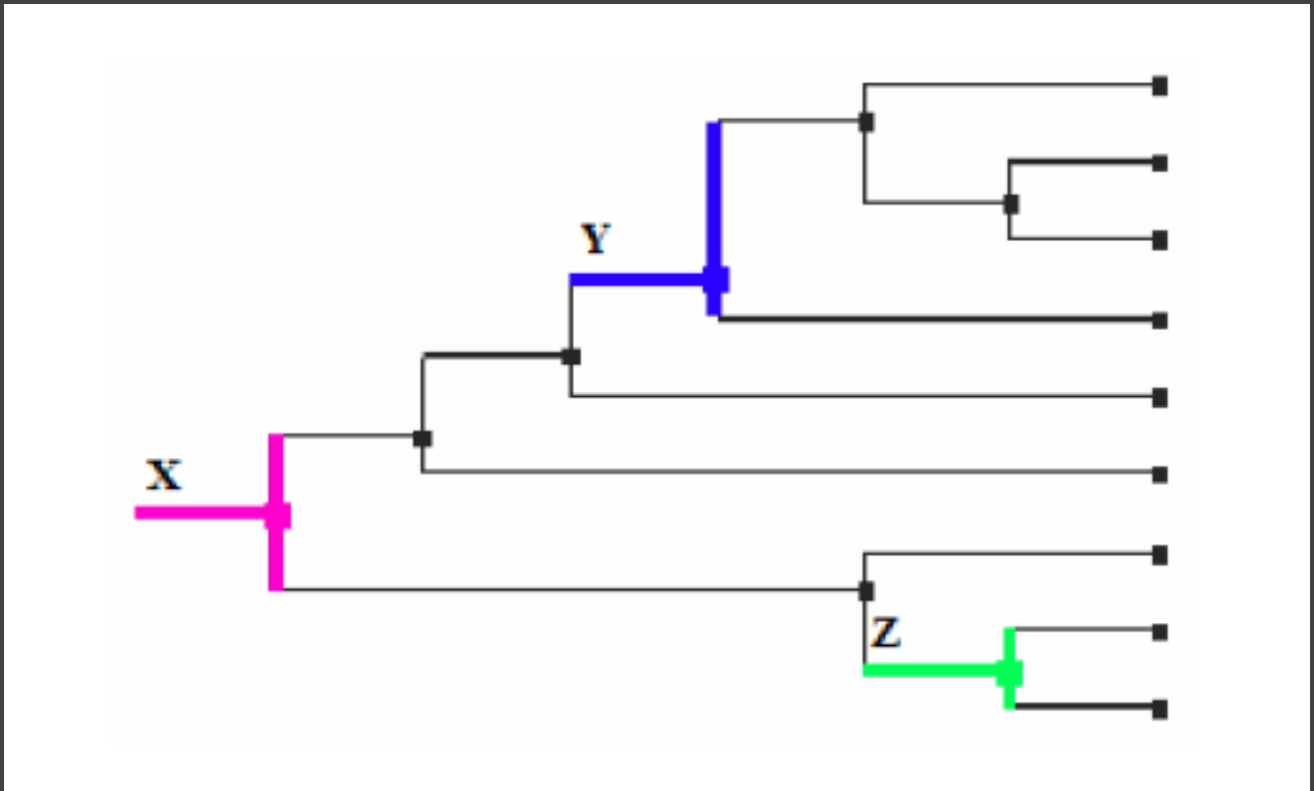
(i) PZN



(ii) RSN

Experimental Task

Compare topological distance between nodes in a dendrogram.



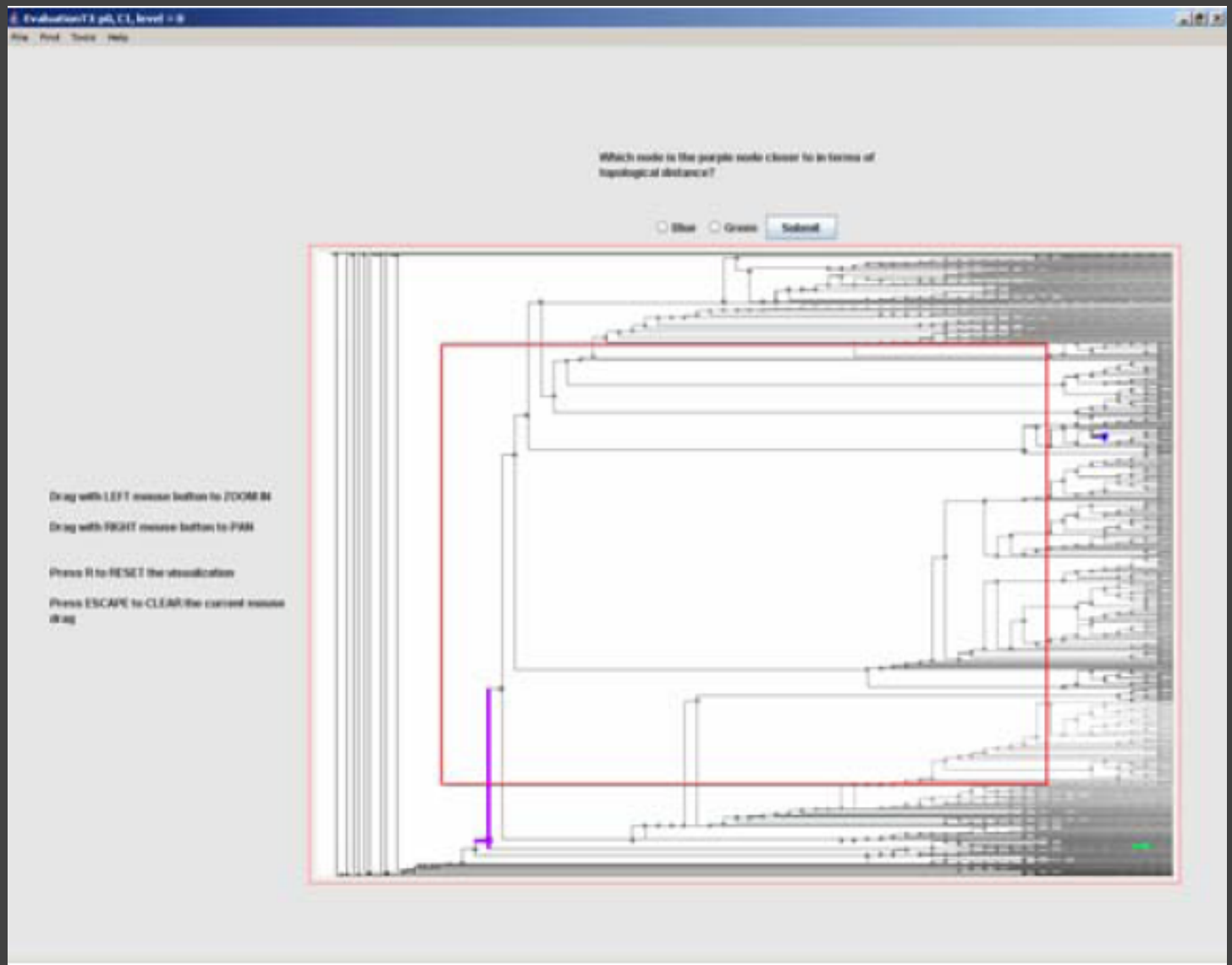
Experiment

Compare performance in 4 conditions:

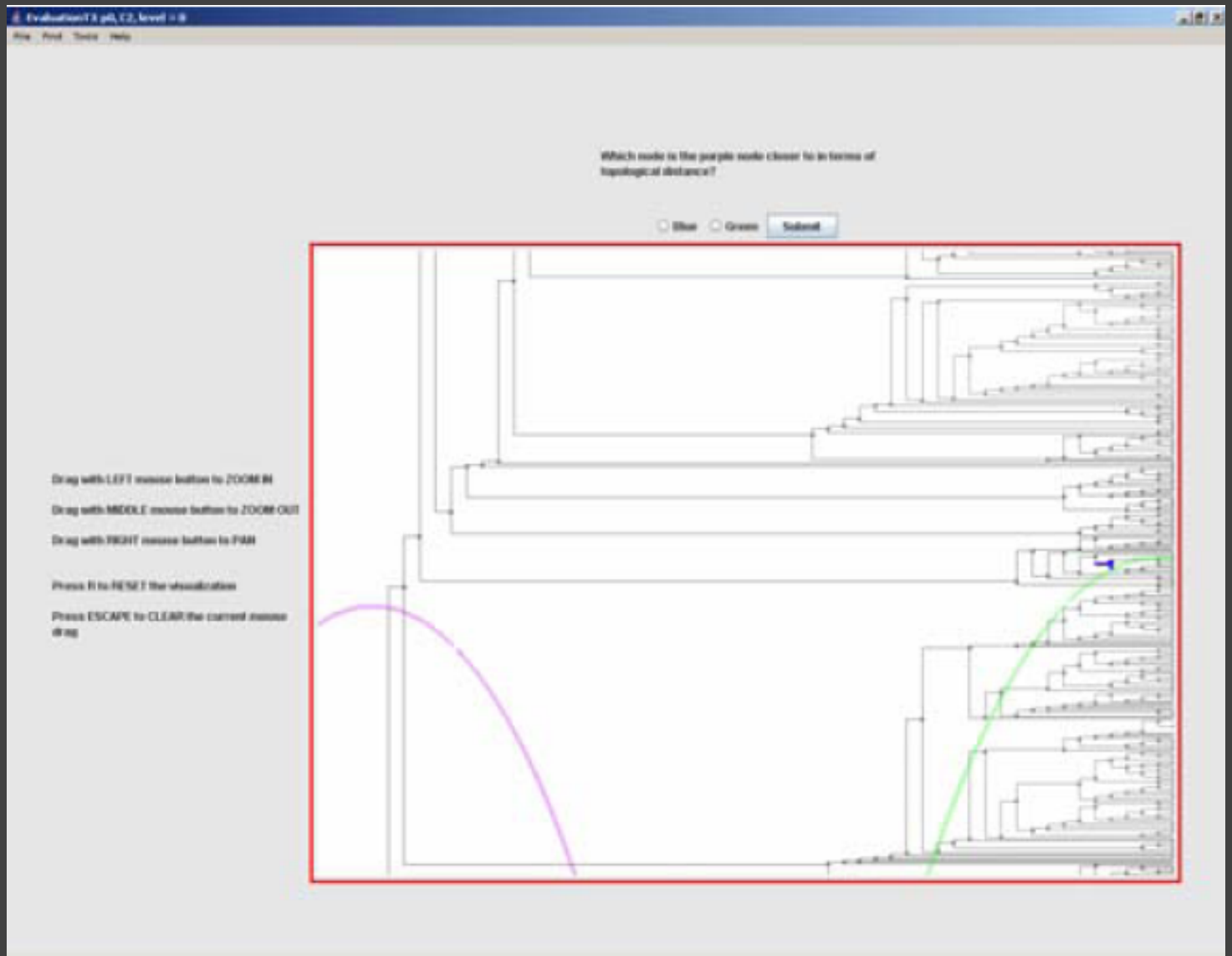
1. Pan & Zoom (no overview)
2. Pan & Zoom (with overview)
3. Rubber Sheet (no overview)
4. Rubber Sheet (with overview)

40 subjects (24F/16M), between 18-39 years old.
Right-handed, normal vision.
Between-subjects design.

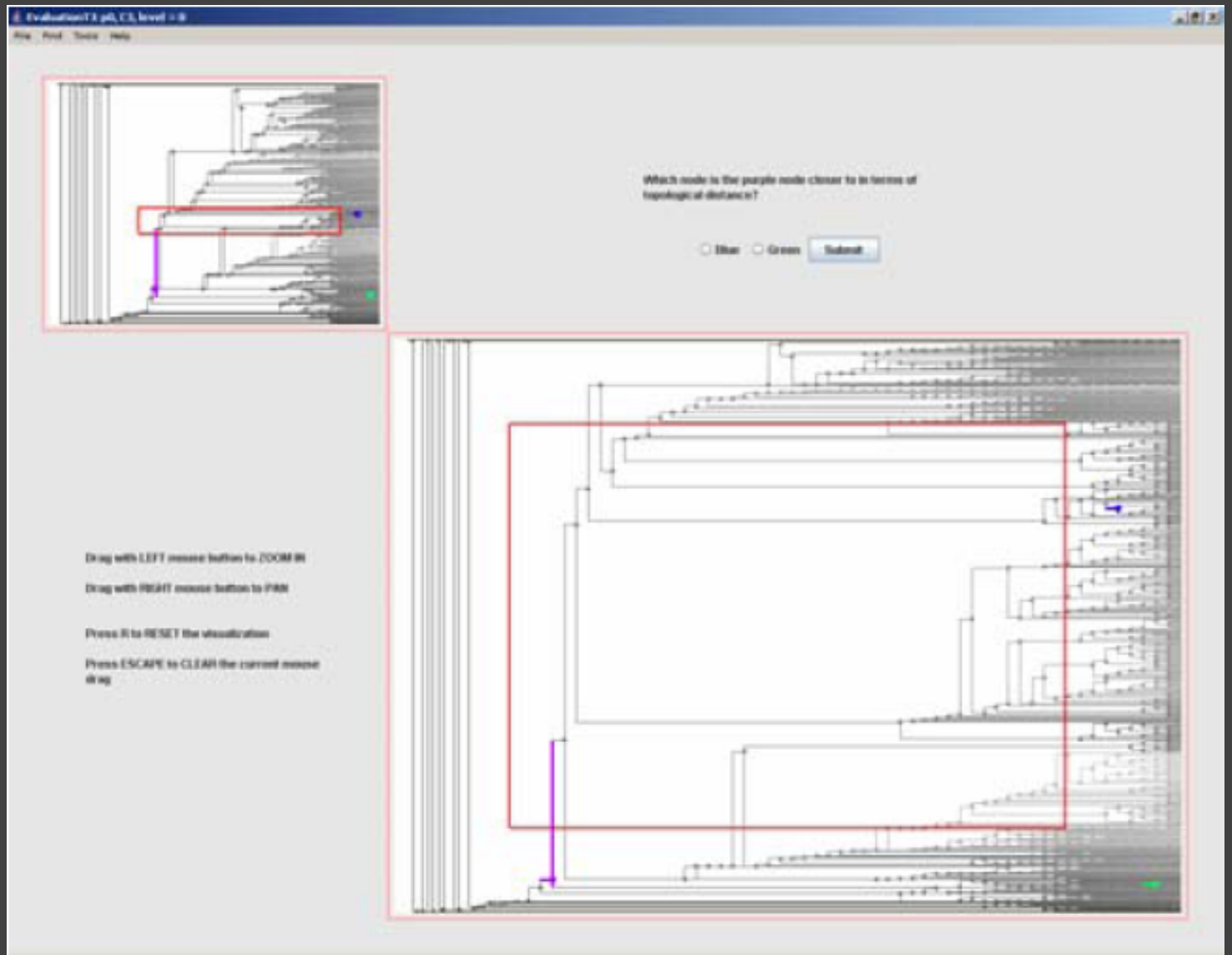
1. Rubber Sheet / No Overview



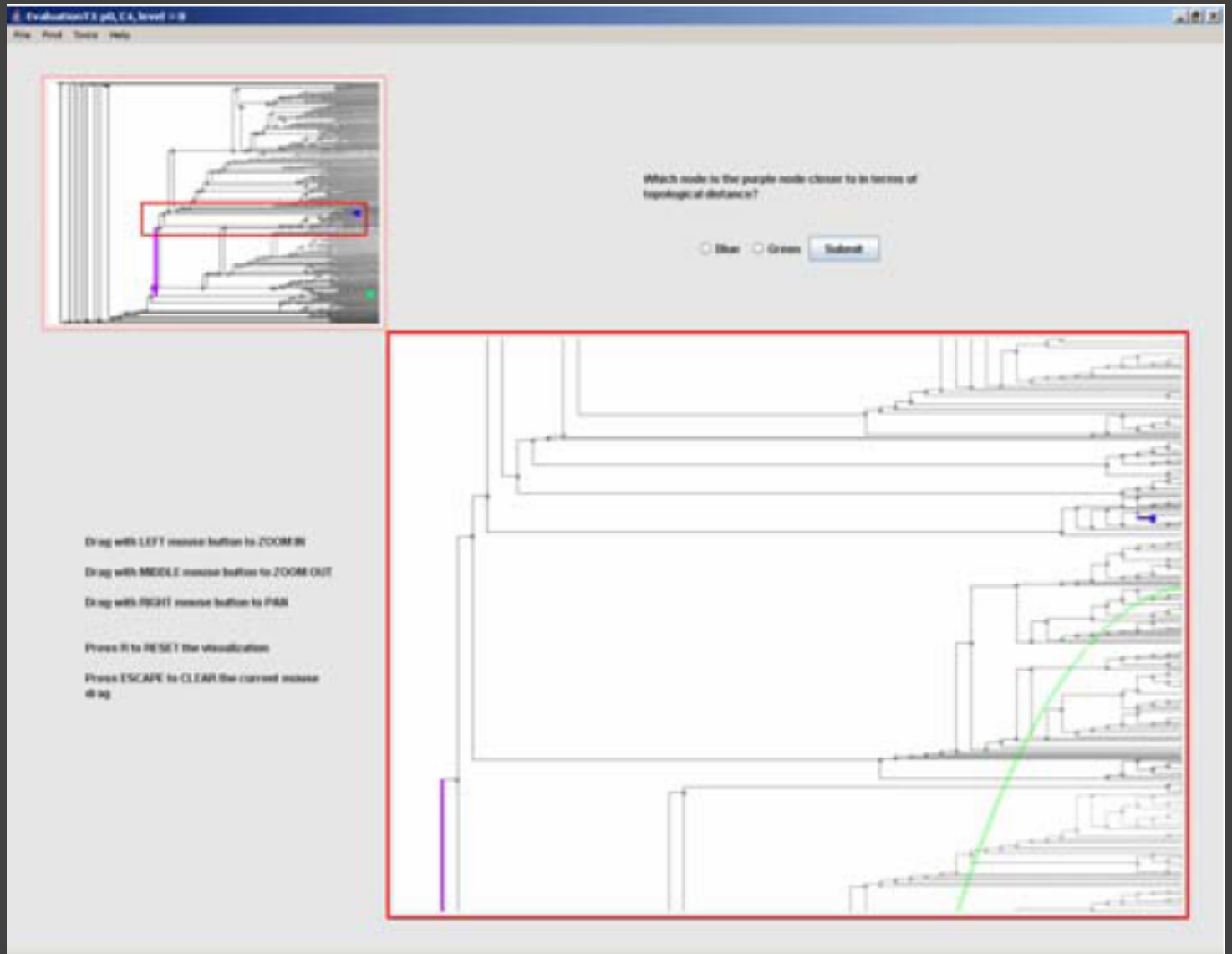
2. Pan & Zoom / No Overview



3. Rubber Sheet / Overview



4. Pan & Zoom / Overview



Hypotheses

1. RSN interfaces perform better than PZN interfaces independently of the presence or absence of an overview.
2. For RSN, the presence of an overview does not result in better performance.
3. For PZN, the presence of an overview results in better performance.

Results: H1 False

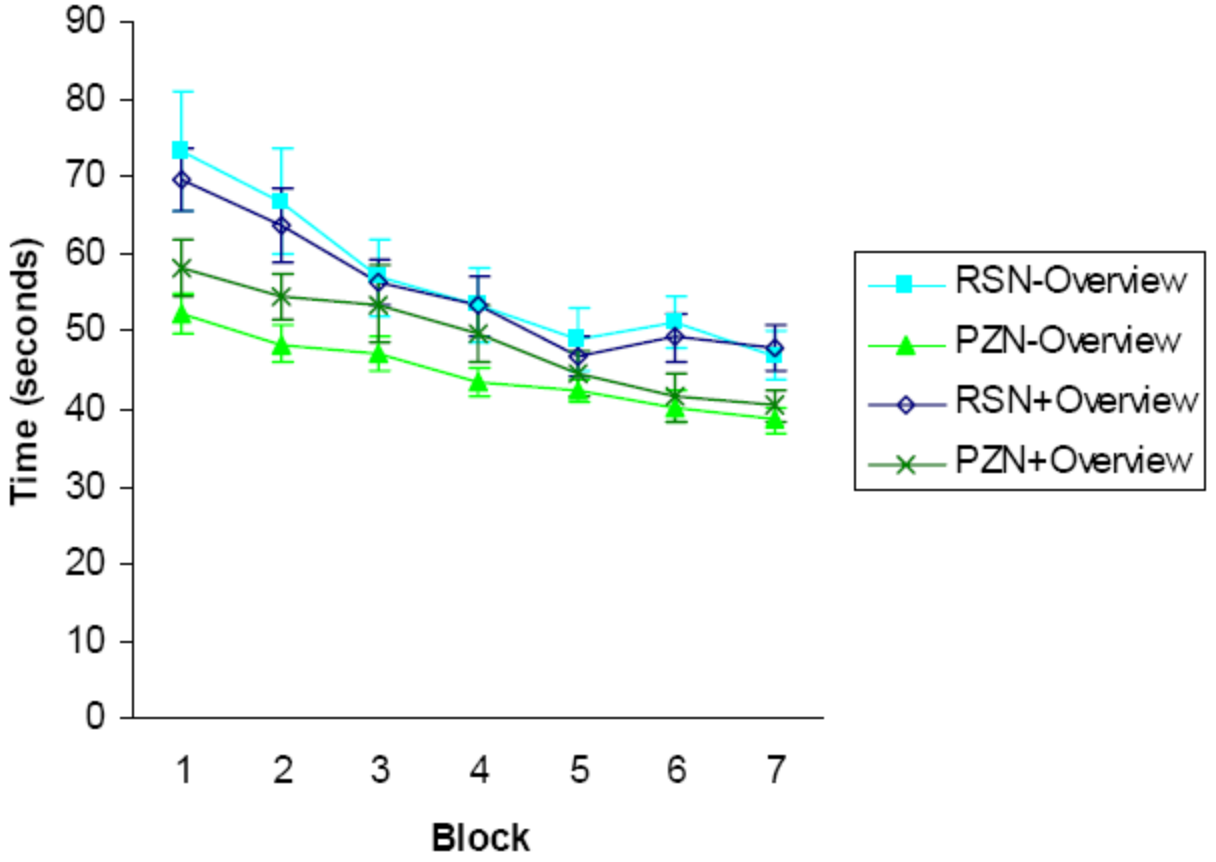


Figure 7: Mean completion times per trial for each interface by block in seconds (N=40).

Results: H2 True, H3 False

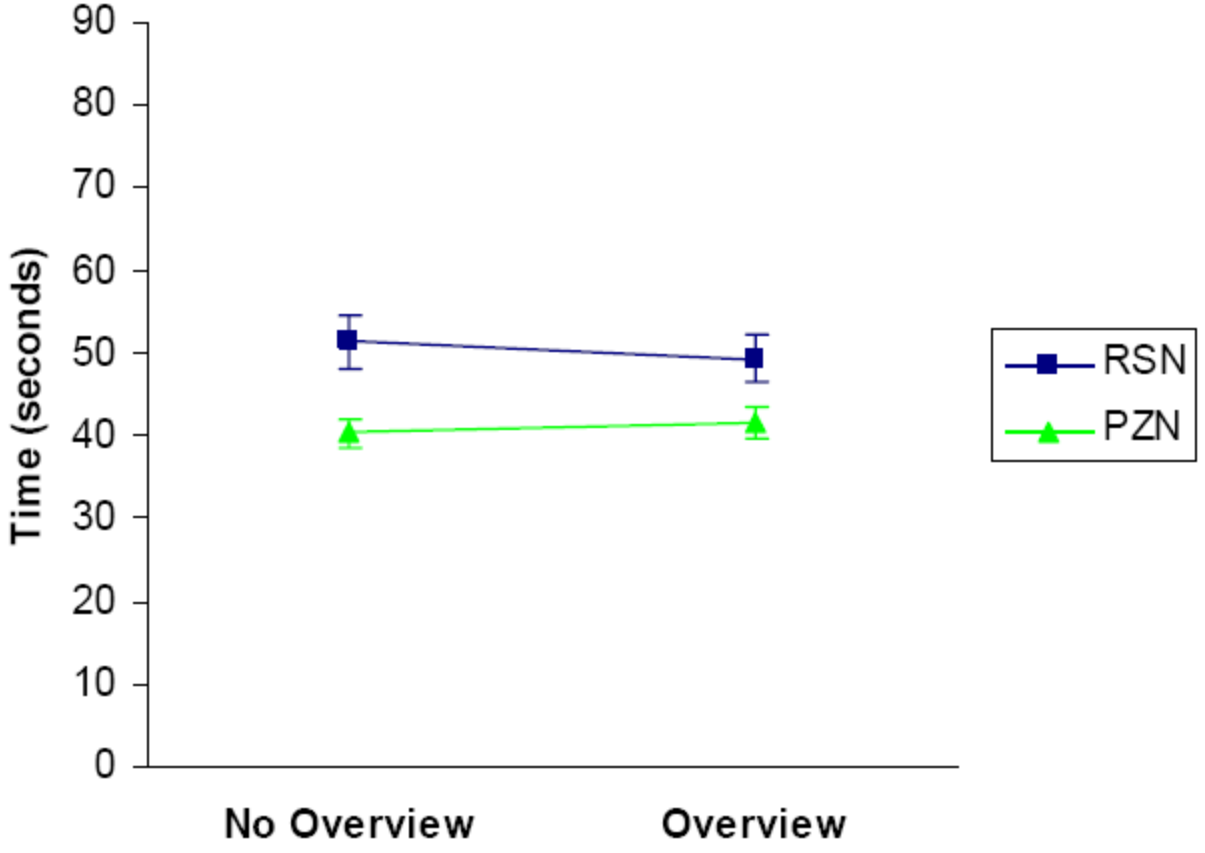


Figure 9: Block 7 mean per-trial completion times in seconds by navigation technique with and without an overview.

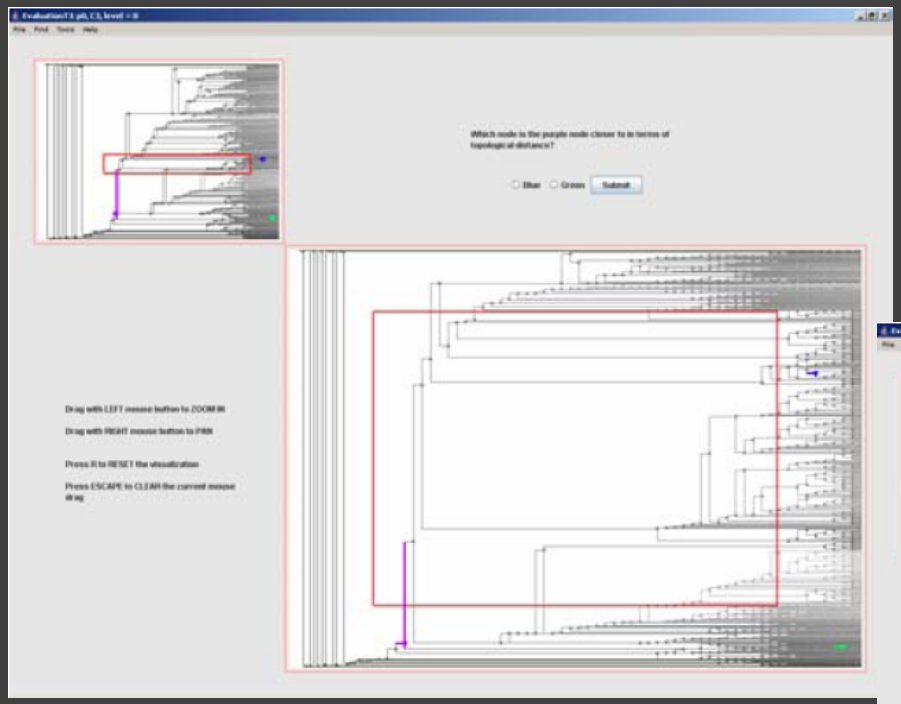
Results

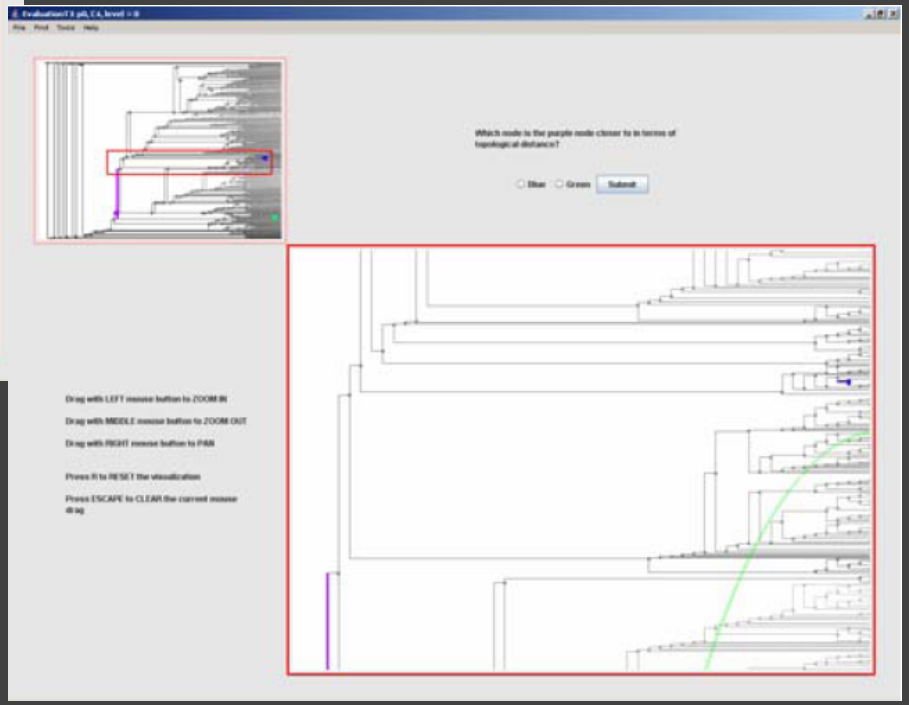
R1. Pan & Zoom had lower completion times, navigation actions, resets, and reported mental demand.

R2. Overview has no significant impact on rubber sheet navigation, though it was reported to reduce physical demand.

R3. Overview has no significant impact on pan & zoom navigation, though it was reported to reduce physical demand.

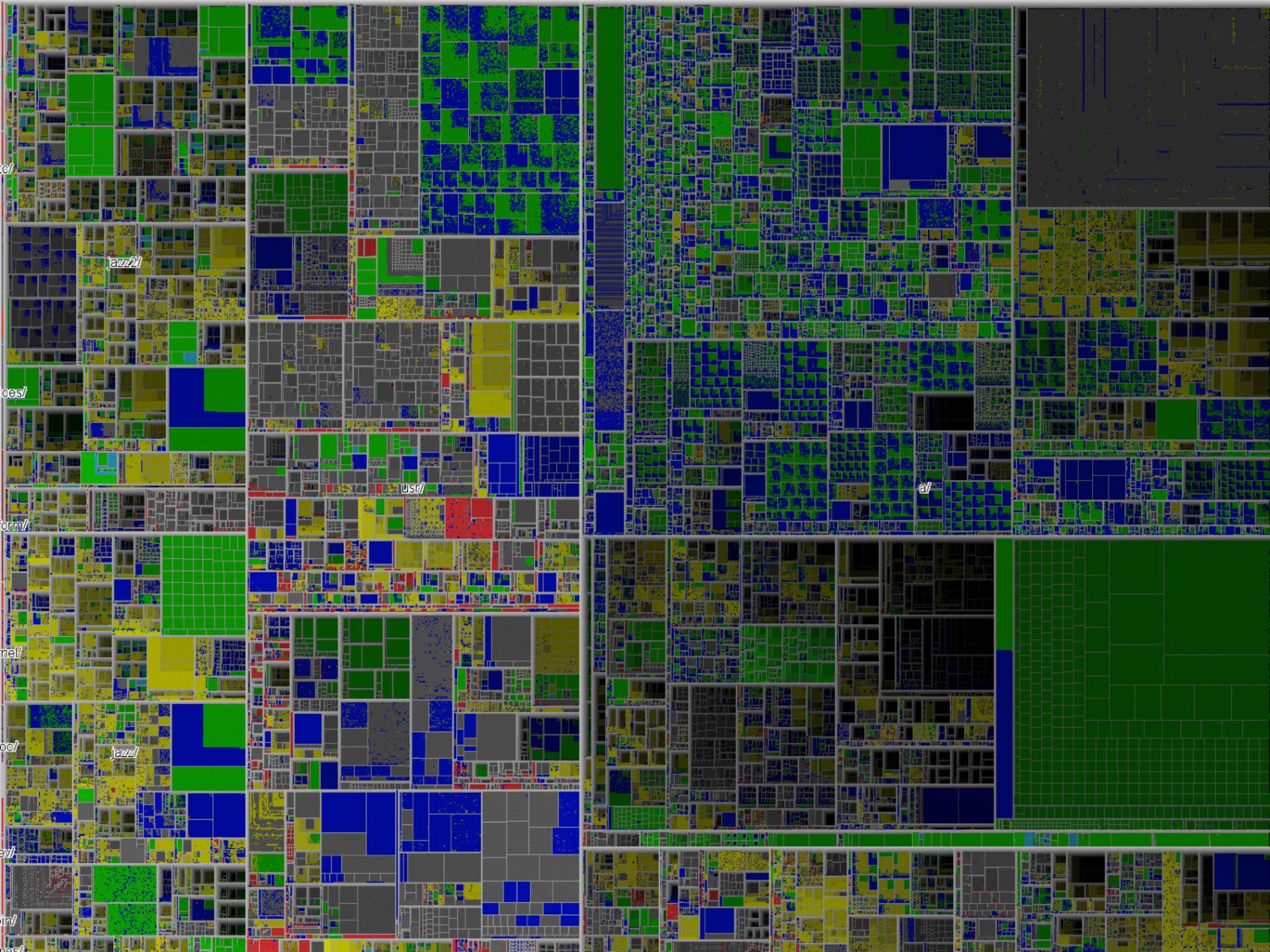
Thoughts?





Does this generalize
for overview displays?

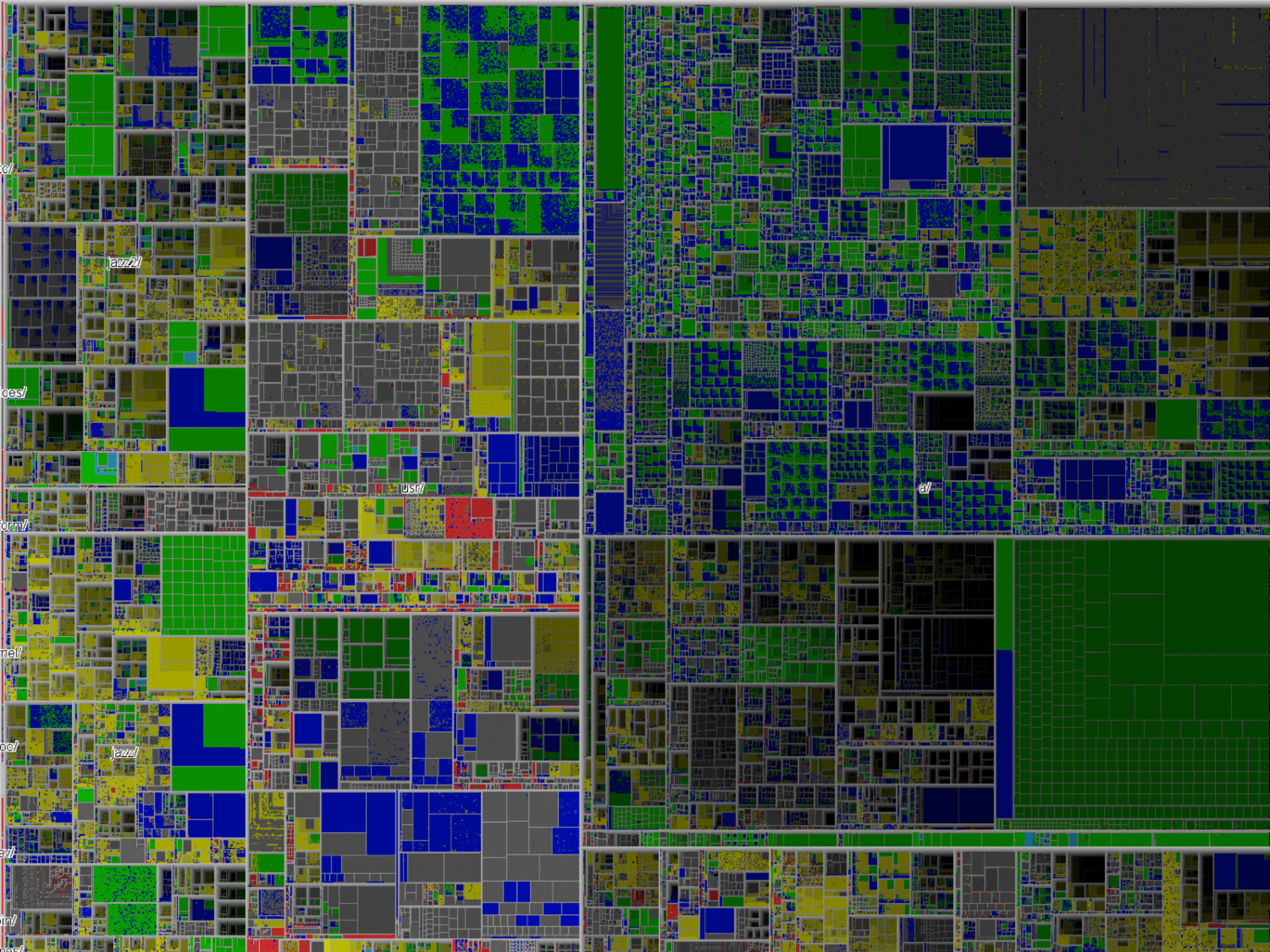
Data Density


jazz2/
usr/
a/
jazz/

$$\text{Data Density} = \frac{(\#\text{ entries in data})}{(\text{area of graphic})}$$

"Graphical excellence… gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space"

[Tufte 83]


jazz2/
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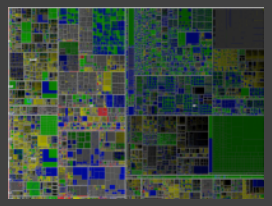

Relative Technology Stock Performance: Jan 2008 - Present

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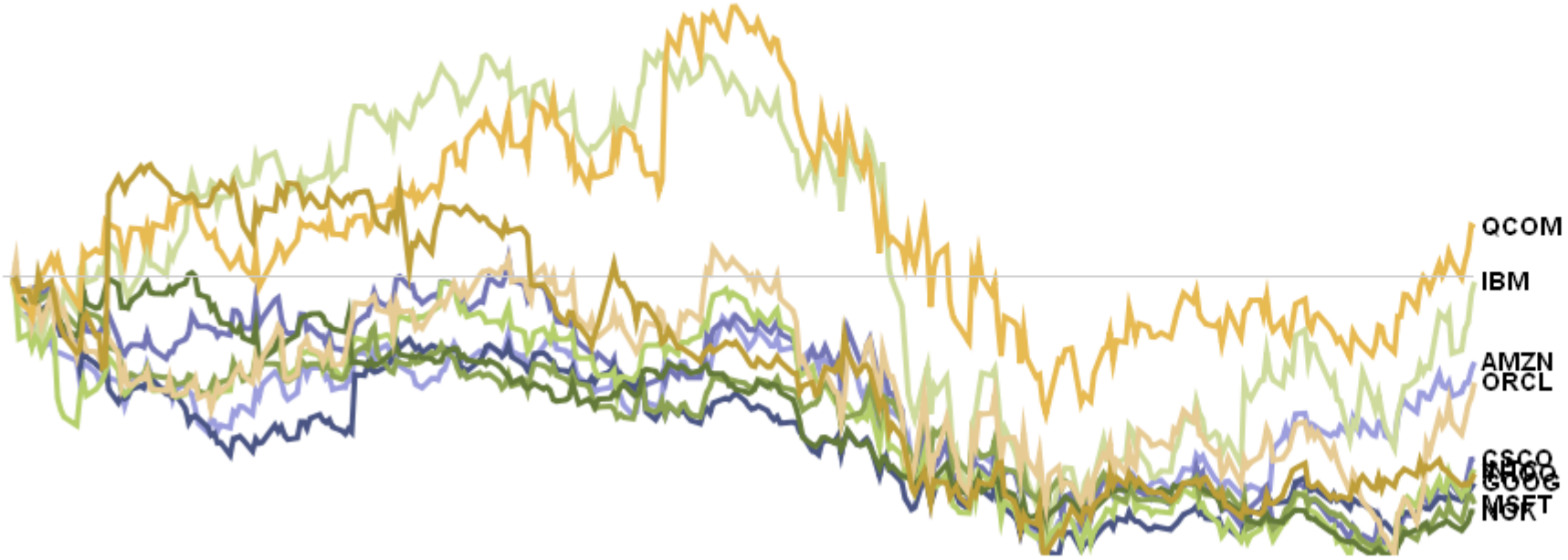

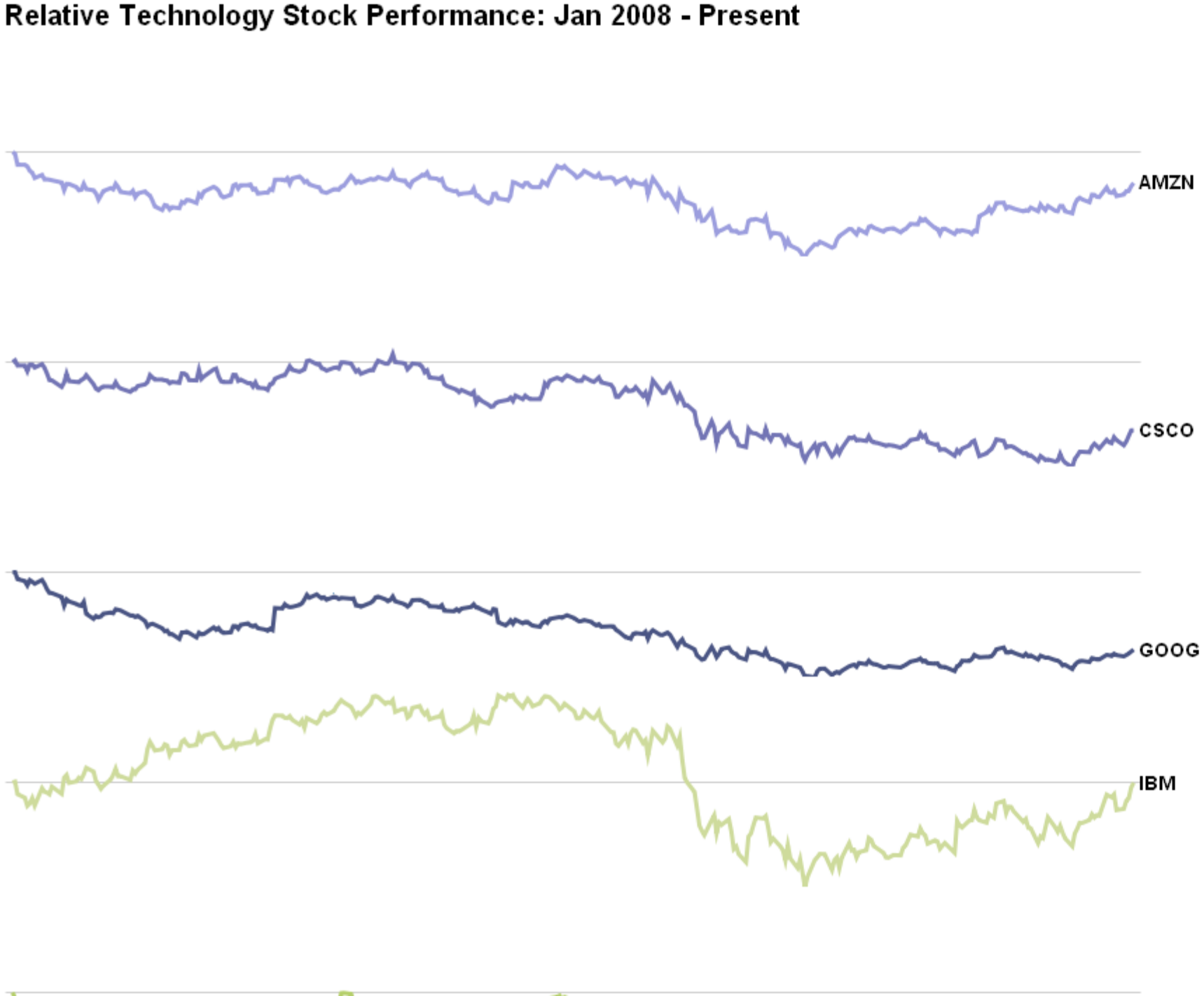
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AMZN
CSCO
GOOG
IBM

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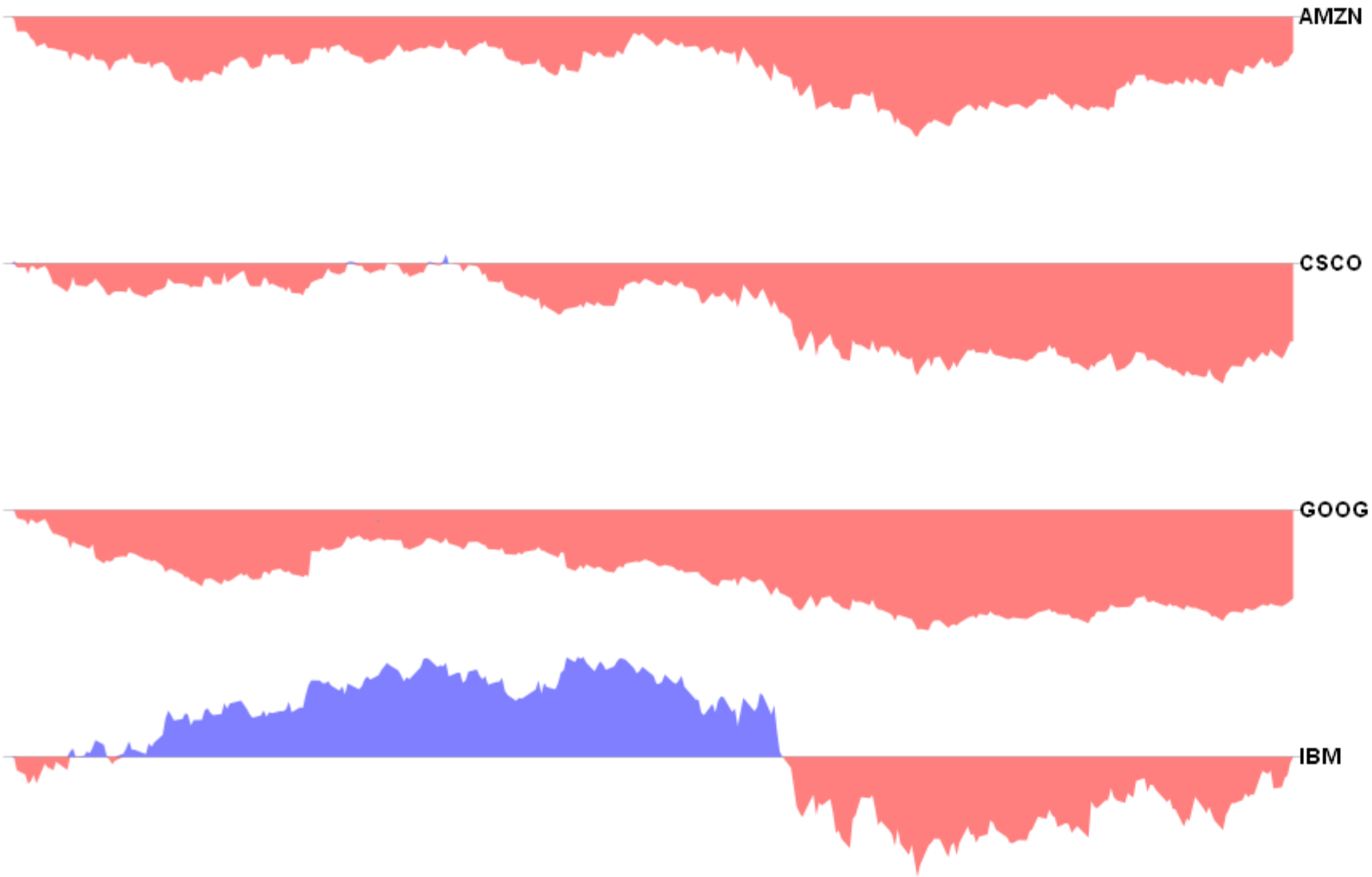

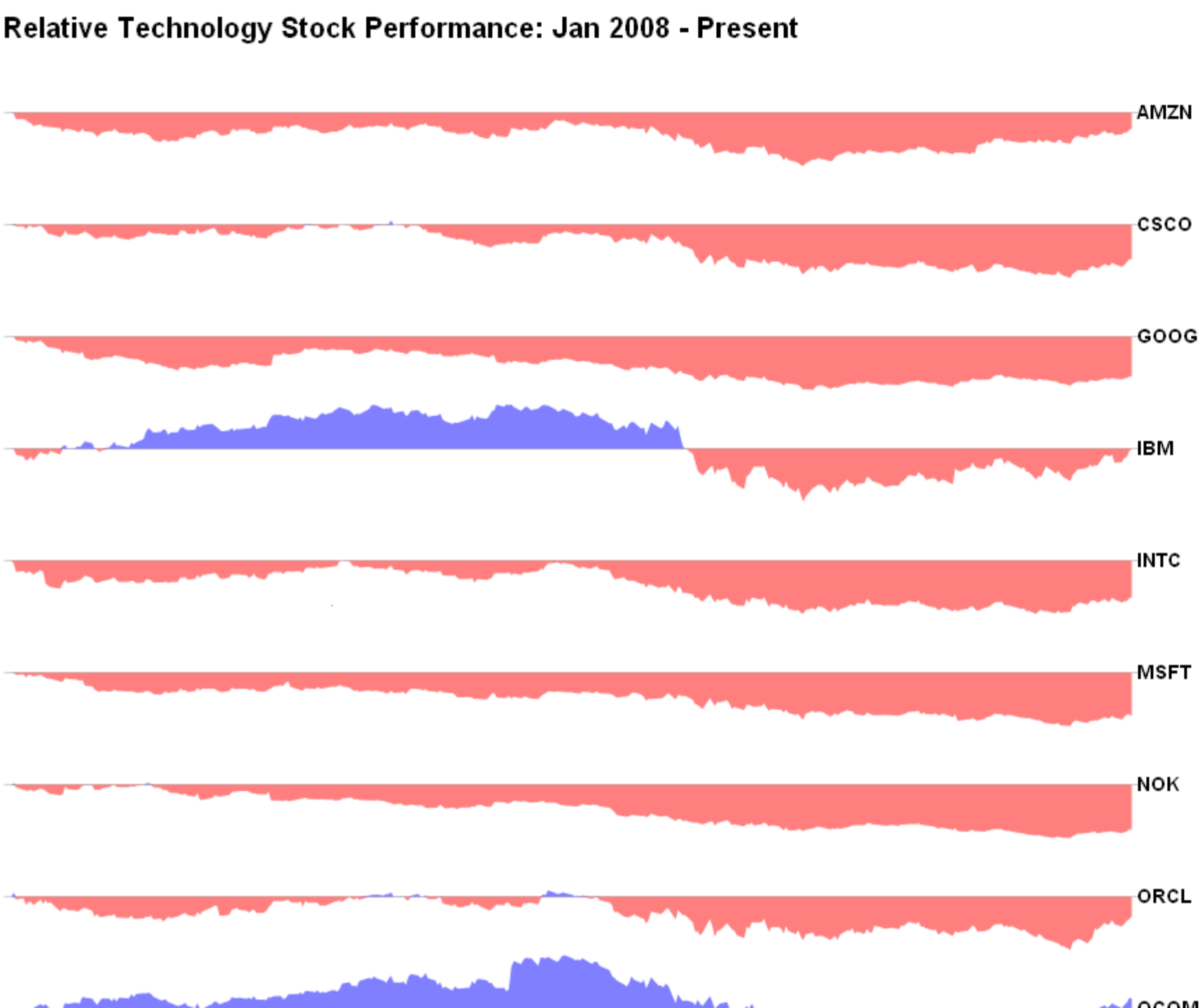
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MSFT
NOK
ORCL

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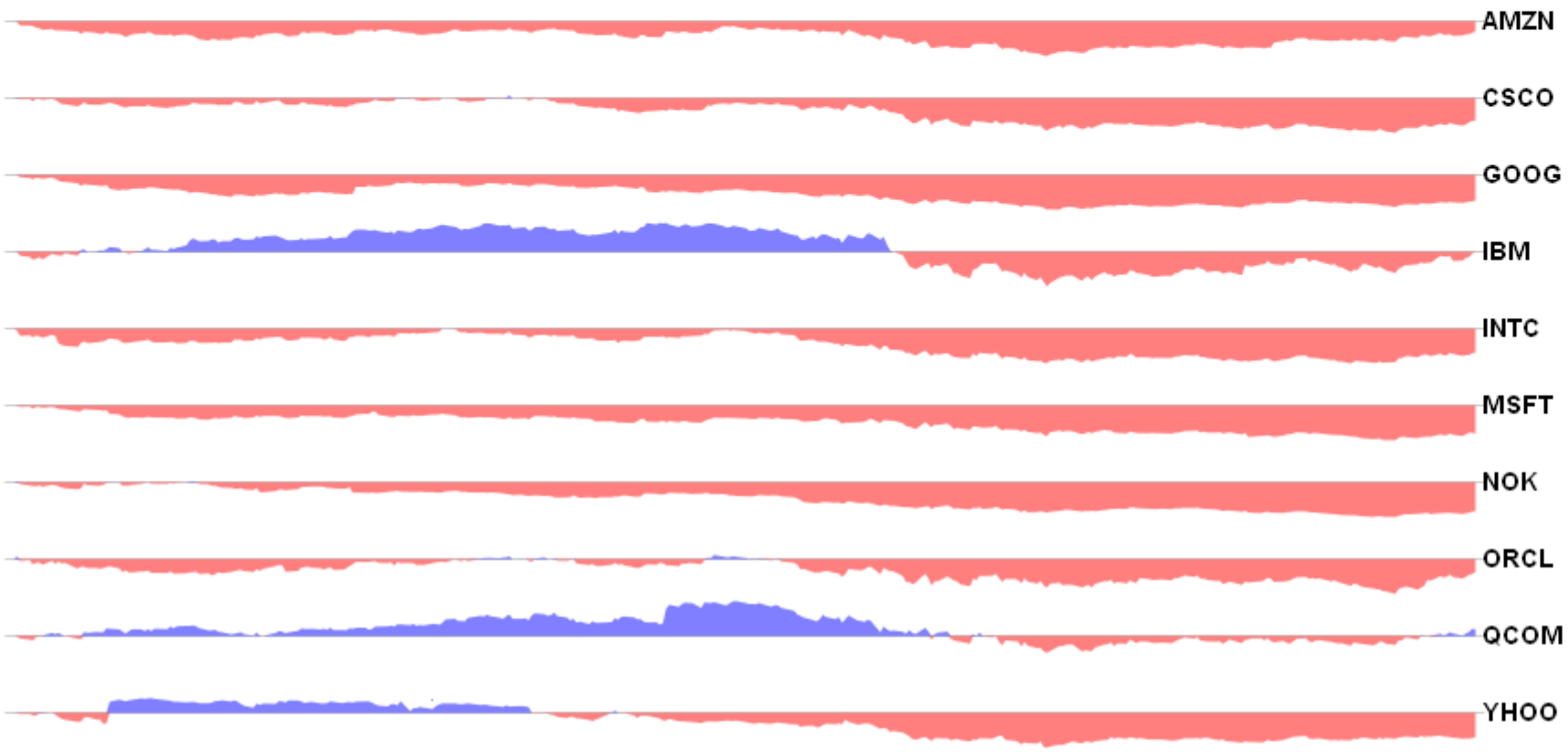

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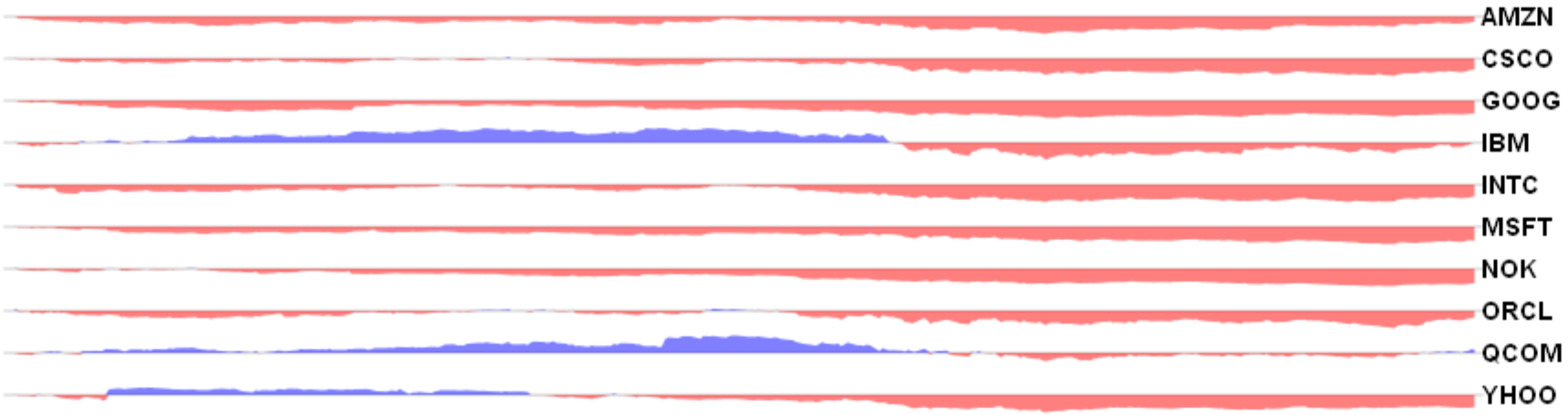

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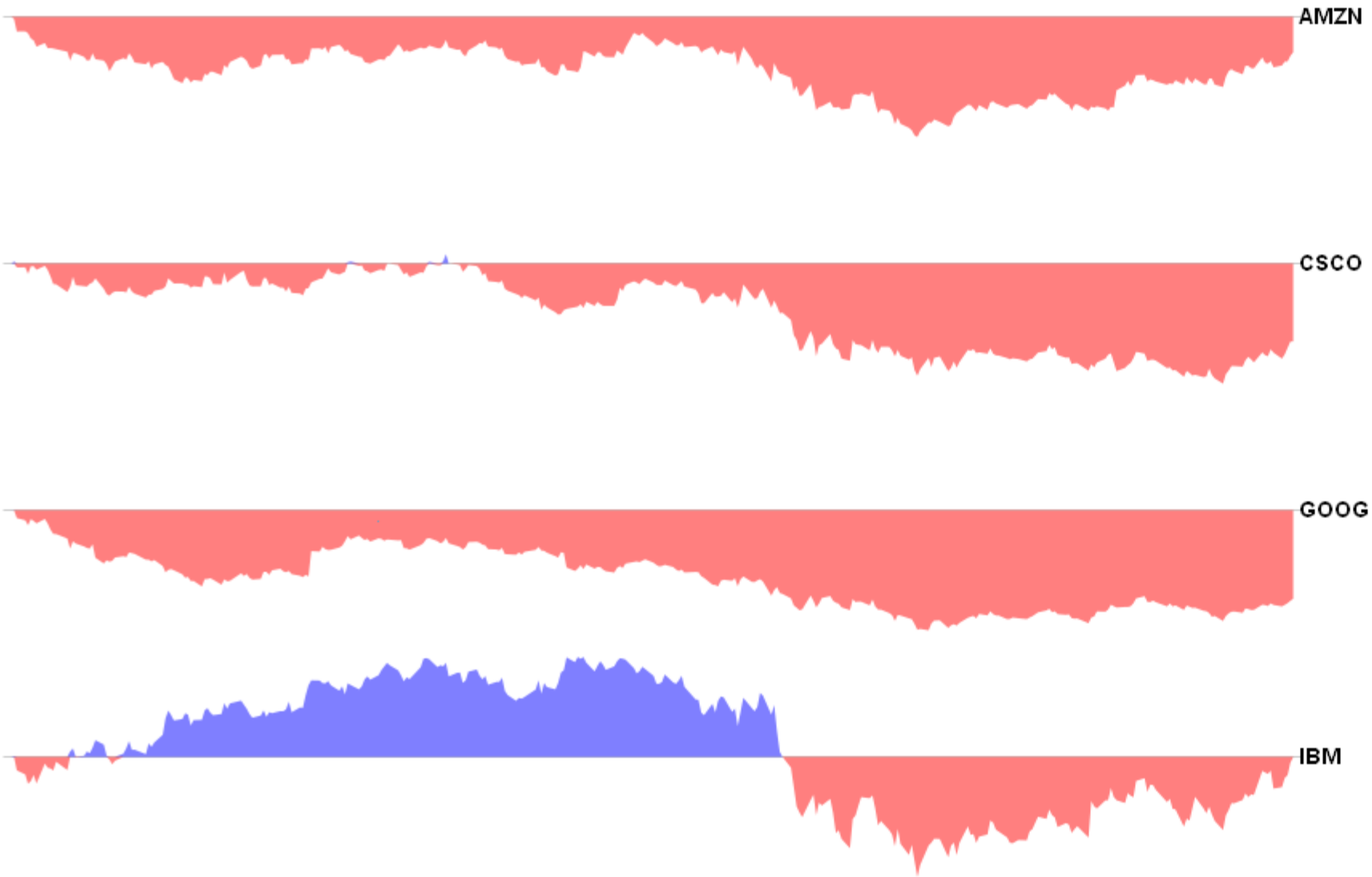

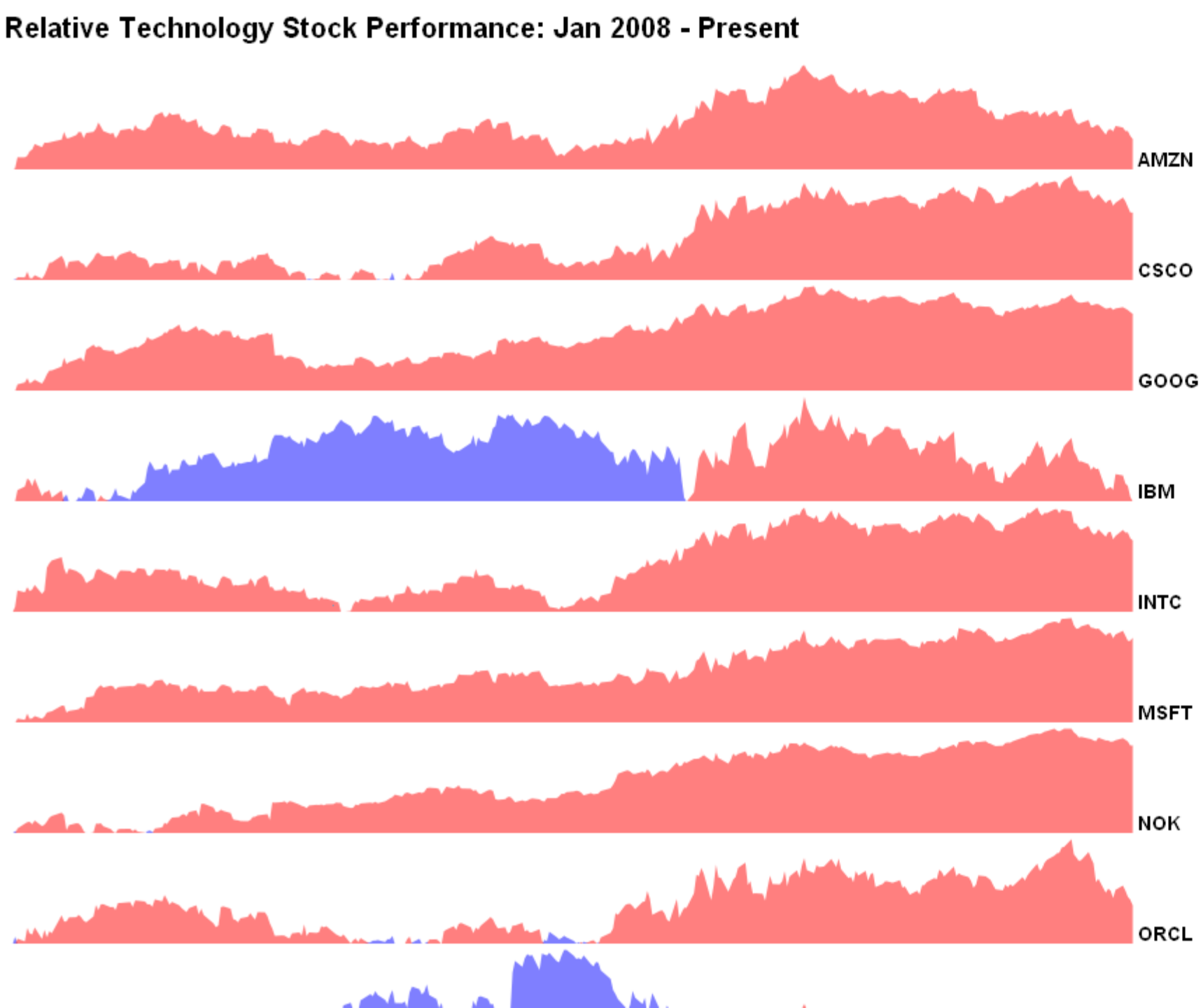
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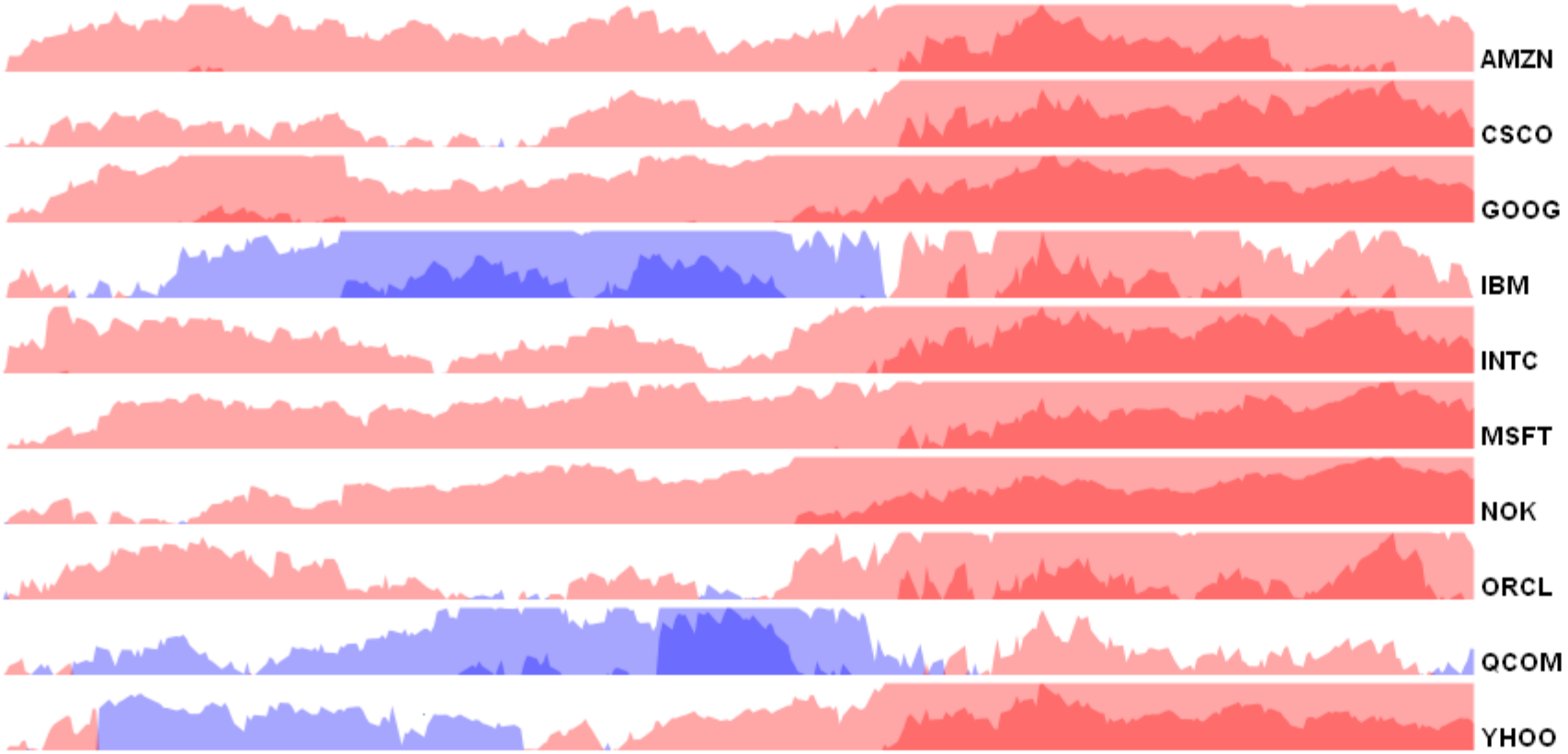
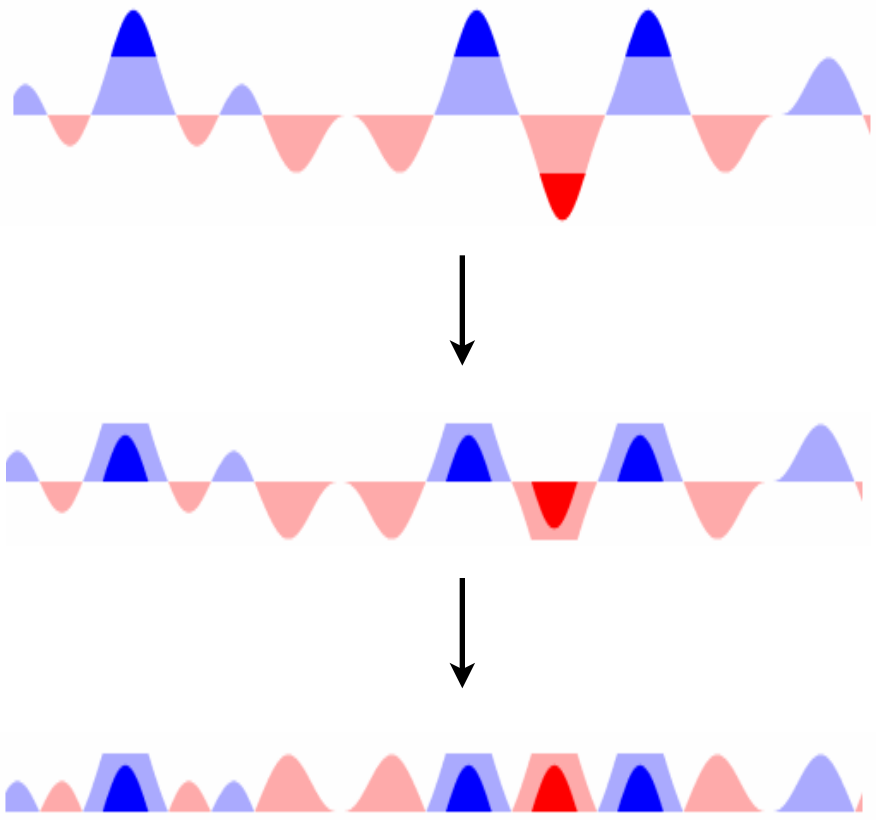


Horizon Graphs

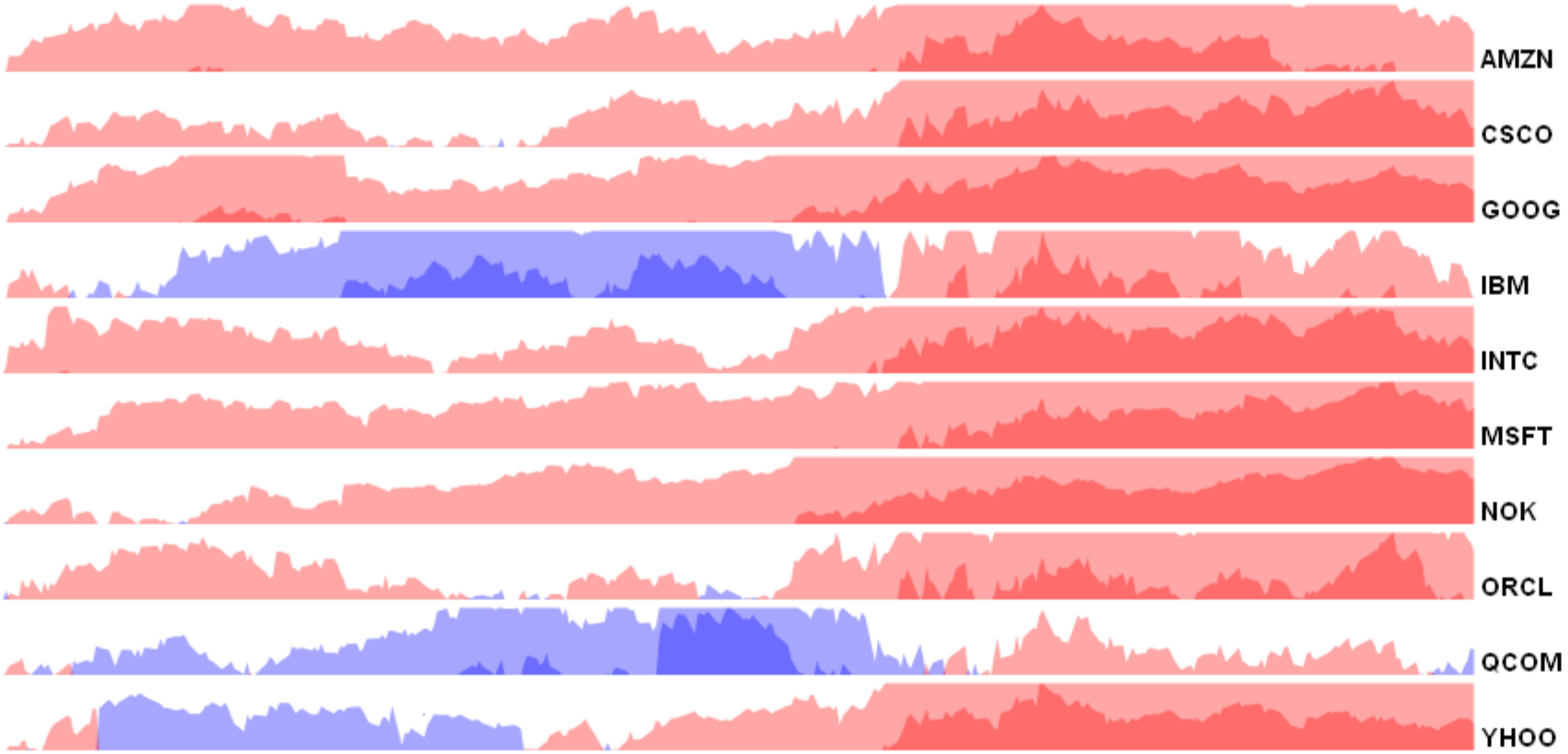


Segment Peaks

Layer Segments

Mirror Negative Values

Relative Technology Stock Performance: Jan 2008 - Present



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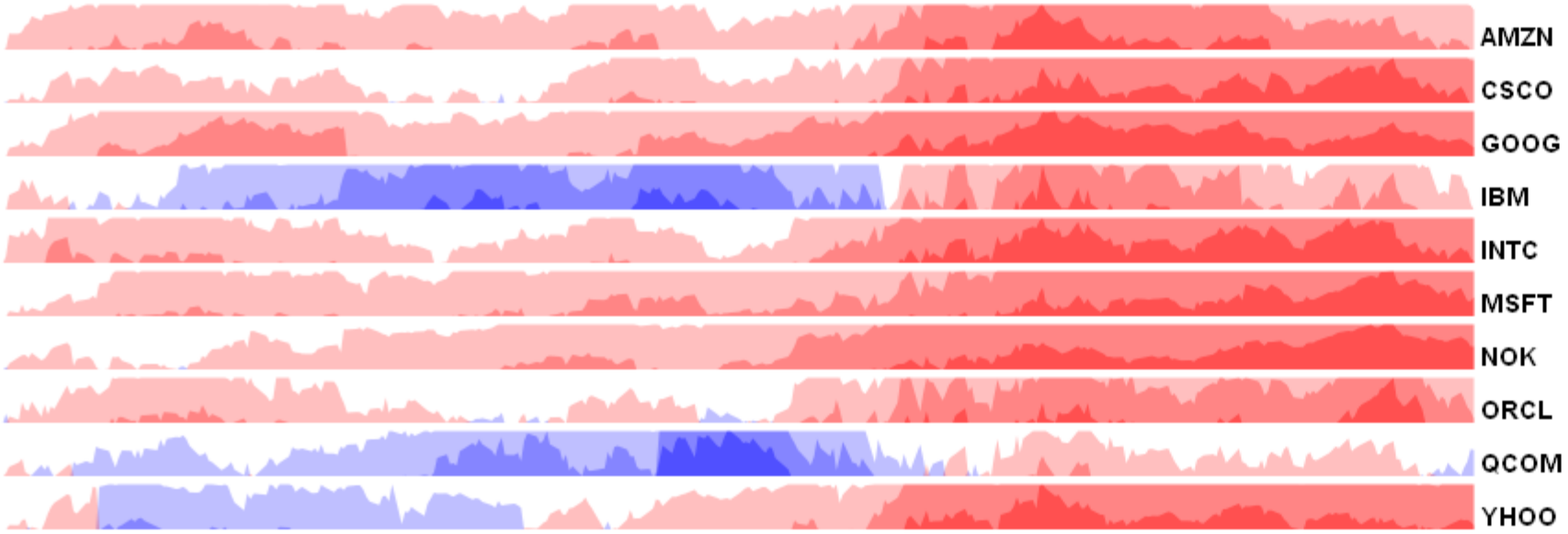

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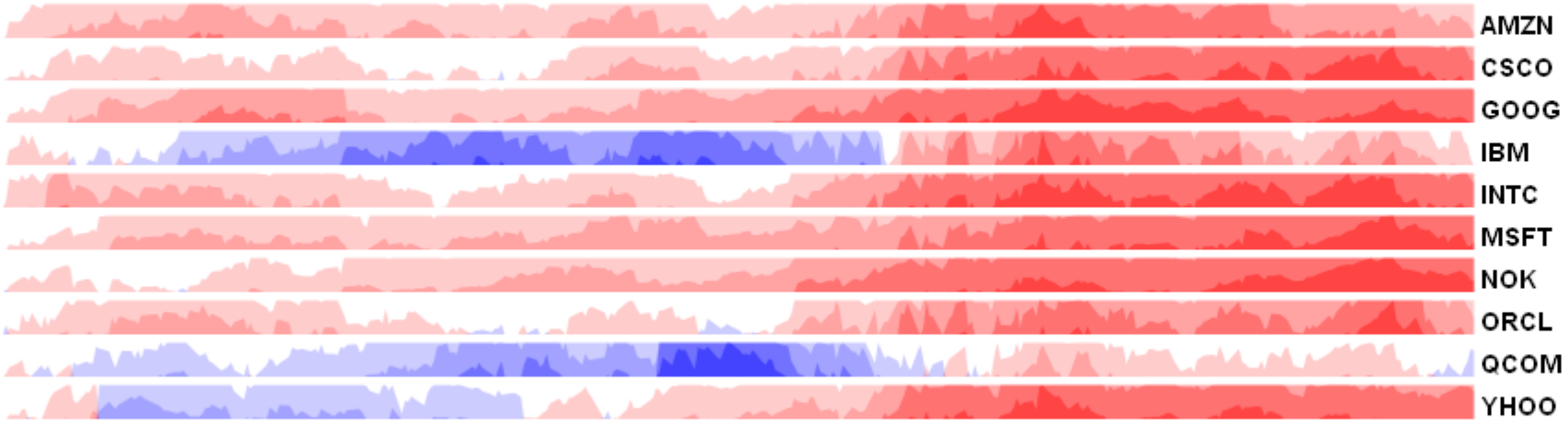

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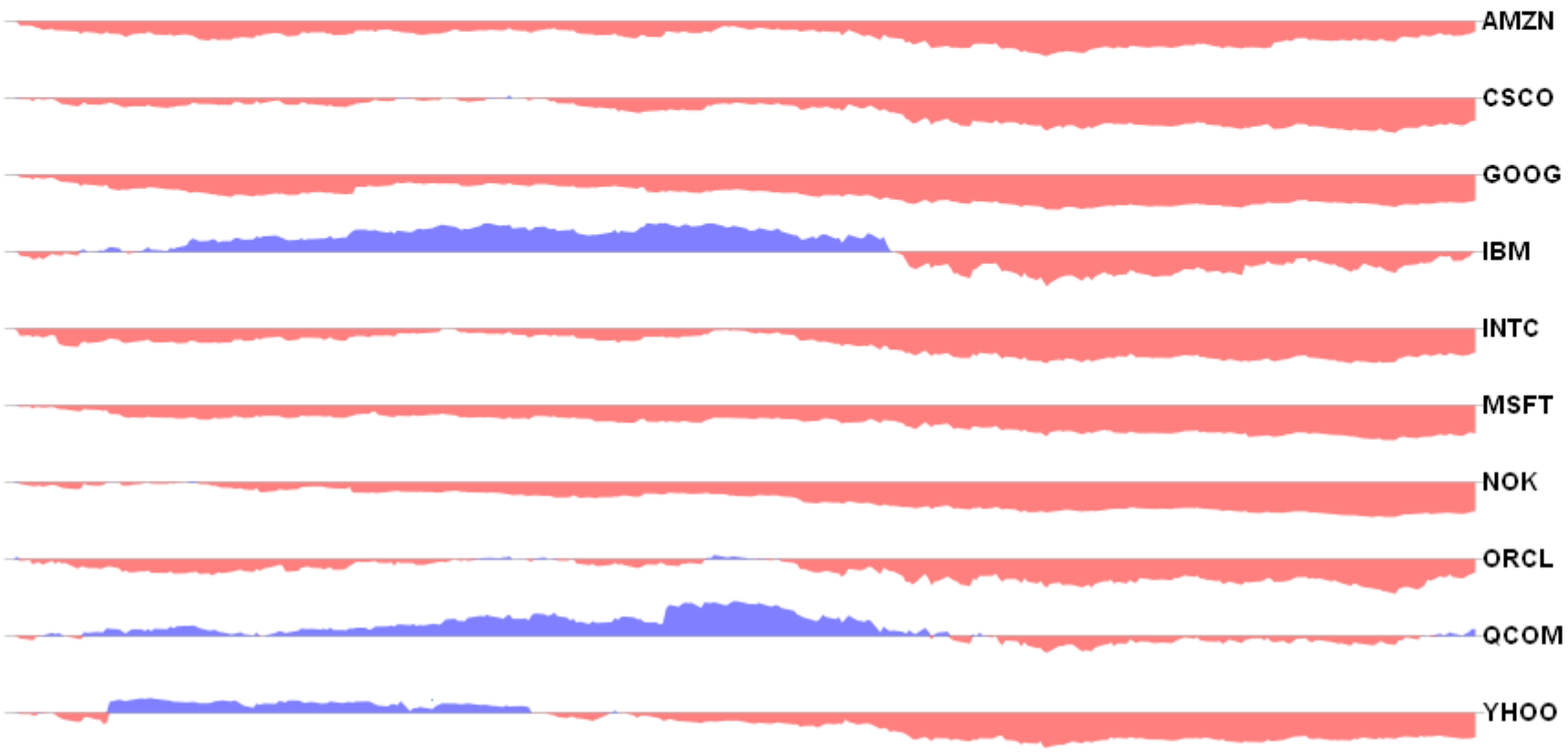
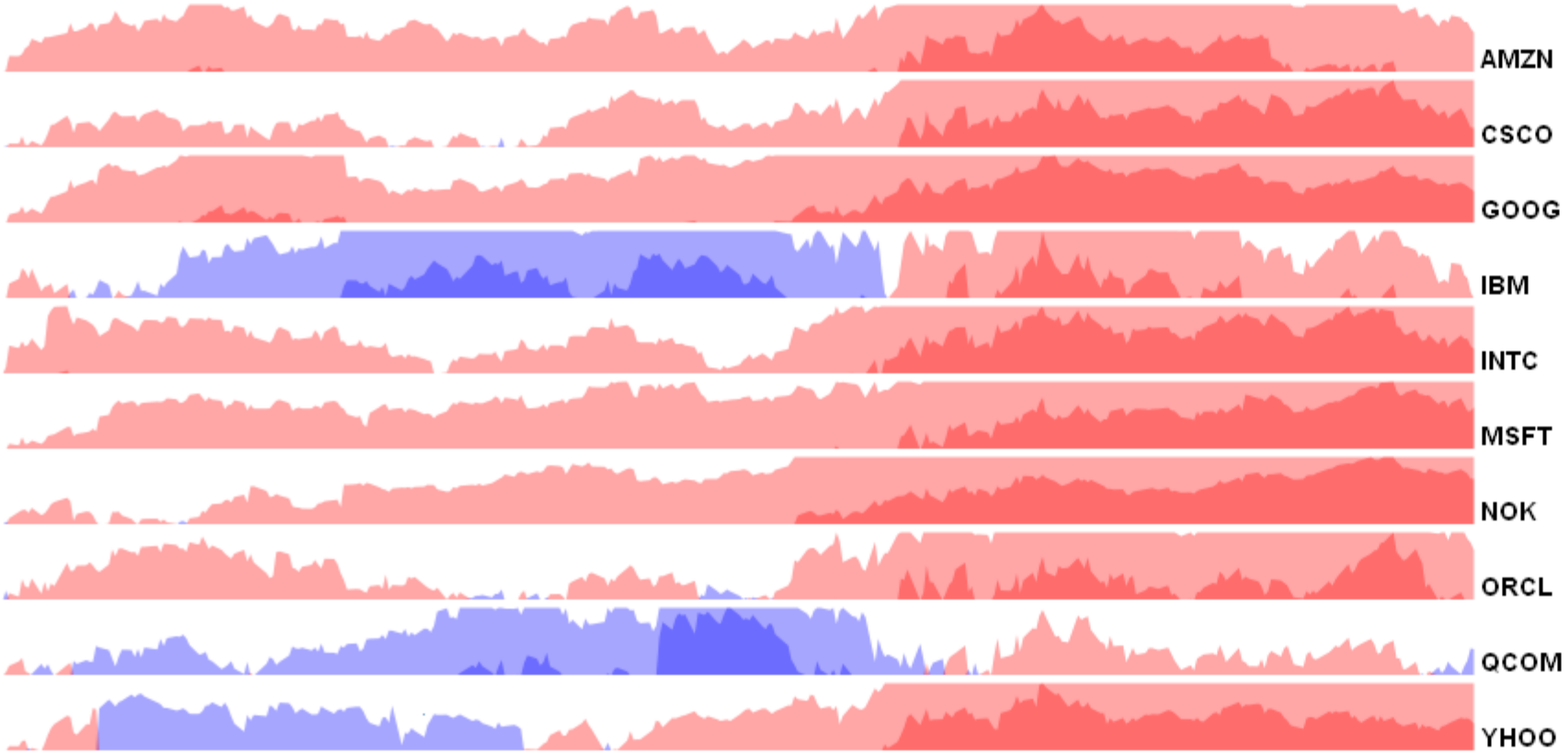
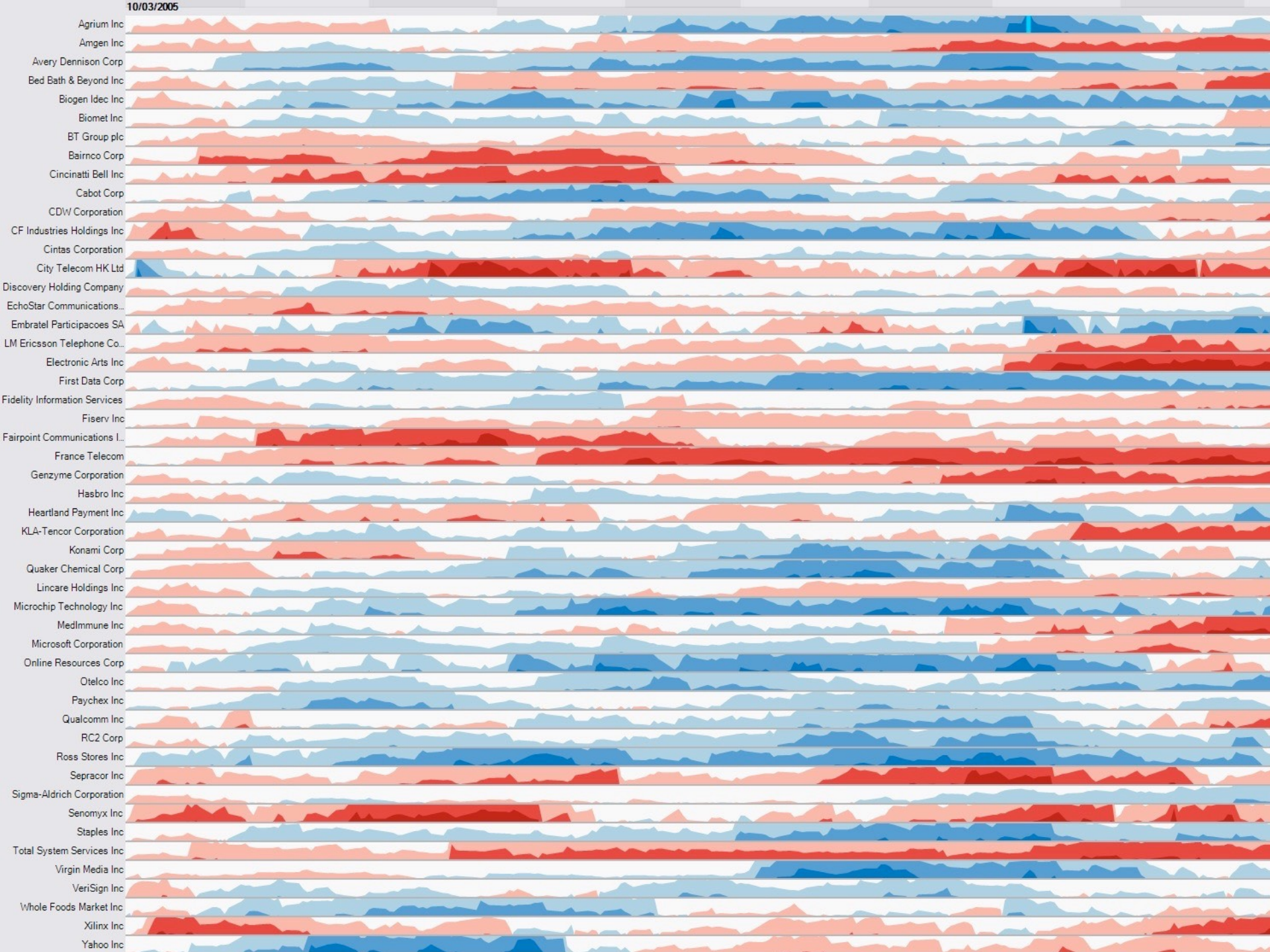


Relative Technology Stock Performance: Jan 2008 - Present

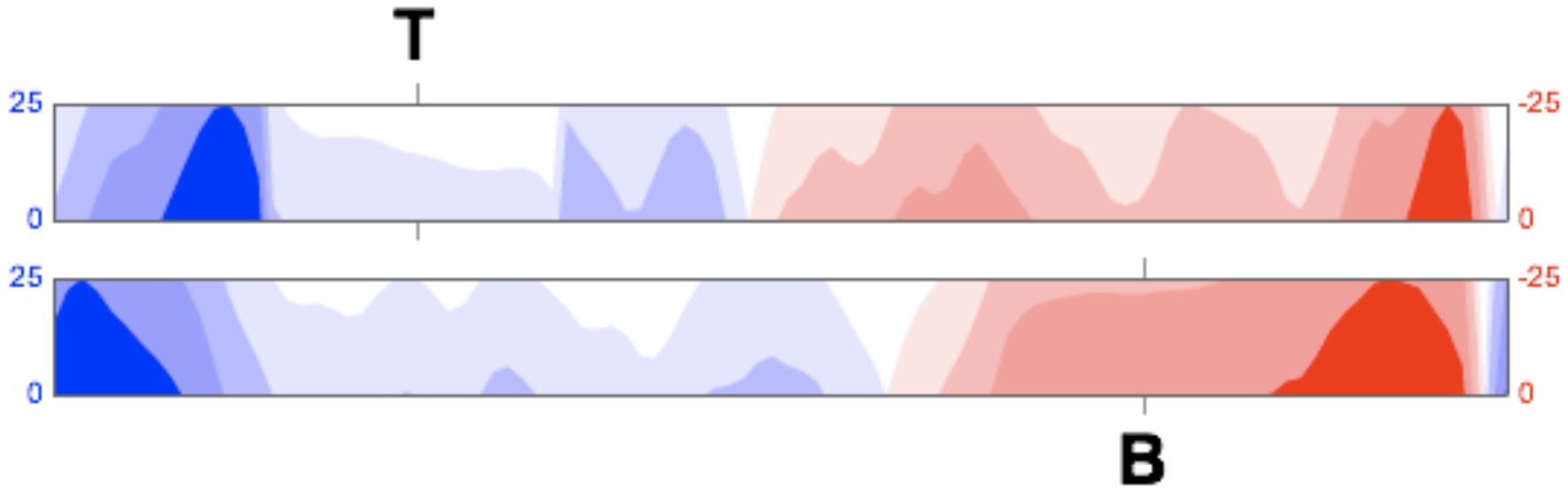



10/03/2005
Agrium Inc
Amgen Inc
Avery Dennison Corp
Bed Bath & Beyond Inc
Biogen Idec Inc
Biomet Inc
BT Group plc
Bairnco Corp
Cincinatti Bell Inc
Cabot Corp
CDW Corporation
CF Industries Holdings Inc
Cintas Corporation
City Telecom HK Ltd
Discovery Holding Company
EchoStar Communications...
Embratel Participacoes SA
LM Ericsson Telephone Co...
Electronic Arts Inc
First Data Corp
Fidelity Information Services
Fiserv Inc
Fairpoint Communications I...
France Telecom
Genzyme Corporation
Hasbro Inc
Heartland Payment Inc
KLA-Tencor Corporation
Konami Corp
Quaker Chemical Corp
Lincare Holdings Inc
Microchip Technology Inc
MedImmune Inc
Microsoft Corporation
Online Resources Corp
Otelco Inc
Paychex Inc
Qualcomm Inc
RC2 Corp
Ross Stores Inc
Sepracor Inc
Sigma-Aldrich Corporation
Senomyx Inc
Staples Inc
Total System Services Inc
Virgin Media Inc
VeriSign Inc
Whole Foods Market Inc
Xilinx Inc
Yahoo Inc

Experiment: Chart Type & Size

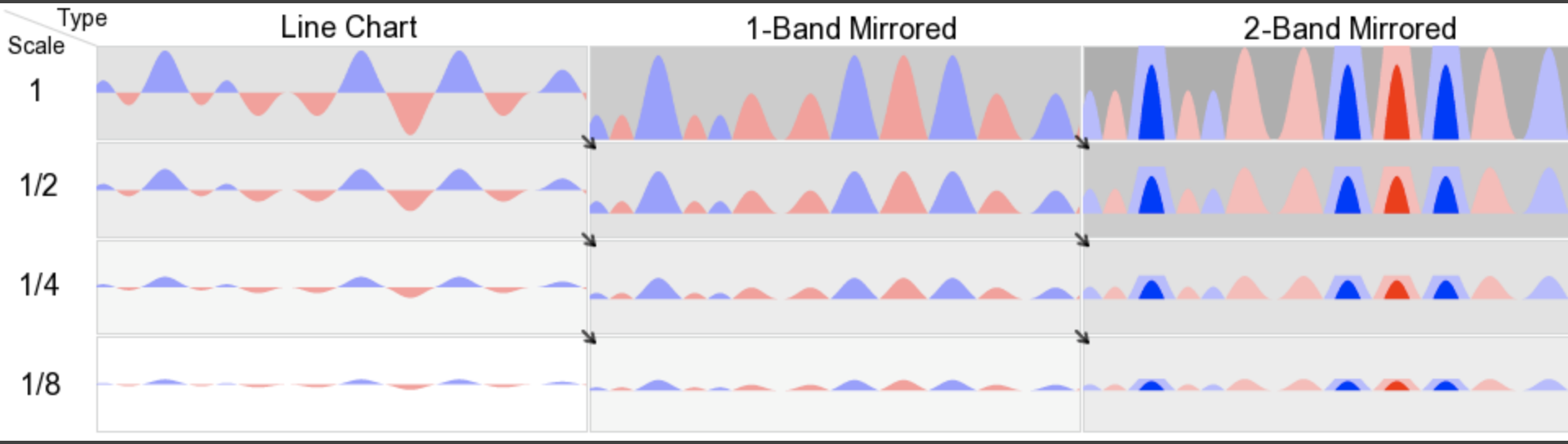
Q1: How do mirroring and layering affect estimation time and accuracy compared to line charts?

Q2: How does chart size affect estimation time and accuracy?



Estimate the difference between T and B (0-200) to within 5 values.

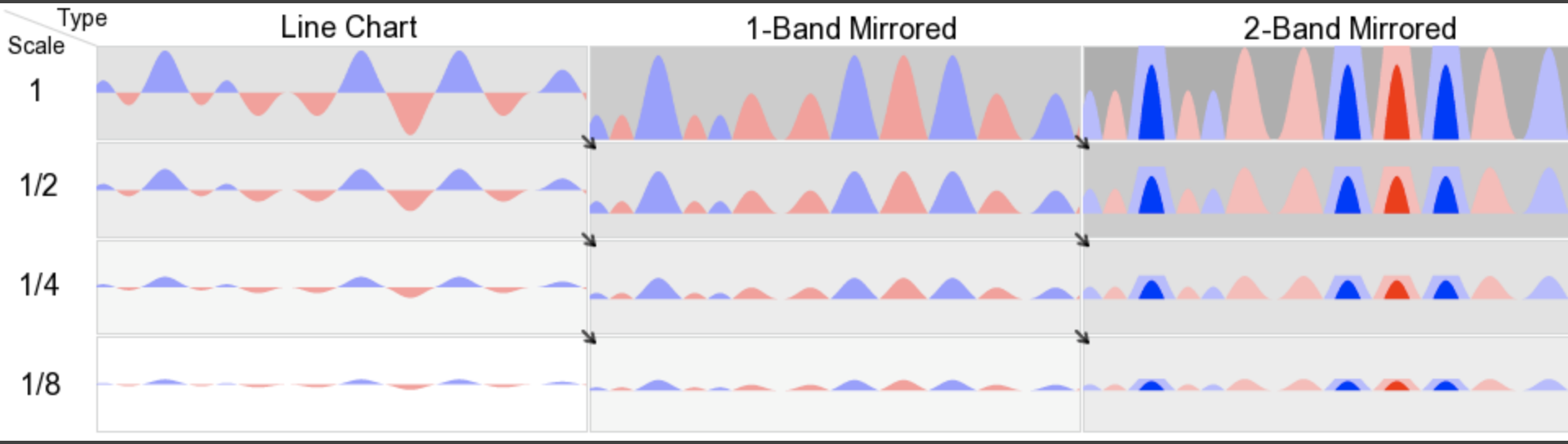
Experiment Design



3 (chart type) x 4 (size) within-subjects design

- N = 30 (17 male, 13 female), undergrads
- 14.1 inch LCD display, 1024 x 768 resolution
- At scale = 1, chart is 13.9 x 1.35 cm (48 px)

Experiment Design

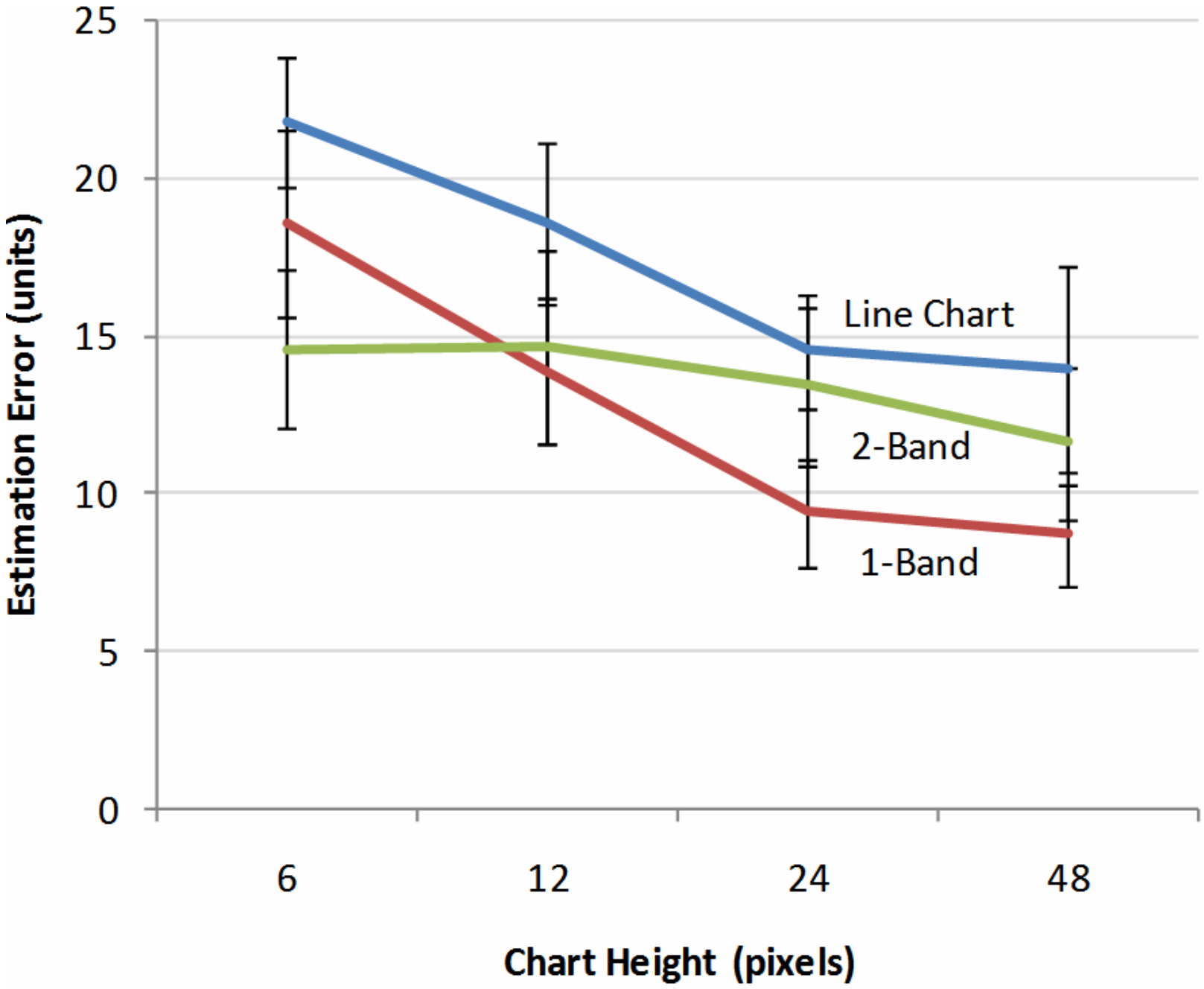


3 (type) x 4 (size) within-subjects design

N = 30 (17 male, 13 female), undergrads

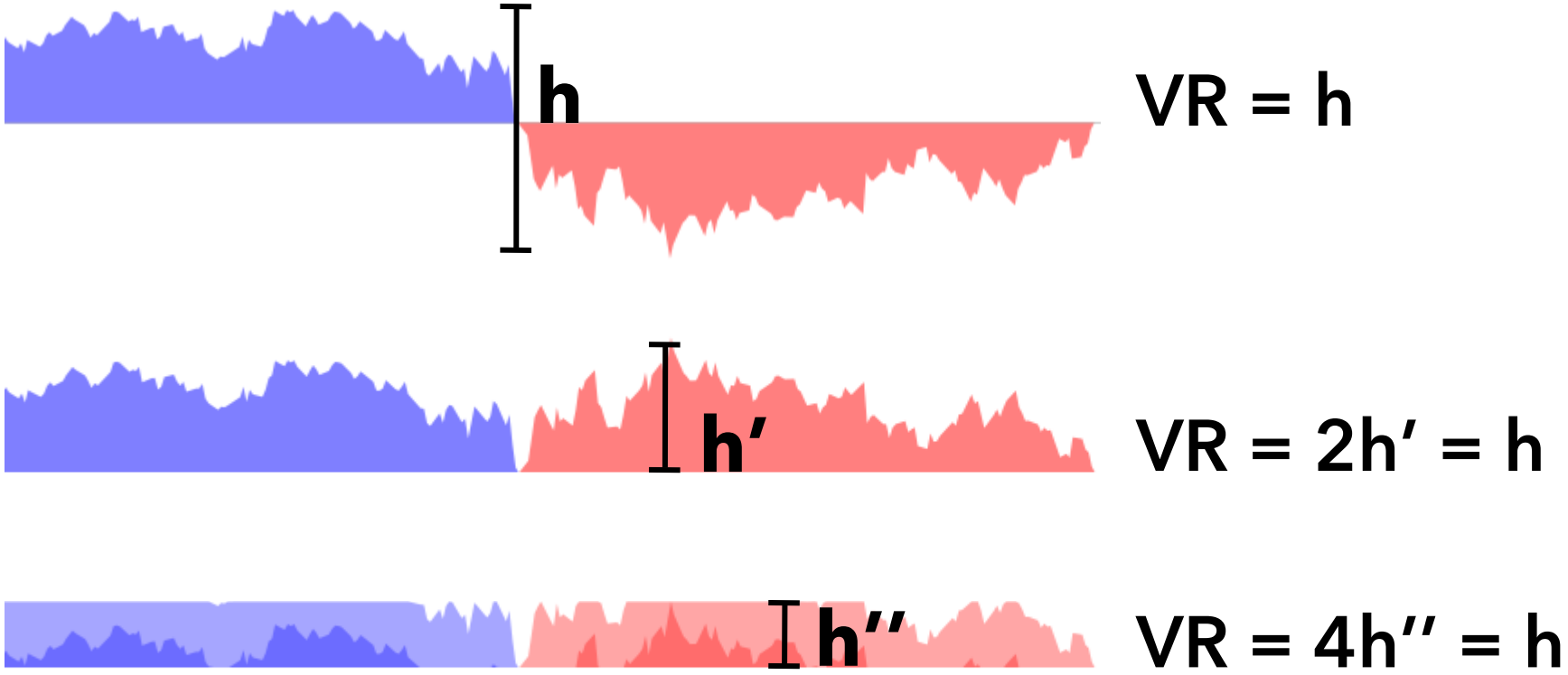
2 (type) x 3 (size:1/8, 1/12, 1/24) follow-up

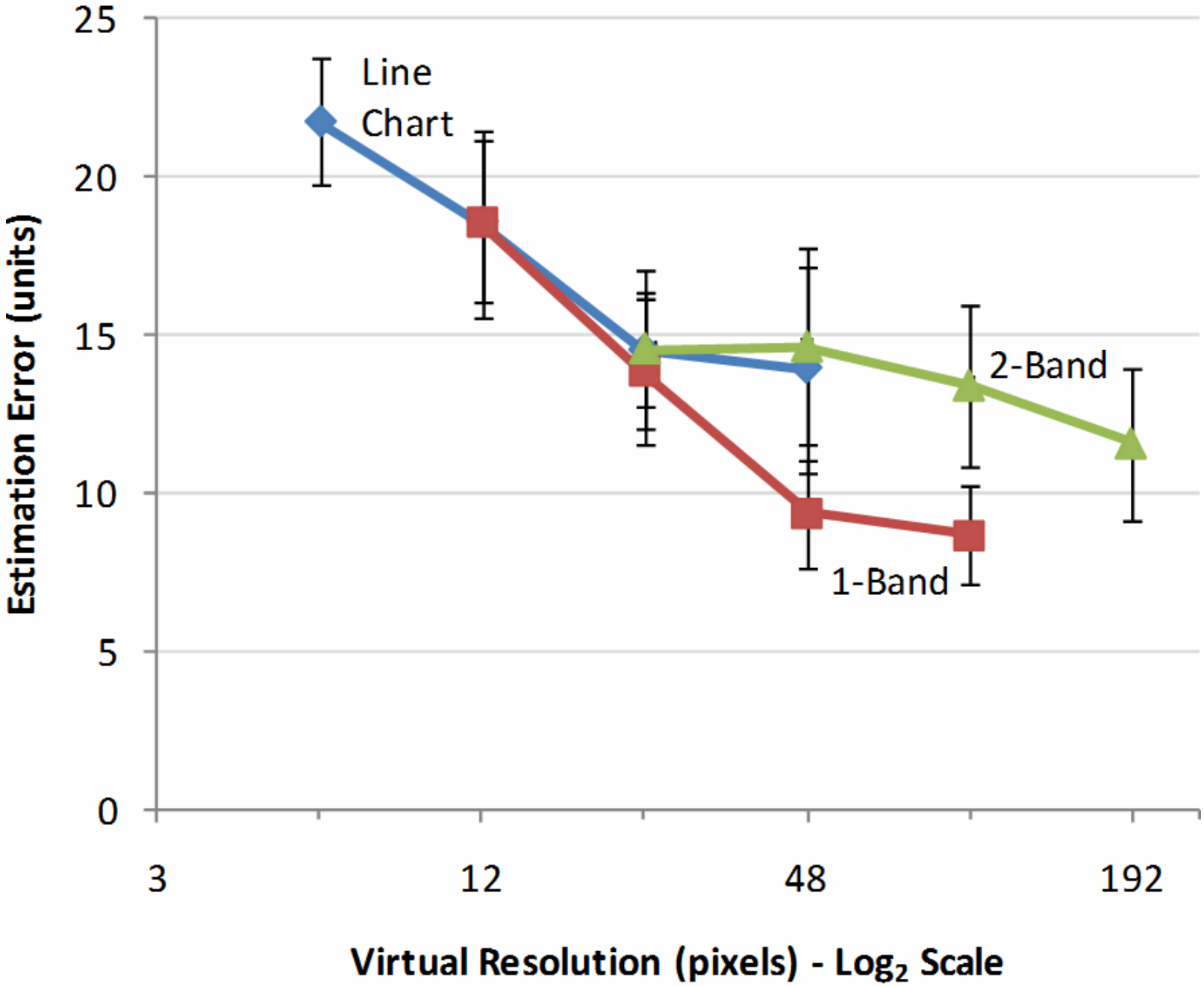
N = 8 (6 male, 2 female), engineering grads

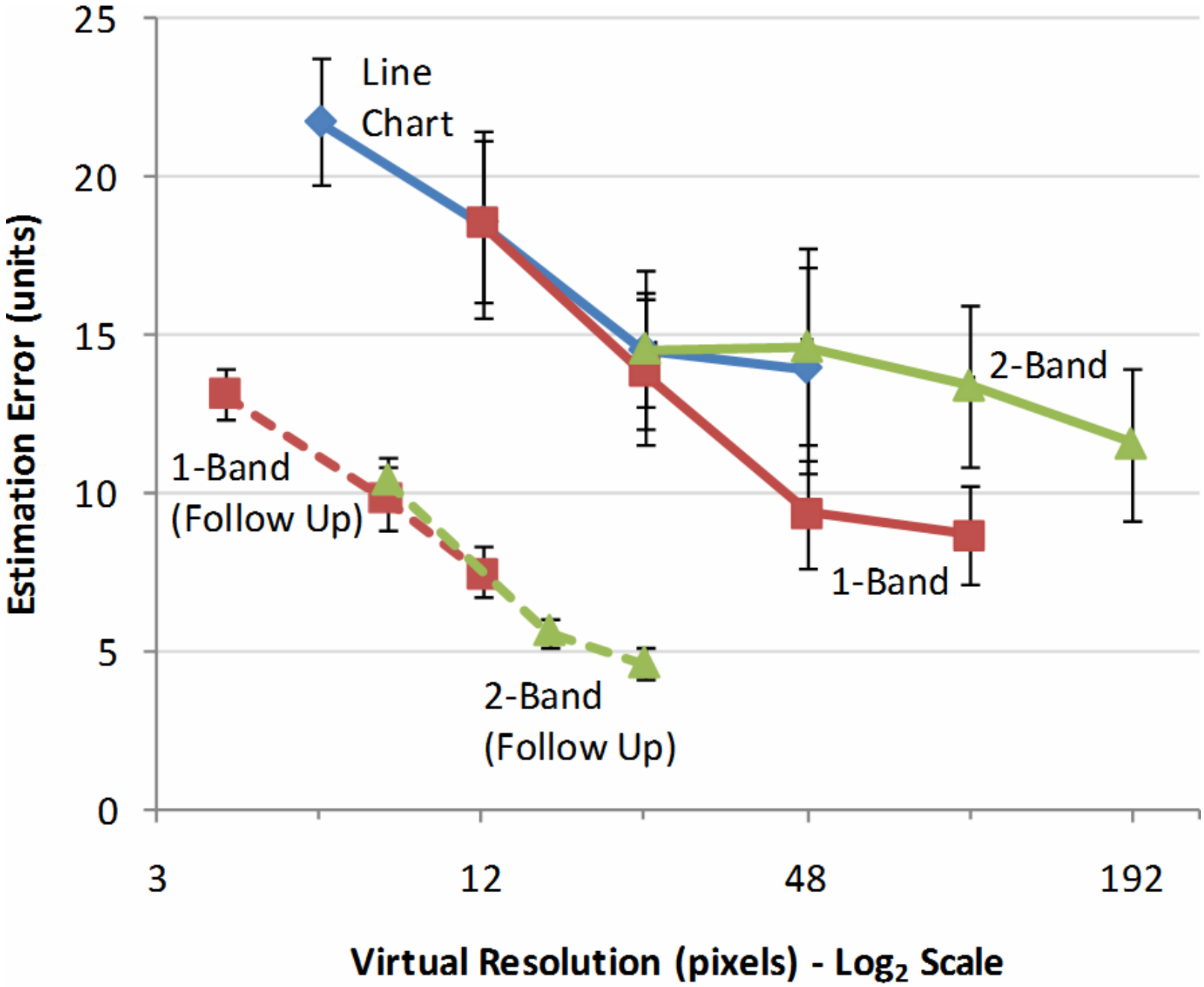

25
20
15
10
5
0
Estimation Error (units)
Line Chart
2-Band
1-Band
6
12
24
48
Chart Height (pixels)

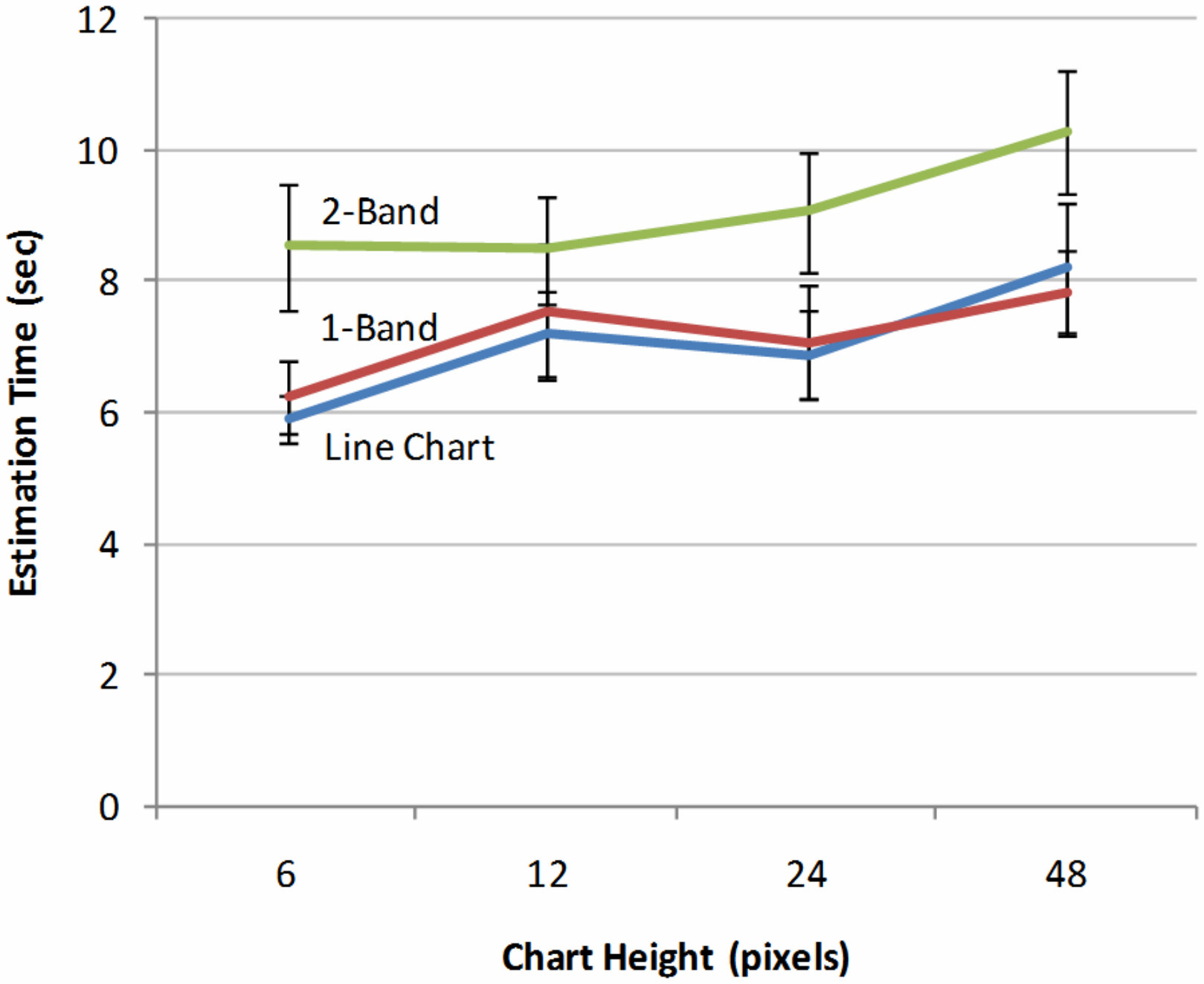
Virtual Resolution (VR)

The un-mirrored, un-layered height of a chart




25
20
15
10
5
0
Estimation Error (units)
Line
Chart
2-Band
1-Band
3
12
48
192
Virtual Resolution (pixels) - Log2 Scale


25
20
15
10
5
0
Estimation Error (units)
Line
Chart
2-Band
1-Band
(Follow Up)
1-Band
2-Band
(Follow Up)
3
12
48
192
Virtual Resolution (pixels) - Log2 Scale


12
10
8
6
4
2
0
Estimation Time (sec)
2-Band
1-Band
Line Chart
6
12
24
48
Chart Height (pixels)

Experiment Results

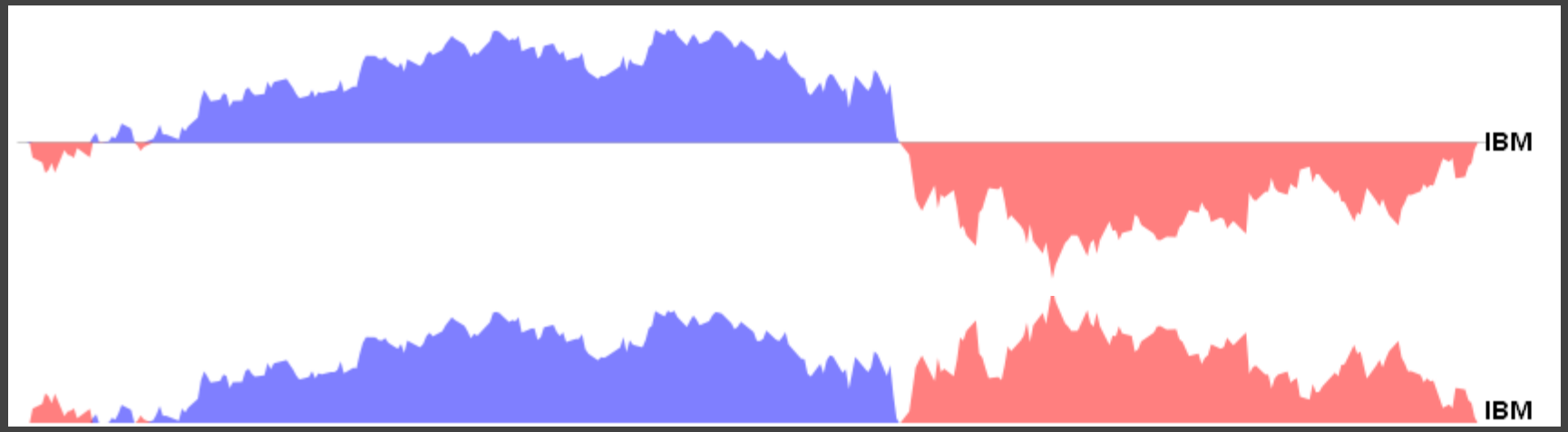
Q1: 2-band horizon graph (but not mirrored graph) has higher baseline estimation time and error.

Q2: Estimation error increases as the *virtual resolution* decreases.

Estimation time decreases as the *physical height* decreases.

Design Guidelines

Mirroring does not hamper perception

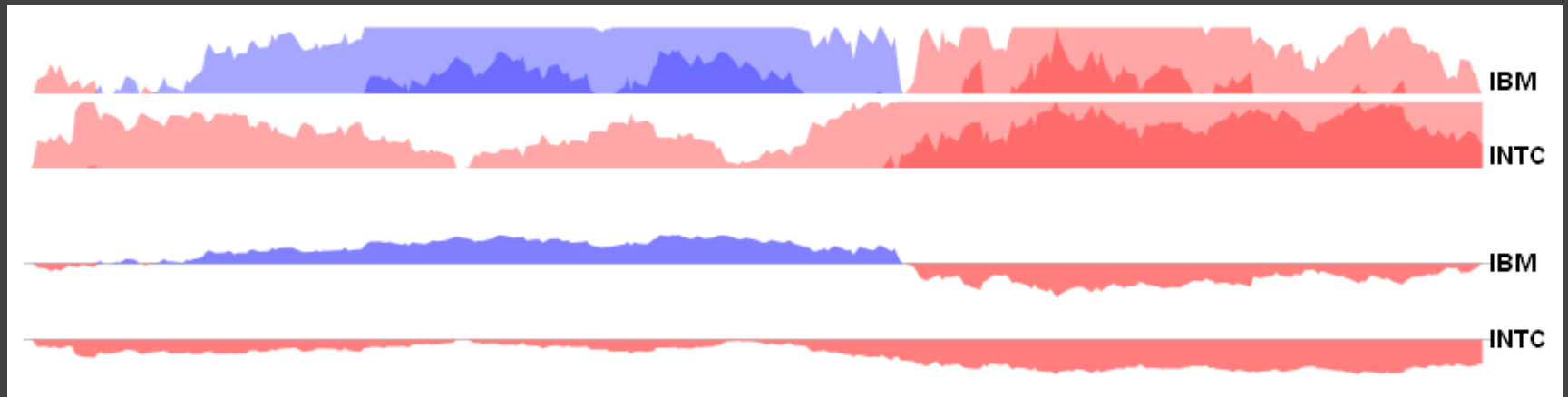


Design Guidelines

Mirroring does not hamper perception

Layered bands beneficial for smaller charts

- **2-band mirror charts** more accurate for heights under 6.8mm (24 pixels @ 1024x768)
- Predict benefits for 3 bands under 1.7mm (6 px)



Design Guidelines

Mirroring does not hamper perception

Layered bands beneficial for smaller charts

Optimal chart sizing

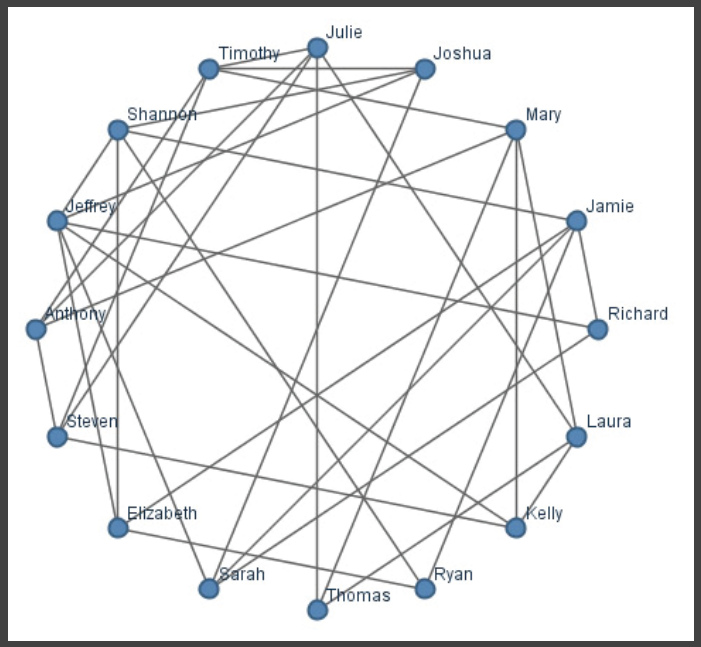
- **Sweet spots** in time/error curves
- 6.8mm (24 px) for line chart & mirrored chart
- 3.4mm (12 px) for 2-band horizon graph

FOLLOW-UP QUESTION:

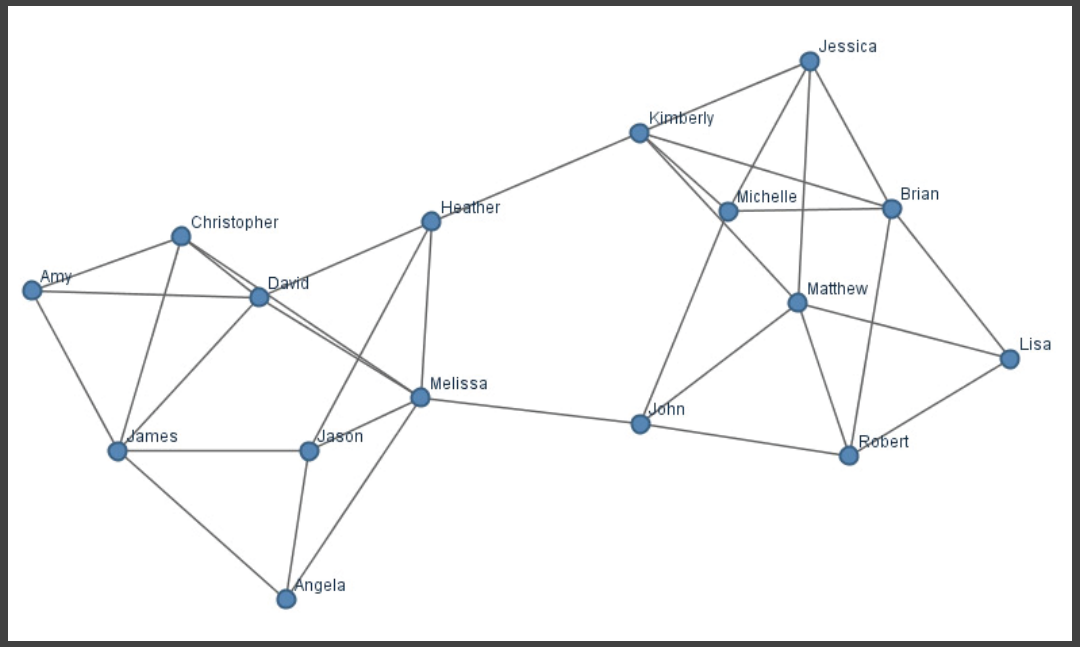
What other **tasks** and **performance measures** should one test?

Perceptual Organization of Node-Link Diagrams

Perceptual Organization of Graphs



Circular



Force-Directed

Experiment Design

Factors

Circular or Force-Directed Seed Layout

# of Between-Cluster Edges (“masking”)

All graphs had two primary clusters

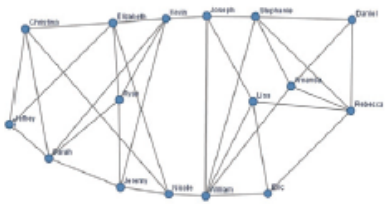
Measures

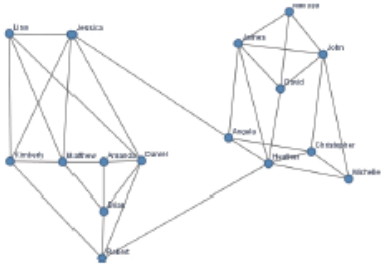
# of Edge Crossings

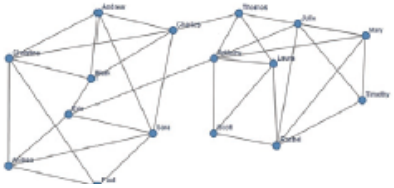
Average Edge Length

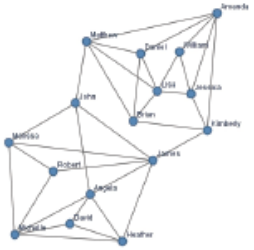
Average Node Distance

within or between clusters

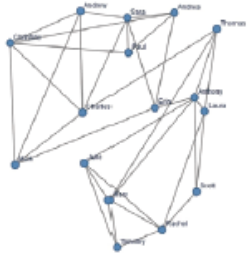


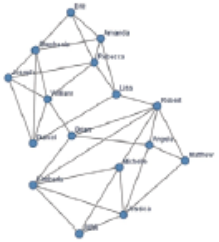


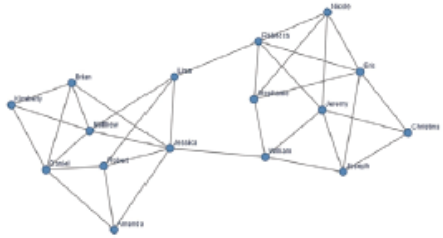


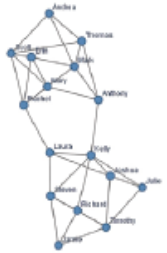


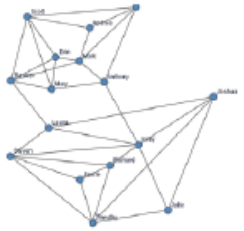
Circular











Force-Directed

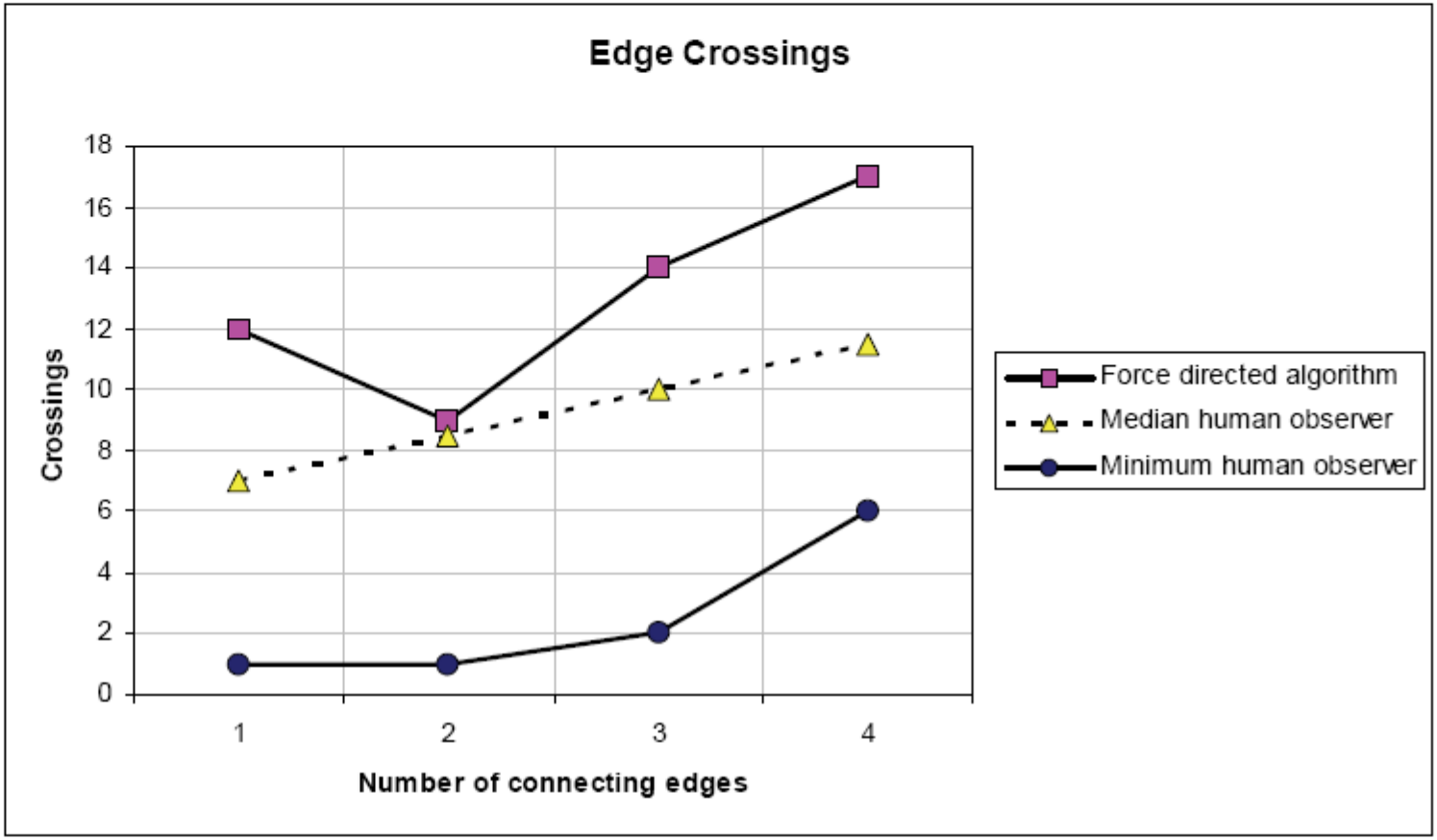


Figure 4. Edge Crossings. Human observers produced graph layouts with fewer edge crossings than the force-directed graph algorithm.

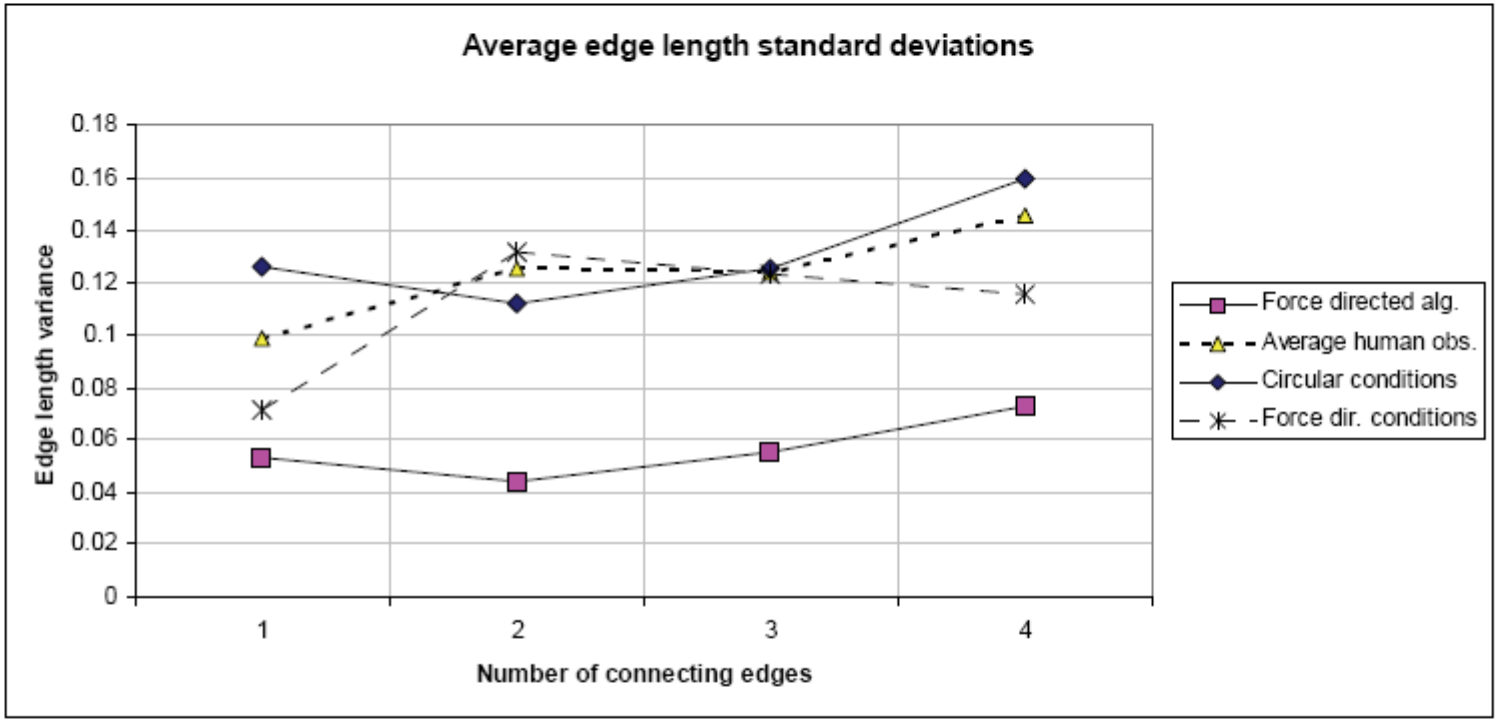


Figure 5. Edge Length Distribution. Human observers did not focus on maintaining equal edge length as much as the force directed algorithm.

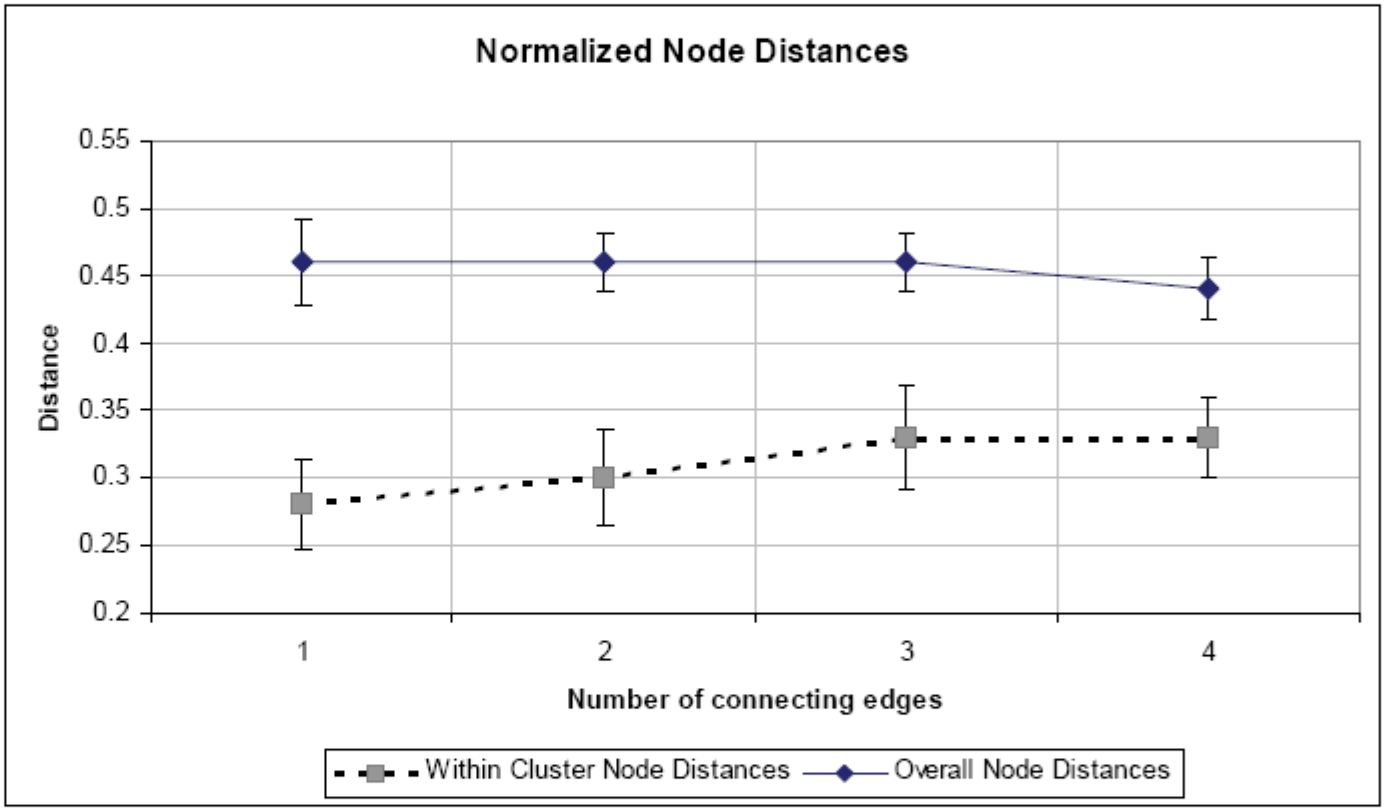
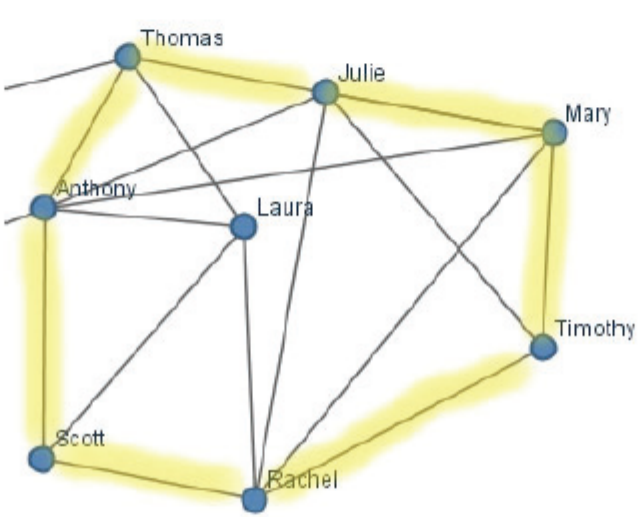


Figure 7. Cluster Extraction. For all levels of masking, the distance between nodes within a cluster is significantly smaller than the overall inter-node distance, demonstrating perceptual grouping. Error bars show 95% confidence intervals



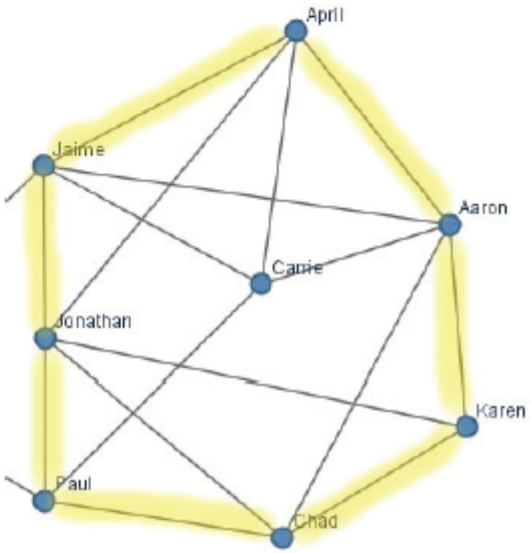


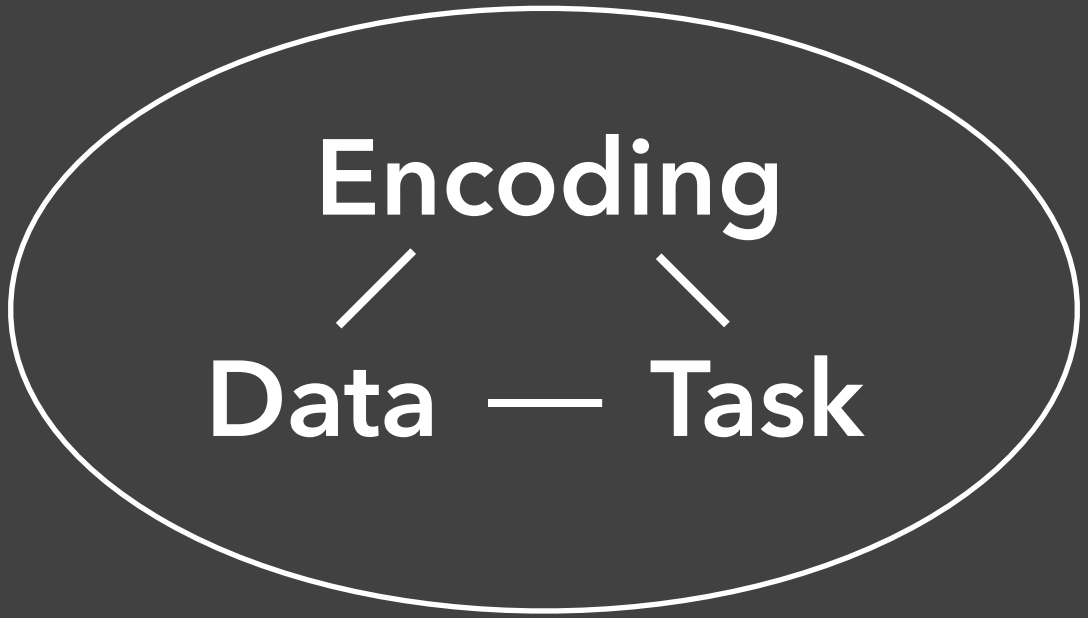
Figure 9. Cluster Hulls. Two examples of user-generated layouts where cluster edges formed a hull enclosing the cluster, organizing it into a single perceptual group.

Summary

Design and analyze visualization techniques in context of real-world use.

Time/error analyses can be insightful, but they don’t provide a complete picture.

Performance measures may be more suited to serious analysis than casual use?



Users & Domain

Administrivia

Final Project Deliverables

Demonstration Video (<= 2 min)
Due on YouTube & Canvas by midnight Wed 12/8.

Final Project Showcase
We will show demo videos in class, Thu 12/9.

Interactive Web Page & GitHub Repo
All materials online by midnight Tue 12/14.

Read assignment description for more!

Course Evaluation

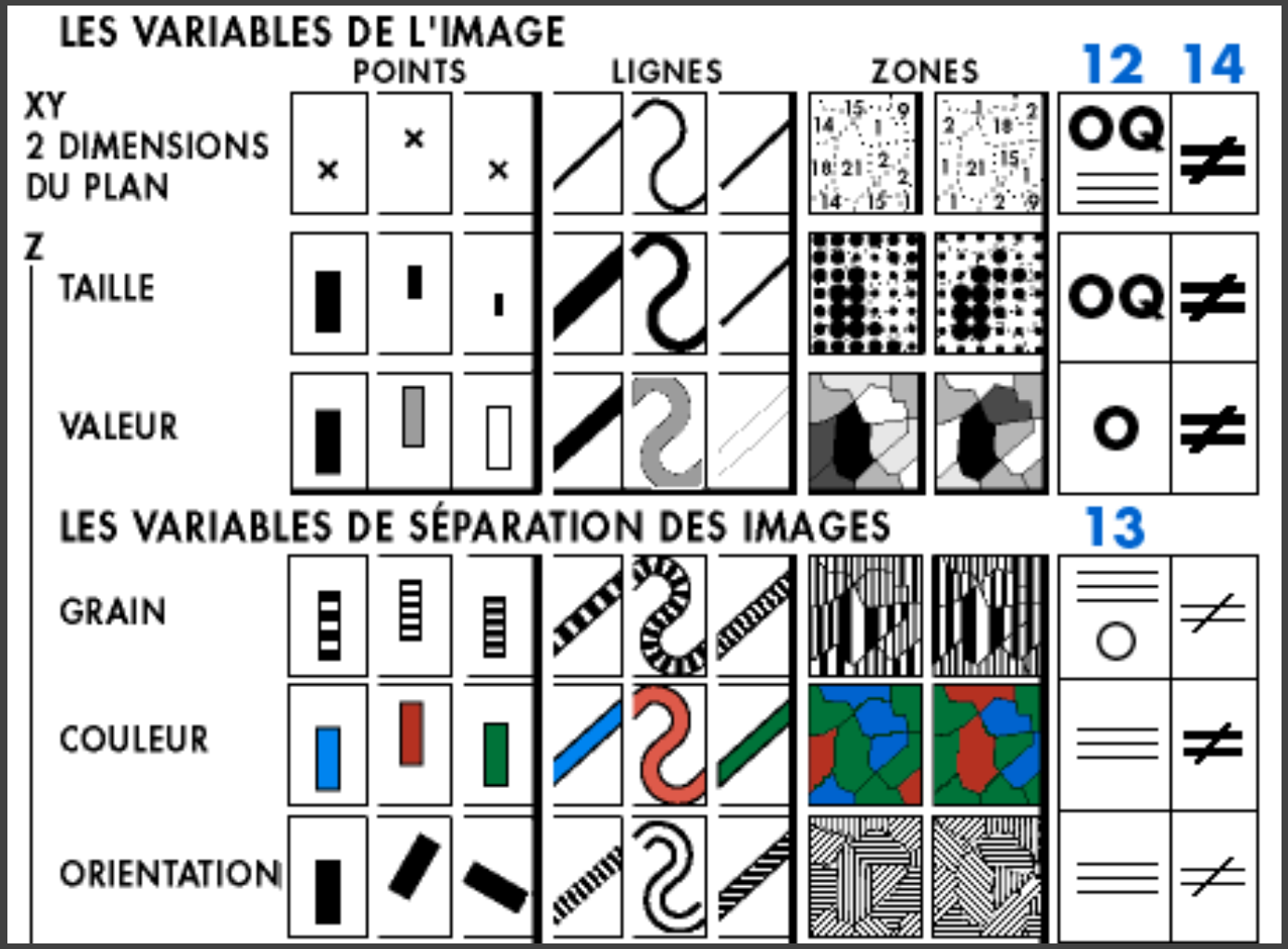
Official course evaluation, due by 12/12

Your opinion is valued!

https://uw.iasystem.org/survey/249033

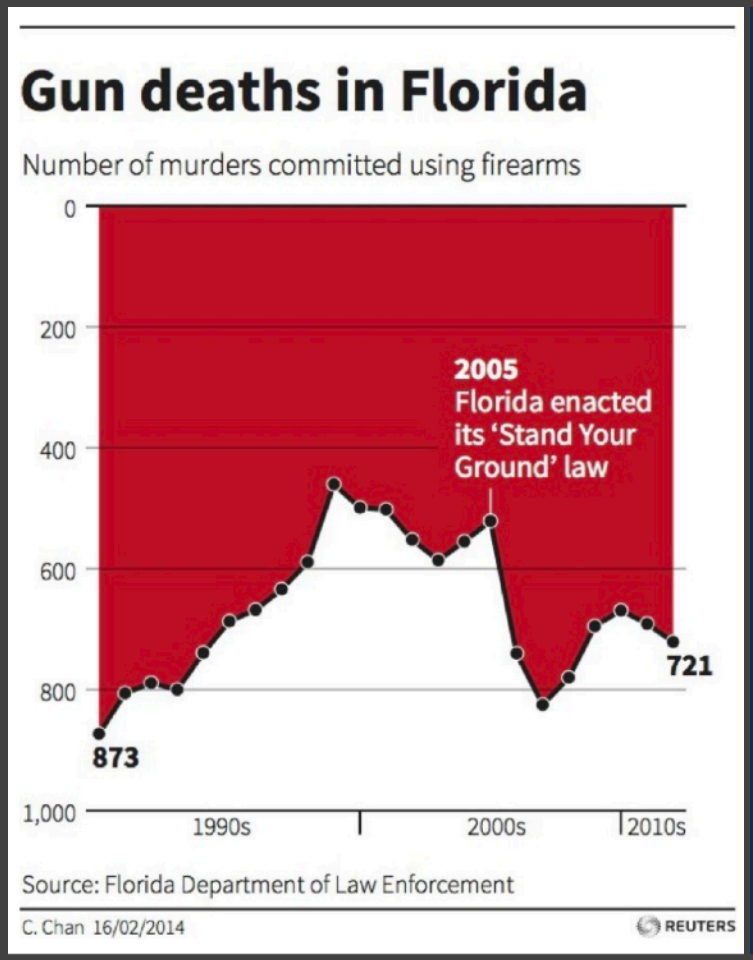
Course Summary

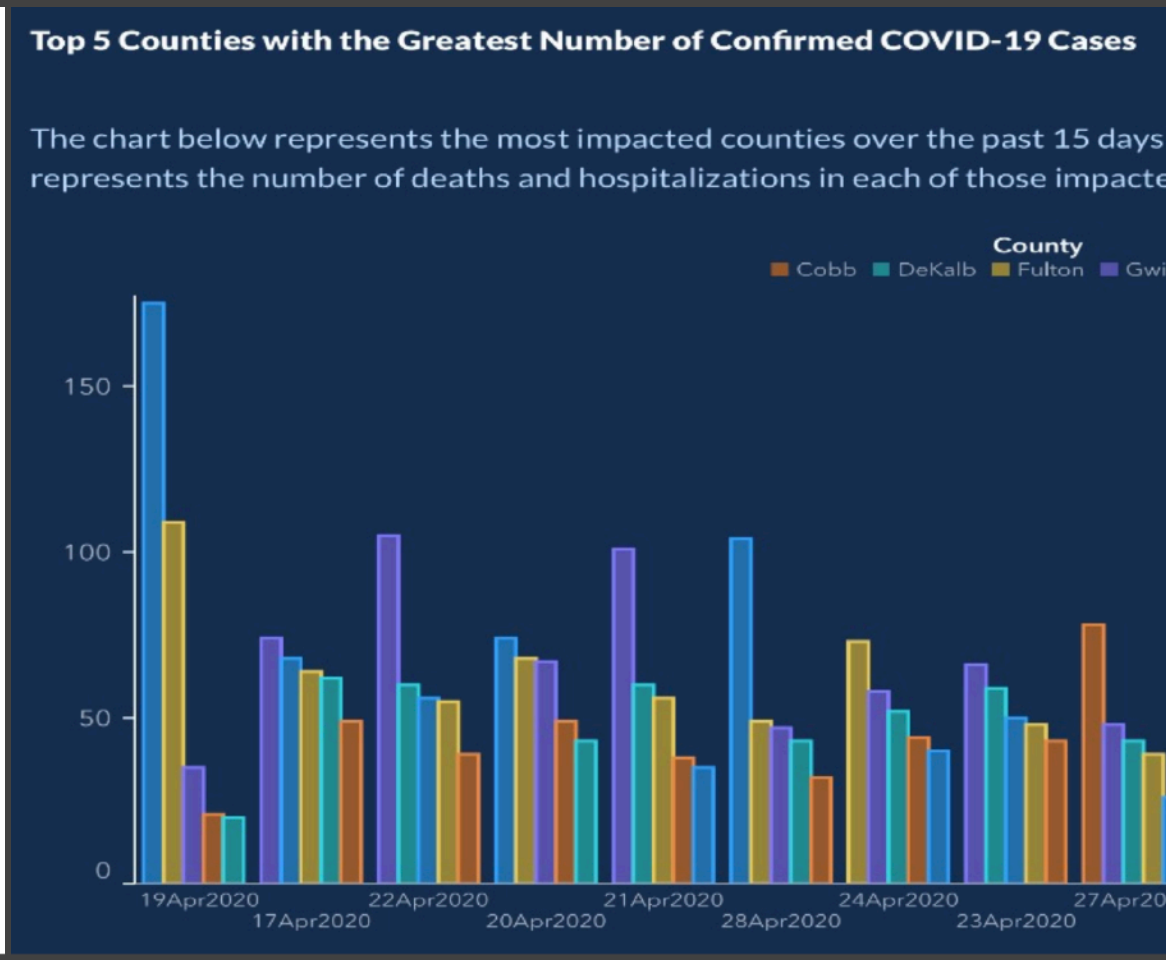
Data and Image Models



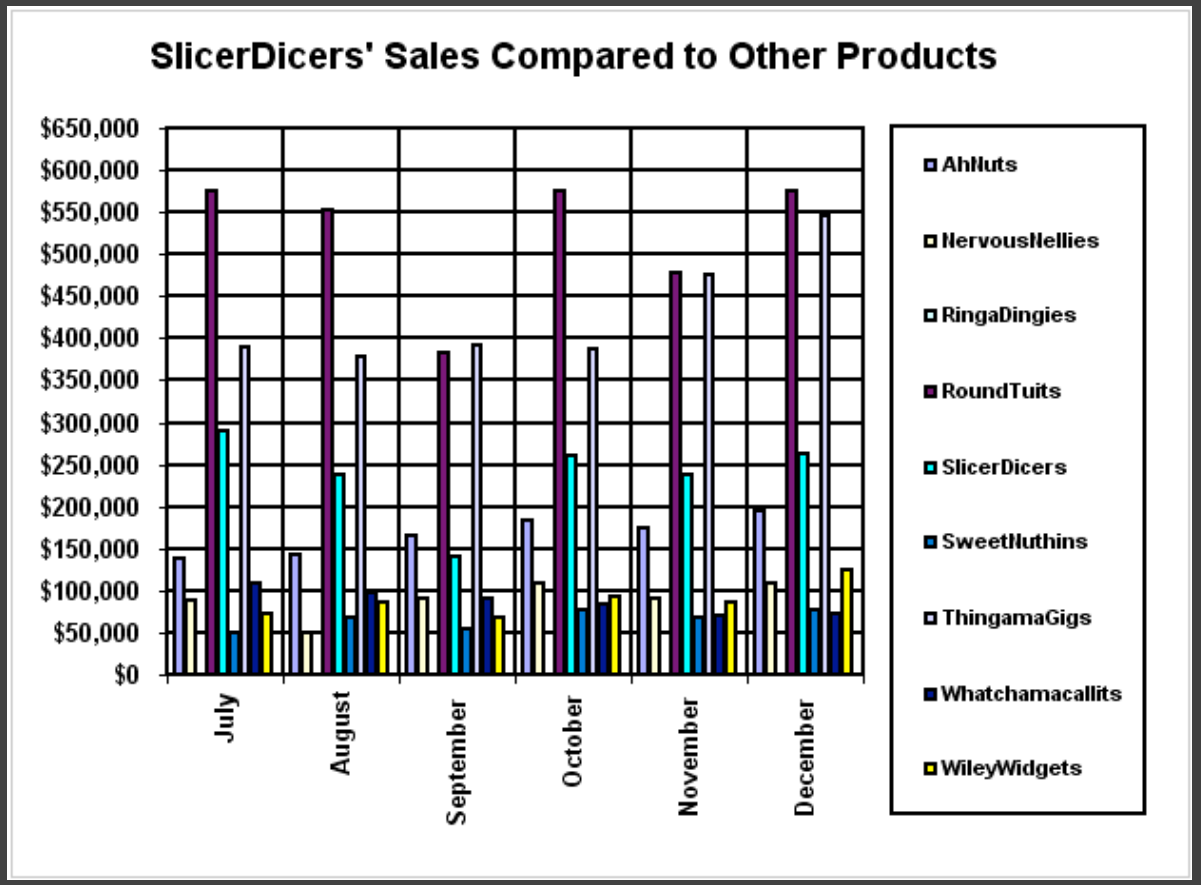
Sémiologie Graphique [Bertin 67]

Deception & Ethics

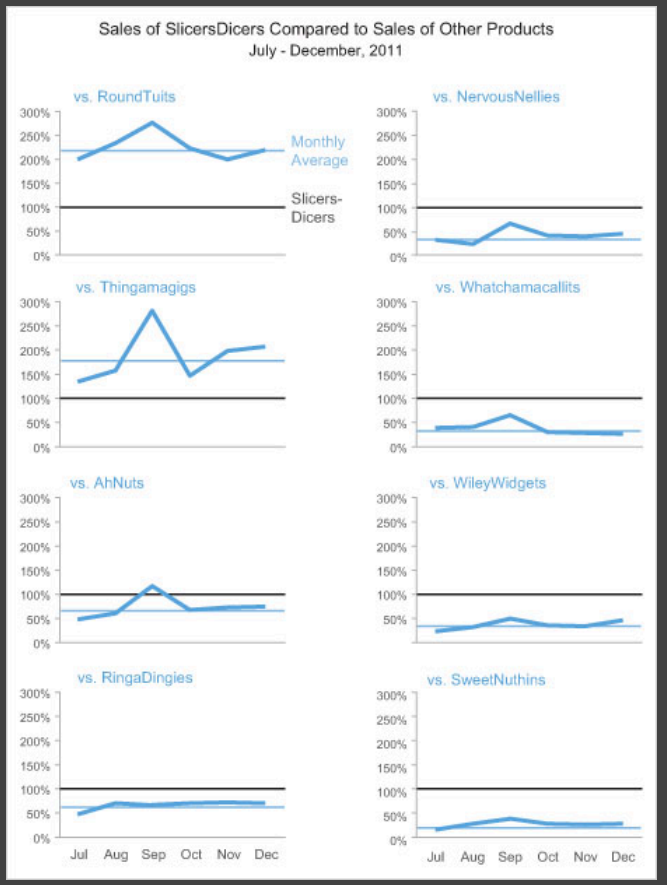




Visualization Design

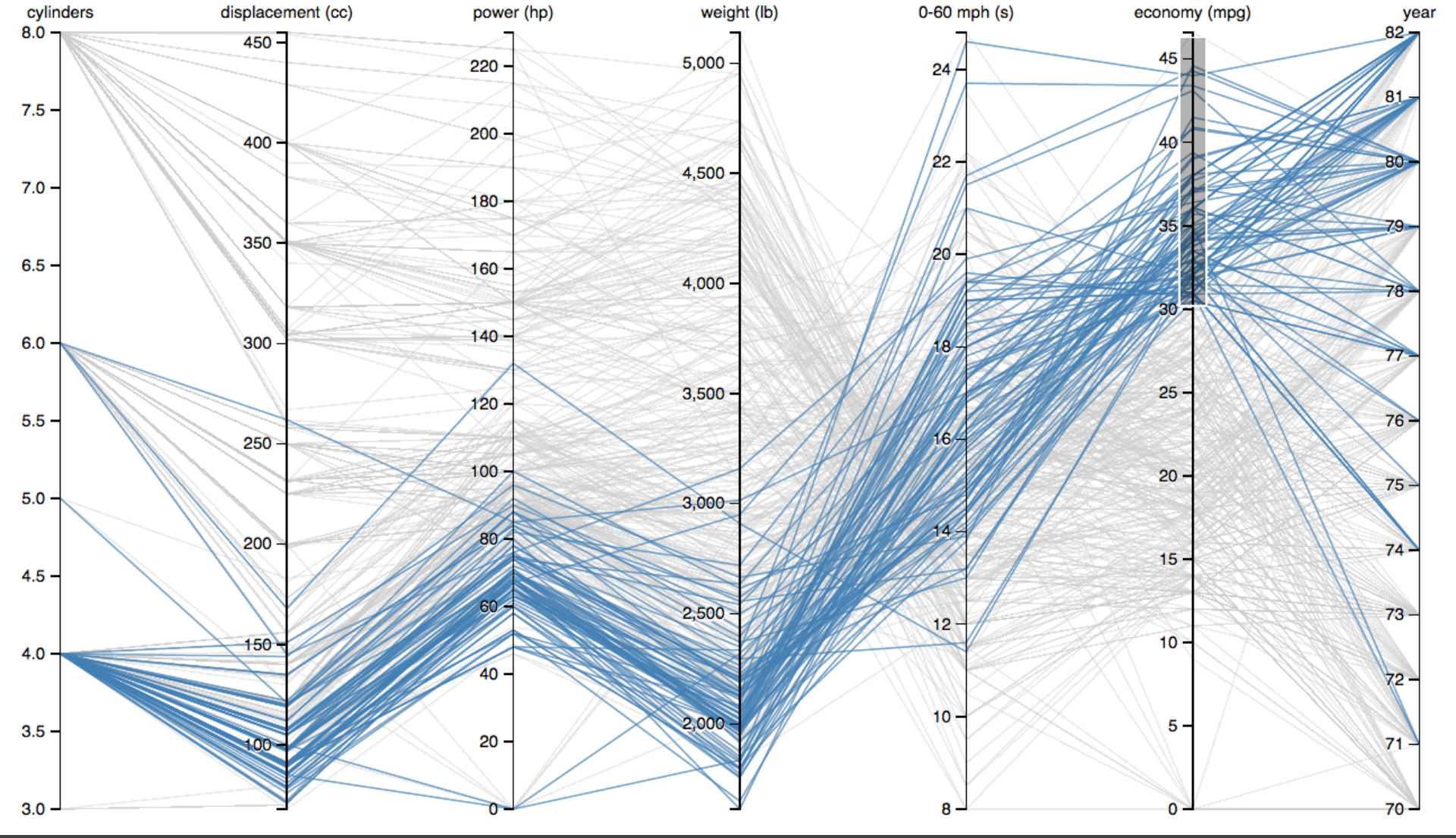


Problematic design

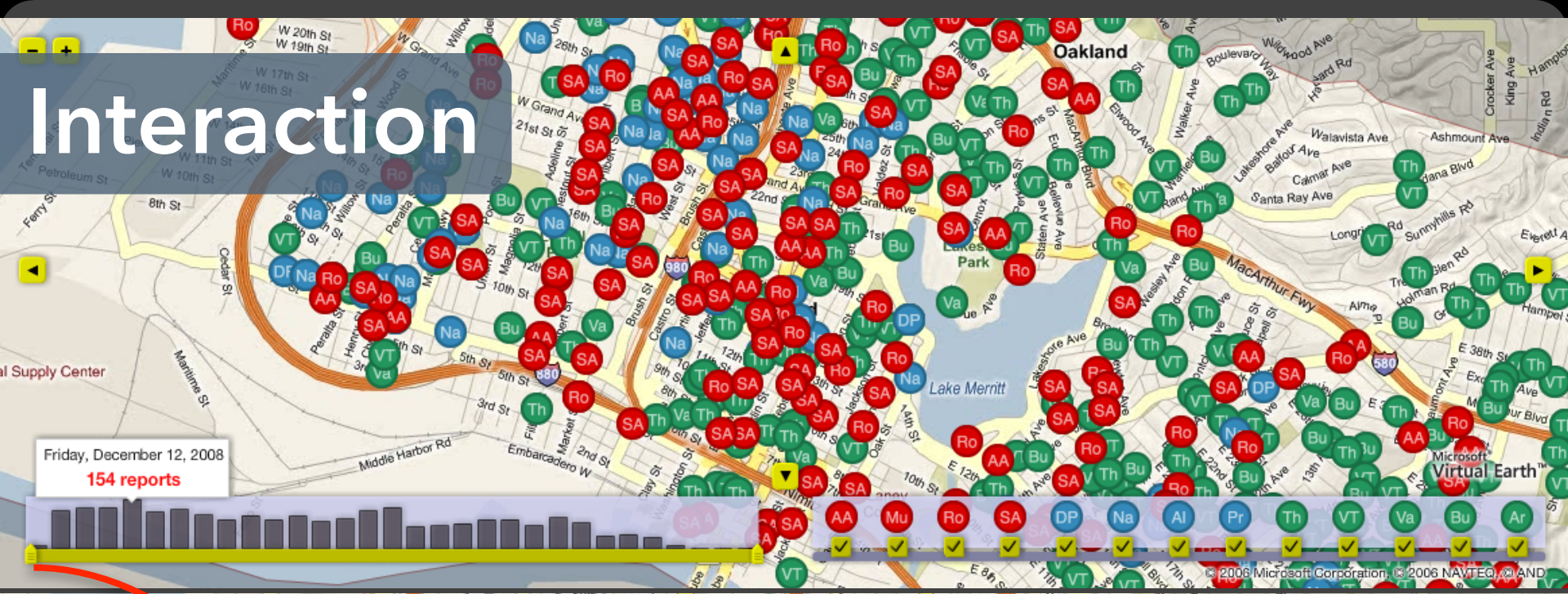


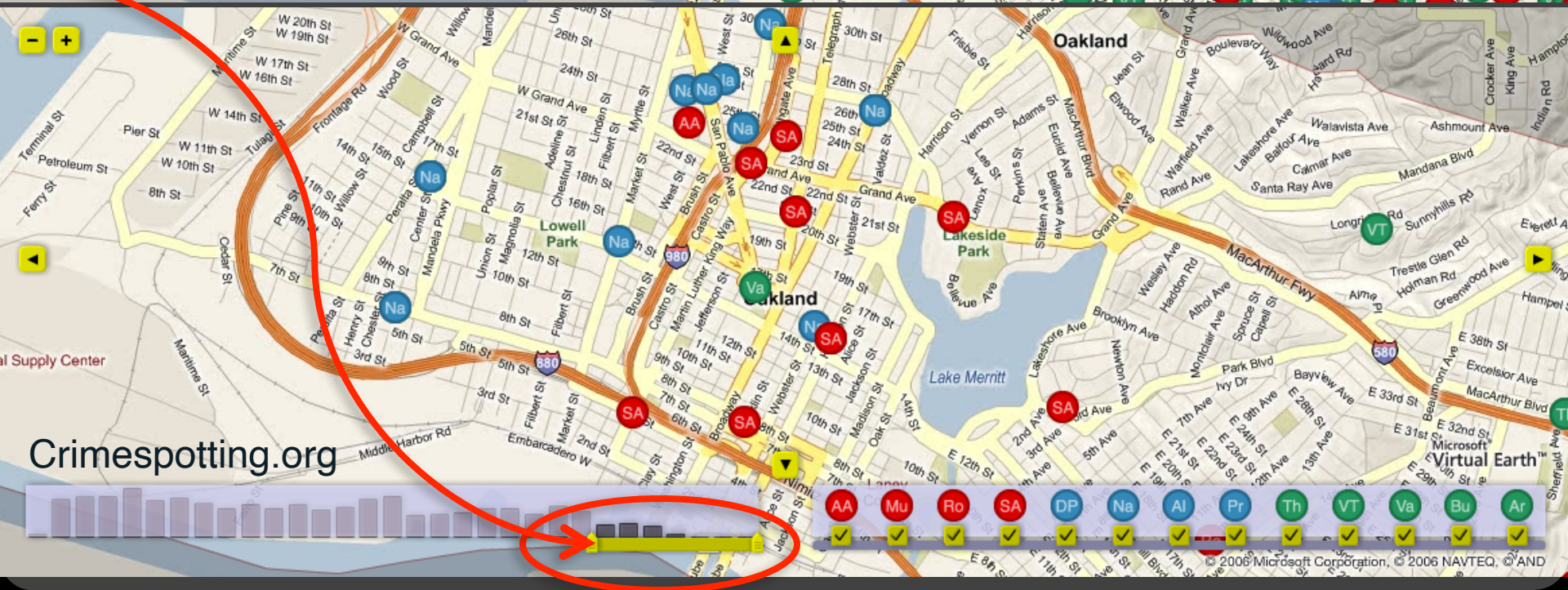
Redesign

Exploratory Data Analysis

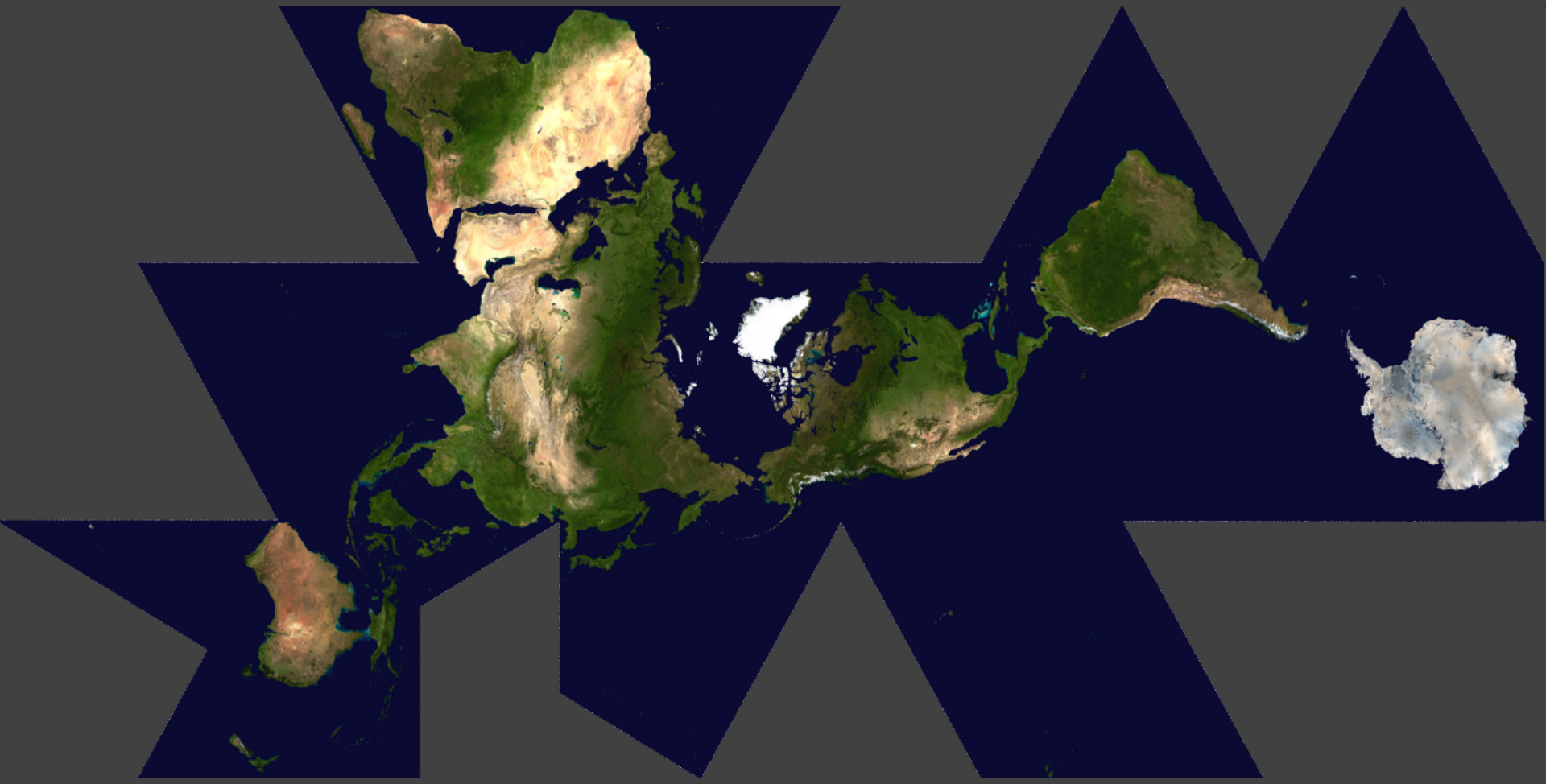


Interaction





Maps



Dymaxion Maps [Fuller 46]

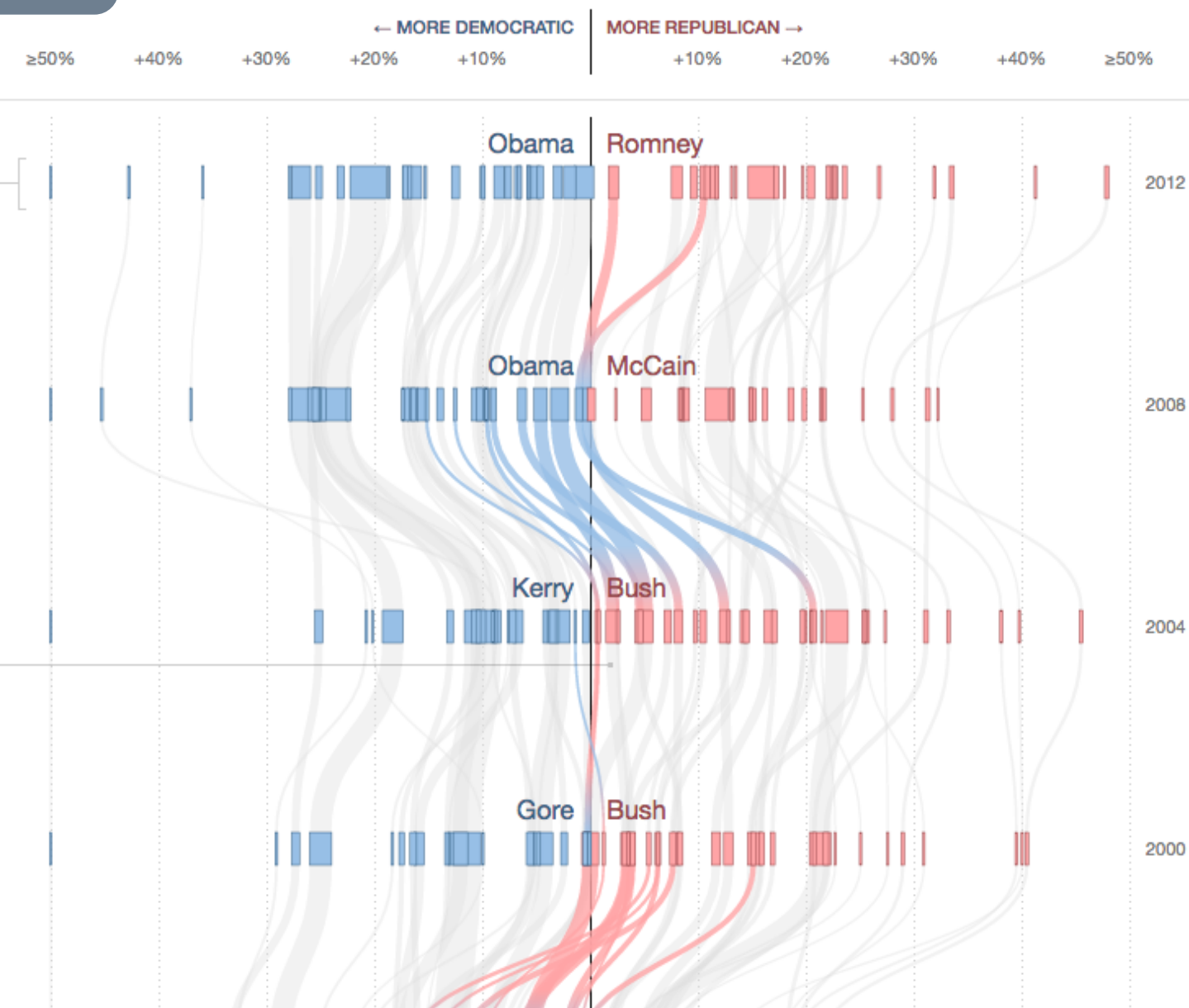
Narrative

Recent elections have placed a heavy emphasis on "swing states" — Ohio, Florida and the other competitive states. Yet in the past, many more states shifted between the Democratic and Republican parties. A look at how the states stack up in the [illegible] they have shifted over past elections.

Each box represents a state sized by number of electoral votes.

Each curve shows how much it shifted left or right between elections

Chart **Size of Lead** | Chart **Electoral Votes**



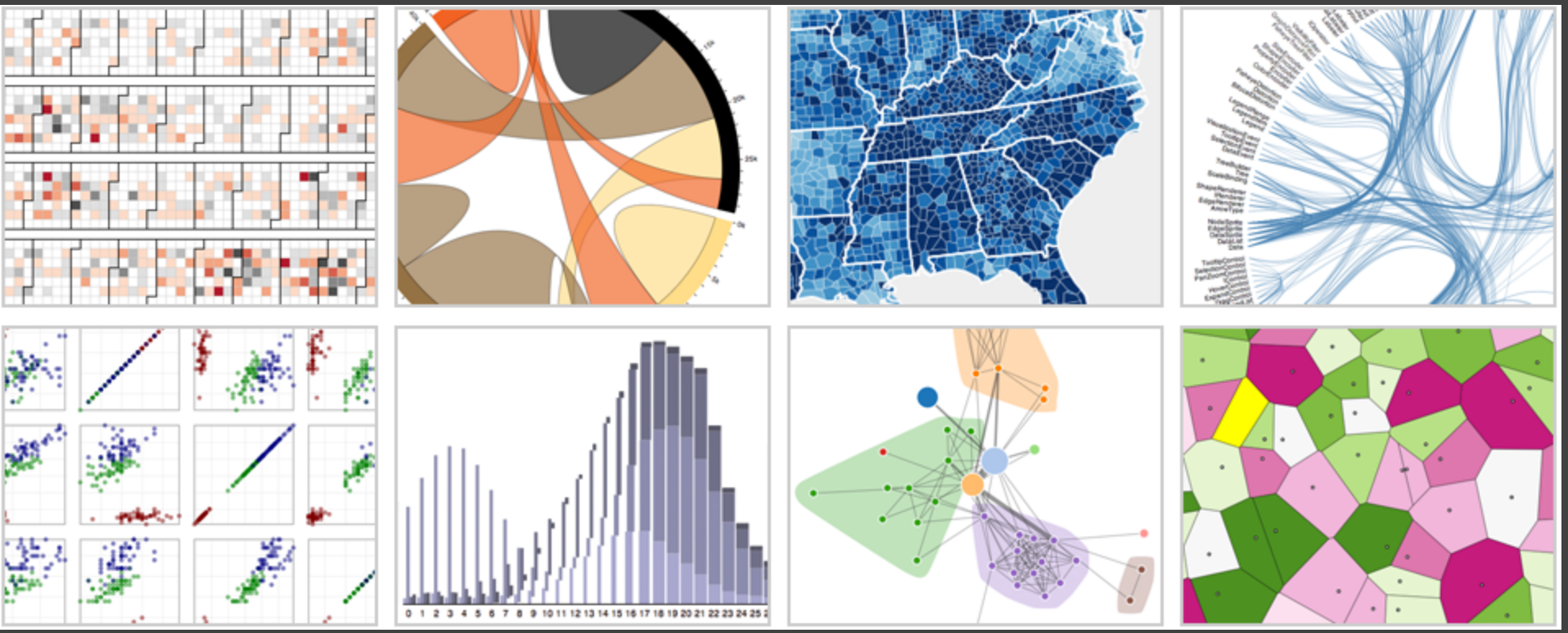
Obama Re-elected
The country voted about 5 percentage points more Republican in 2012 than in 2008. Obama lost North Carolina and Indiana, but won every tossup except Florida, which remains too close to call.

Highlight Tossups

As Goes Ohio
Ohio, which has voted for the winner in every election since 1964, provided the decisive electoral votes in 2004, and it is the state likeliest to play that role again this year, according to the FiveThirtyEight model.

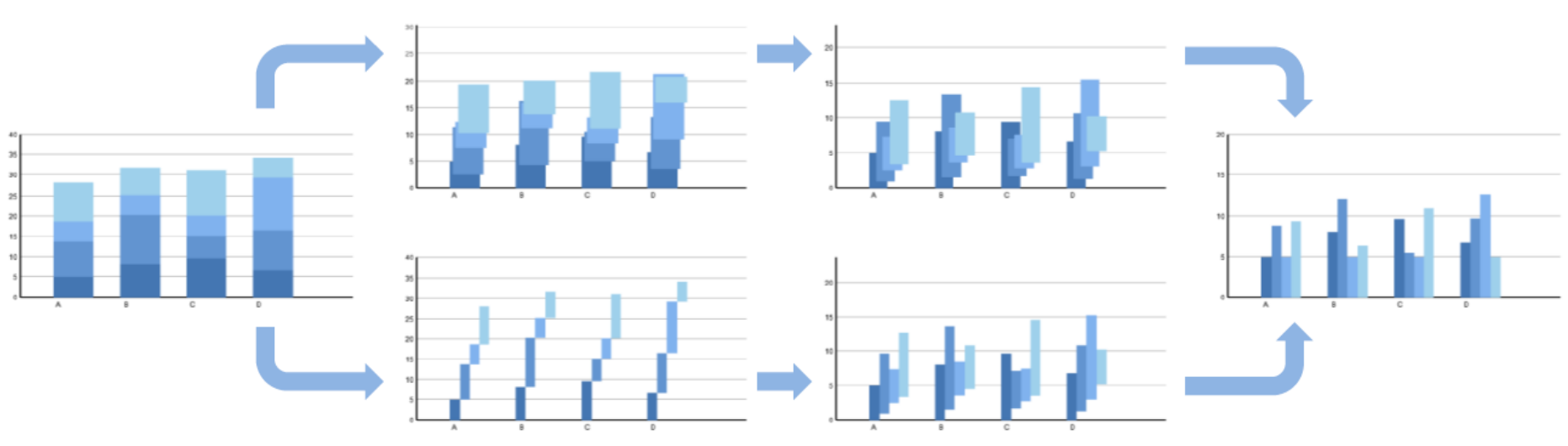
Highlight Ohio

Visualization Software



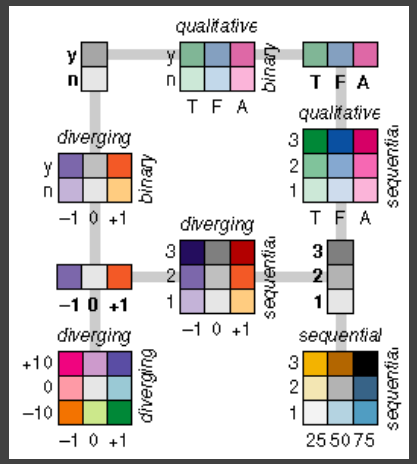
D3: Data-Driven Documents

Animation

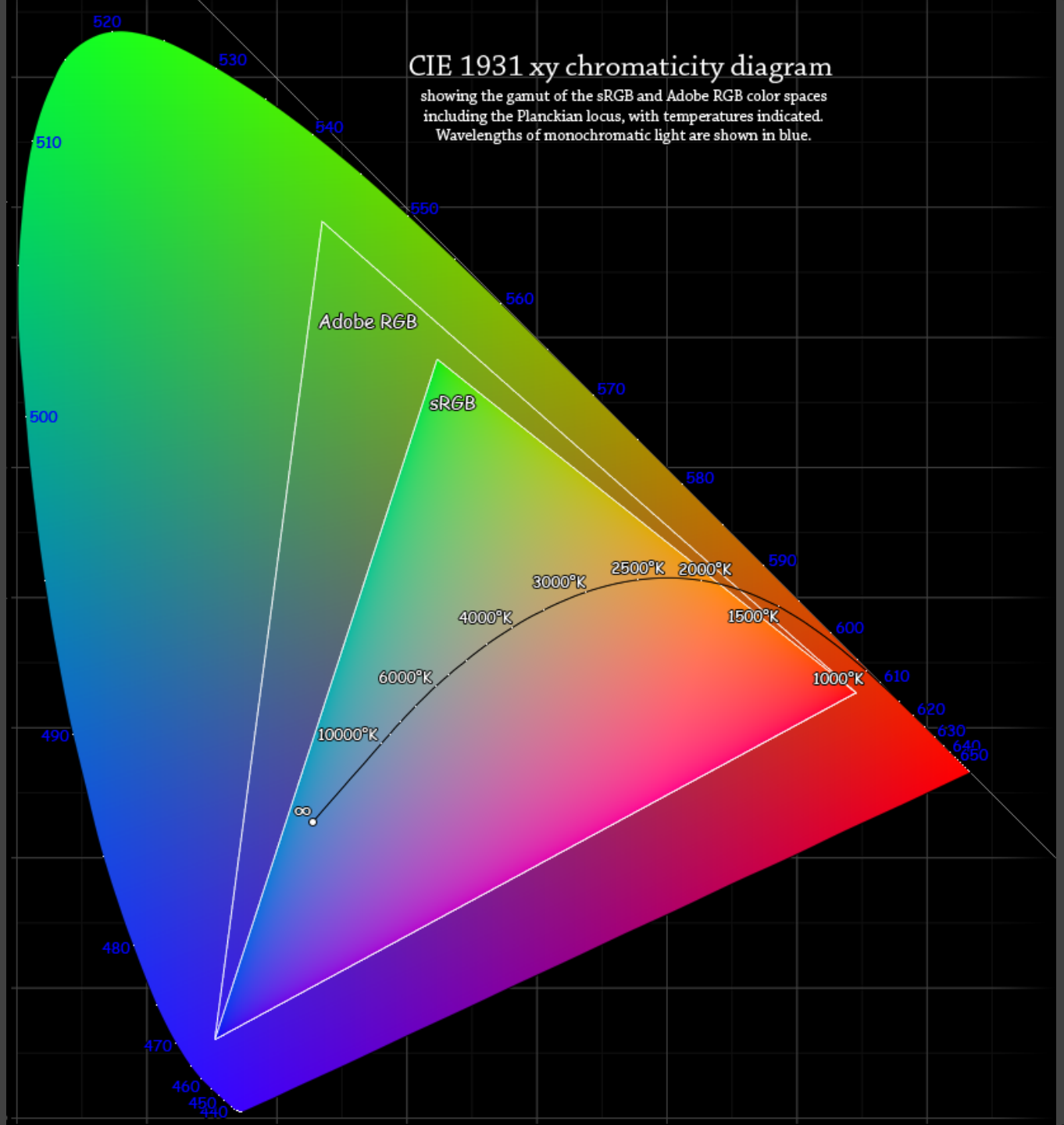


Animated transitions in statistical data graphics [Heer & Robertson 07]

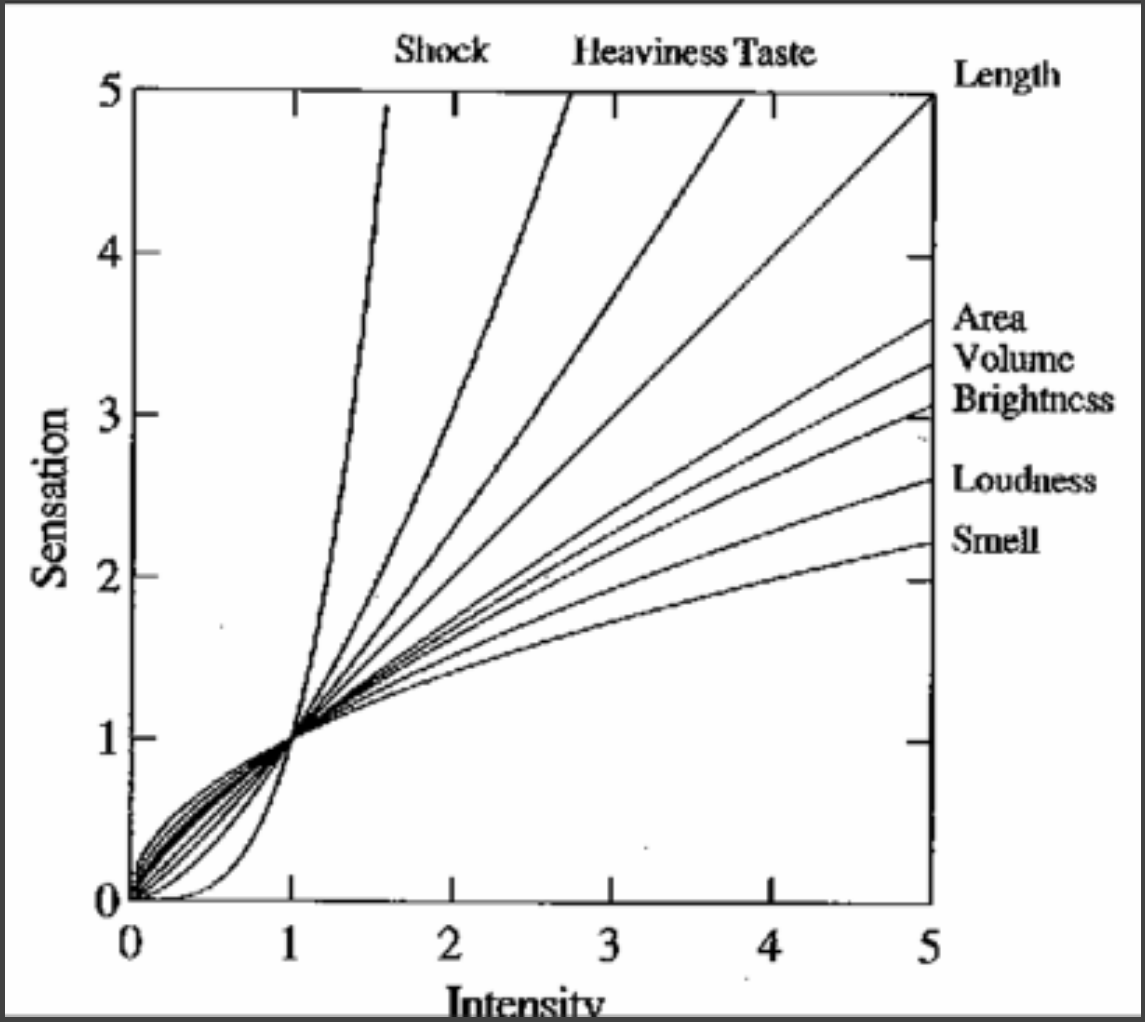
Color



Color Brewer

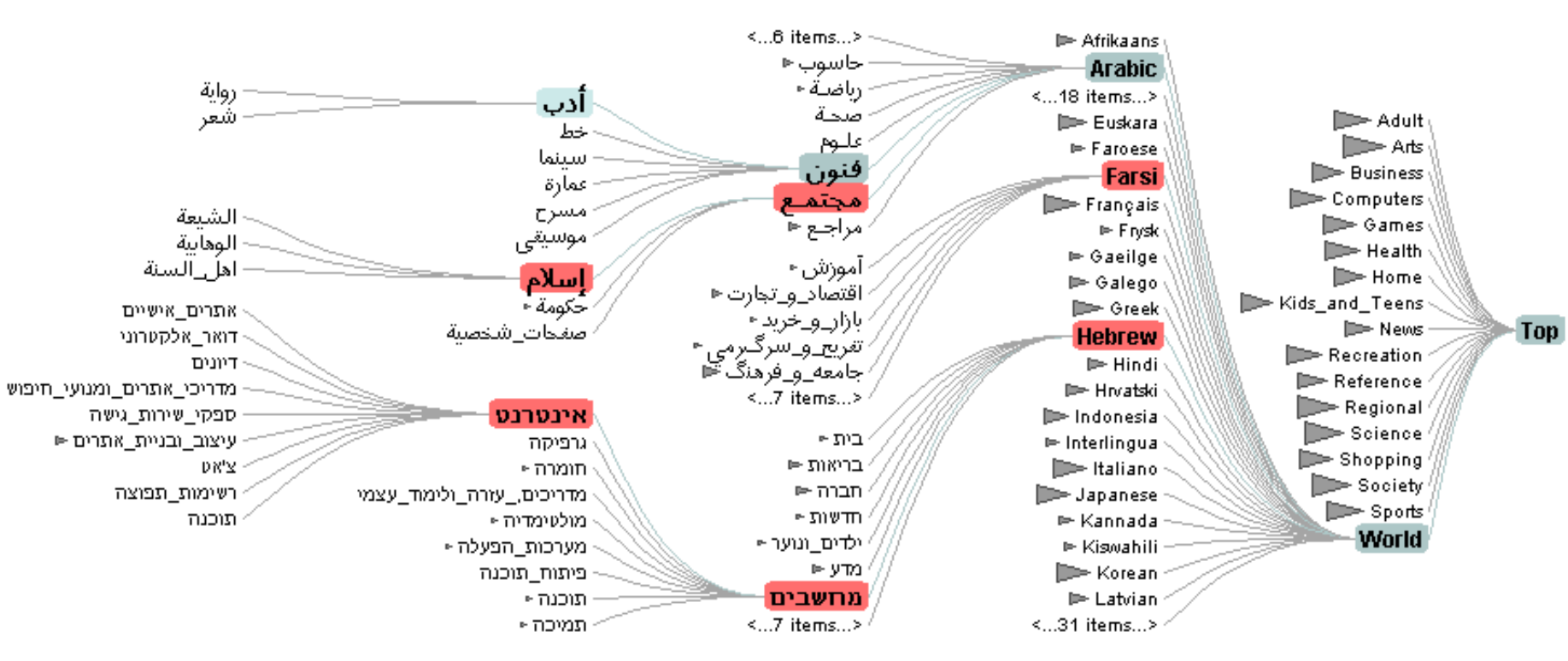


Graphical Perception



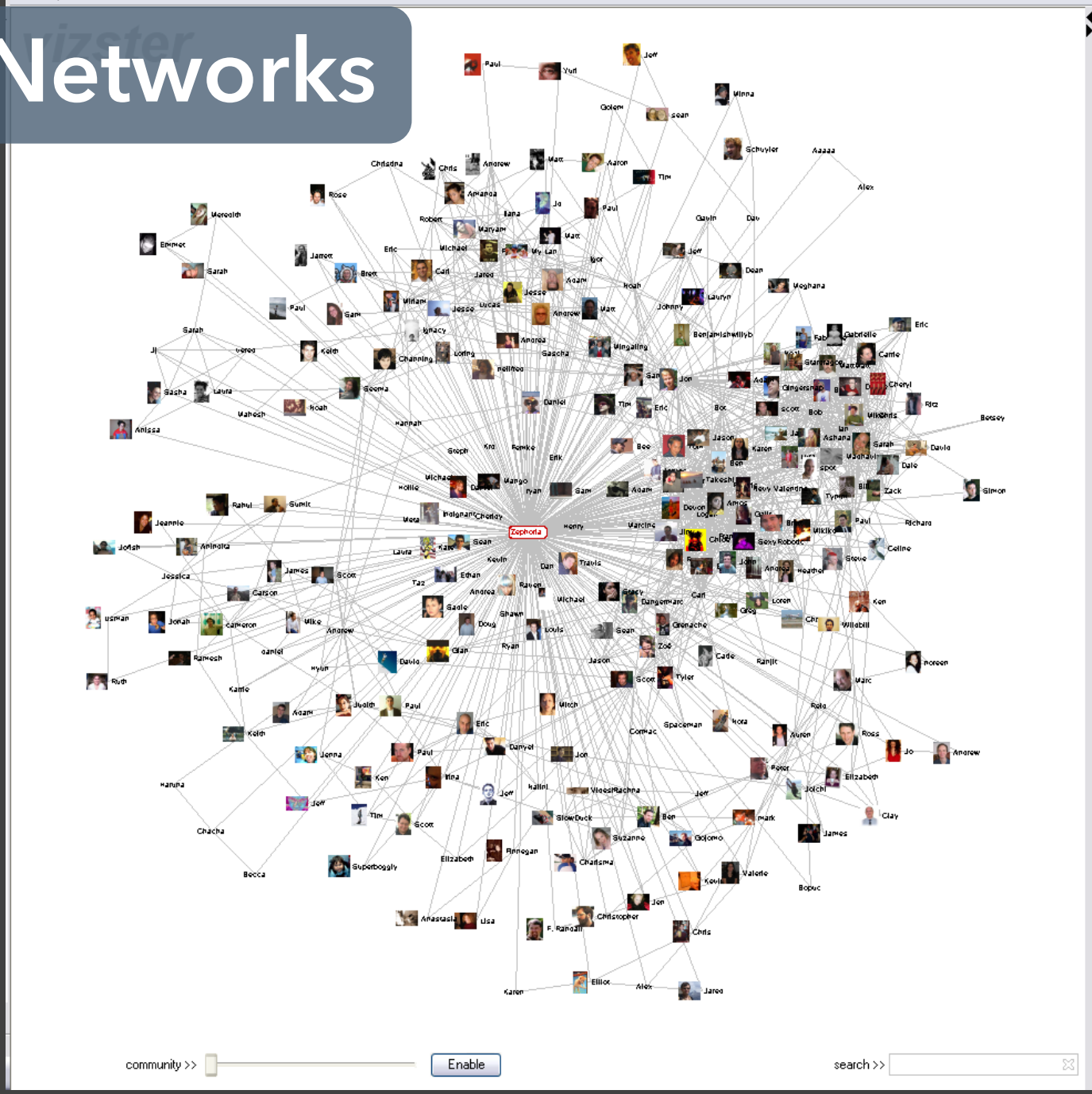
The psychophysics of sensory function [Stevens 61]

Hierarchies



Degree-Of-Interest Trees [Heer & Card 04]

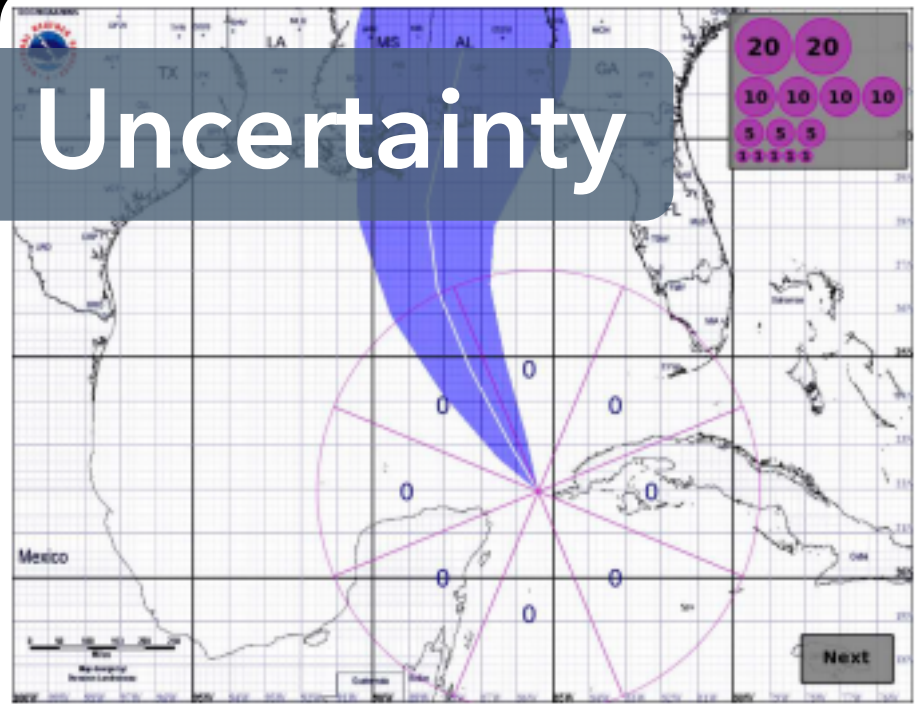
Networks

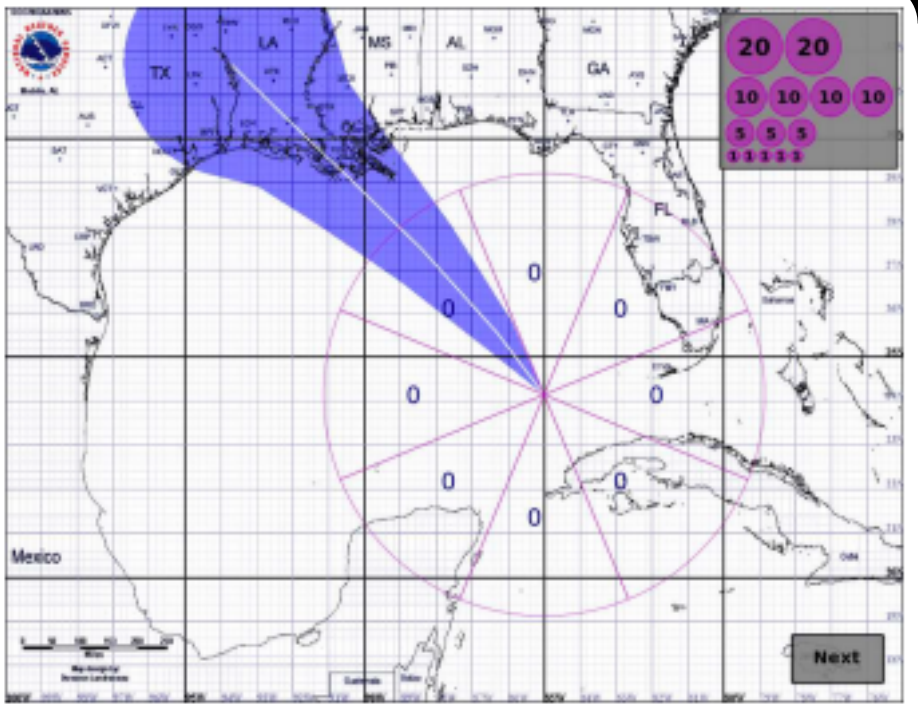


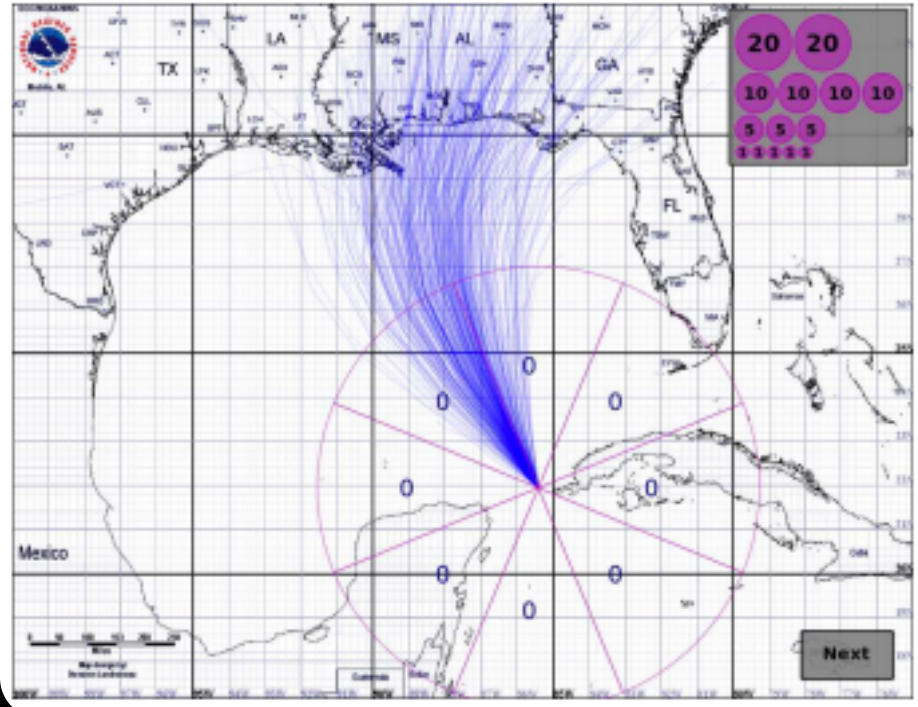
Zephoria

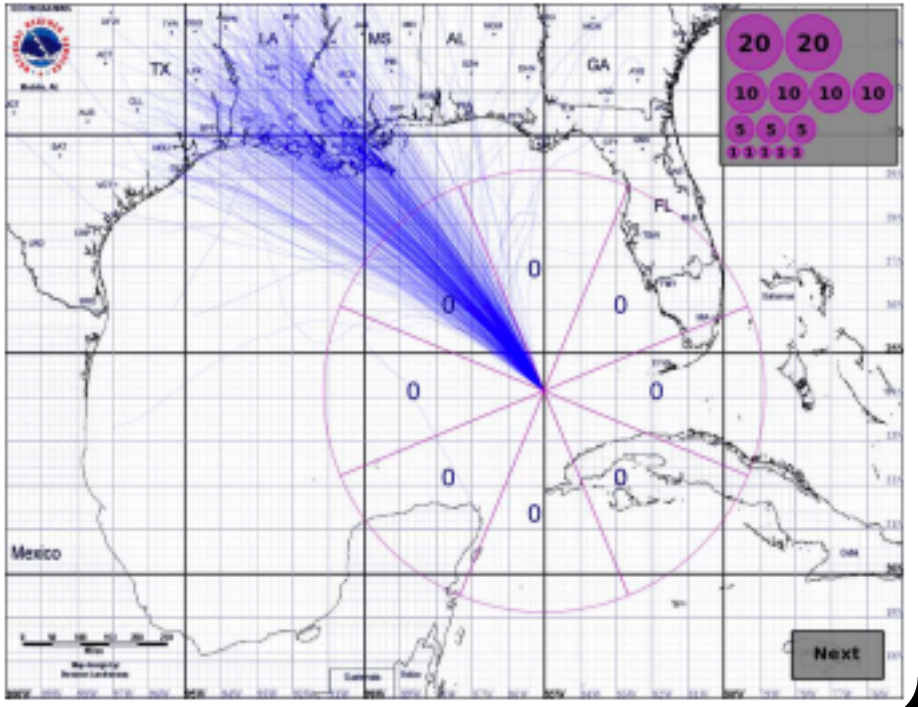
User ID	21721
Friends	266
Age	??
Gender	Female
Status	Single
Location	San Francisco, CA
Hometown	Lancaster, PA
Occupation	researcher: social networks, identity, context
Interests	apophenia, observing people, culture, questioning power, reading, buddhism, ipseity, computer-mediated communication, social networks, technology, anthropology, stomping
Music	psytrance/goa/trance [Infected Mushroom, Son Kite... Iboga/Digital Structures], Ani Difranco, downtempo, Thievery Corporation, Beth Orton, Morcheeba, Ween, White Stripes
Books	Authors: Erving Goffman, Stanley Milgram, Jeanette Winterson, Eric Schlosser, Leslie Feinberg, Dorothy Allison, Italo Calvino, Hermann Hesse
TV Shows	??
Movies	Koyaanisqatsi, Amelie, Waking Life, Tank Girl, The Matrix, Clockwork Orange, American Beauty, Fight Club, Boys Don't Cry
Member Since	??
Last Login	2003-10-21
Last Updated	2003-10-21
About	[Some know me as danah...] I'm a geek, an activist and an academic, fascinated by people and society. I see life as a very large playground and enjoy exploring its intricacies. I revel in life's chaos, while simultaneously providing my own insane element. My musings: http://www.zephoria.org/thoughts/
Want to Meet	Someone who makes life's complexities seem simply elegant.

Uncertainty









Scalability

1.7 B stars. 1.2 TB of data.
Visualizations running in-browser.

Powered by Falcon 0.13.0

The Future of Visualization

Where is more work required?

What emerging technologies and societal trends will impact visualization design?

What did you find most difficult in creating visualizations and designing techniques?

Thank You!