Interaction

CS 7450 - Information Visualization
September 26, 2016
John Stasko

Learning Objectives

- Understand how interaction can be used to address fundamental challenges in infovis that cannot be handled through representation
- List and give examples from 7 interaction categories of Yi's framework
  - Explain how each is employed for analytic benefit
- Describe the following types of interaction and how each is used
  - Drill down, Generalized selection, Details on demand, Filtering, Faceted browsing, Brushing histograms, Magic lenses
- Explain what dynamic queries are, and list their benefits as well as their limitations/weaknesses
- Explain what brushing & linking is
- Describe different ways that animation is used for benefit
- Give examples of systems/techniques where interaction is fundamental and vital to the technique
- Understand challenges in moving from keyboard/mouse to finger/pen touch interaction

Interaction?

- What do you mean by "interaction"?

Background

- Interaction (HCI)
  = "The communication between user and the system" [Dix et al., 1998]
  = "Direct manipulation and instantaneous change" [Becker et al., 1987]

  "HCI research is far from having solid (and falsifiable) theories of interaction"
  [Beaudouin-Lafon, 2004]

Clarifying…

Interaction

Being interactive, not static

Interaction

Communication, analytic discourse

Main Components

"The effectiveness of information visualization hinges on two things: its ability to clearly and accurately represent information and our ability to interact with it to figure out what the information means."

S. Few
Now You See It, p. 55

"Little Brother"

- Two main components in an infovis
  - Representation
  - Interaction

- Representation gets all the attention
- Interaction is where the action is (no pun intended)

Research Focus

- Very challenging to come up with innovative, new visual representations
- But can do interesting work with how user interacts with the view or views
  - It's what distinguishes infovis from static visual representations on paper
- Analysis is a process, often iterative with branches and side bars

Fundamentally

- For larger data, there is simply too much to show in a coherent manner
- Interaction helps us address that challenge

Interaction

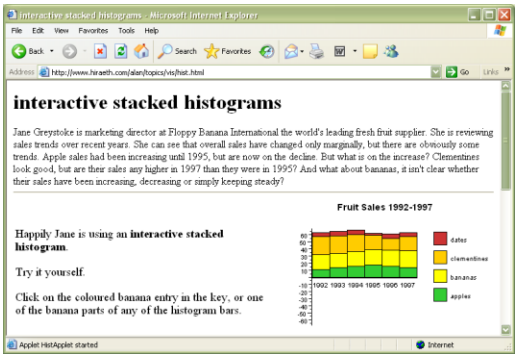
- How do you define "interactive"?

Response Time

- .1 sec
  - animation, visual continuity, sliders
- 1 sec
  - system response, conversation break
- 10 sec
  - cognitive response

Example

Even simple interaction can be quite powerful



Stacked histogram

http://www.hiraeth.com/alan/topics/vis/hist.html

Pause

- Mini-exercise in pairs:
  - List the different "categories" of interaction in information visualization

Interactions (from class)

- Filtering
- Hover
- Sorting
- Zooming
  - Including semantic
- Aggregation
- Highlighting
- Expand/collapse
- Connecting
- Drag & drop
- Changing granularity
- Searching
- Exploring
- Touching
- Hyperlinks
- Feedback
- Scrolling
- Updating
- Timescaling
- Animation
- Keyboard shortcuts
- Drawing

Interaction Types

- Dix and Ellis (AVI '98) propose
  - Highlighting and focus
  - Accessing extra info – drill down and hyperlinks
  - Overview and context – zooming and fisheyes
  - Same representation, changing parameters
  - Linking representations – temporal fusion

Interaction Types

- Keim's taxonomy (TVCG '02) includes
  - Projection
  - Filtering
  - Zooming
  - Distortion
  - Linking and brushing

Another Taxonomy

- Operator
  - navigation, selection, manipulation, distortion, filtering
- Space of interaction
  - screen, data value, data structure, attribute, object, visualization structure
- Parameters of the interaction operator
  - focus, extents, transformation, blender

Ward, Grinstein, & Keim 2010, chapter 10

Few's Principles

- Especially useful ways of interacting with data

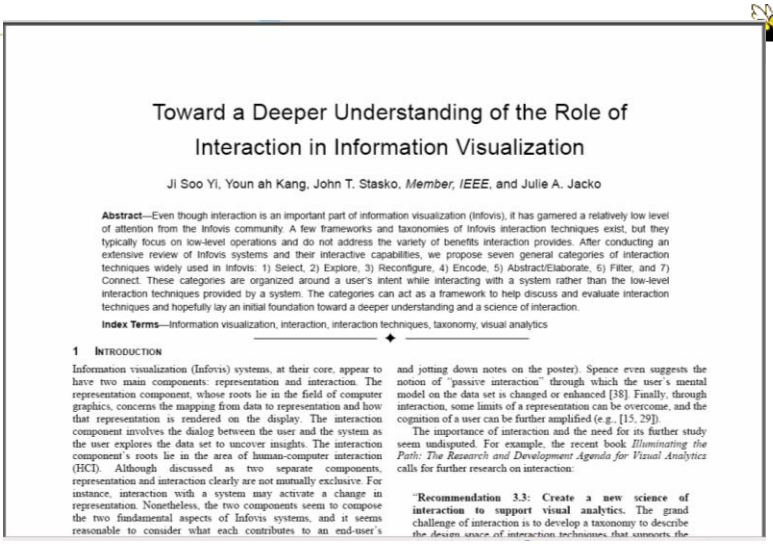
Comparing
Sorting
Adding variables
Filtering
Highlighting
Aggregating
Re-expressing
Re-visualizing
Zooming and panning
Re-scaling
Accessing details on demand
Annotating
Bookmarking

Now You See It Chapter 4

Challenging

- Interaction seems to be a difficult thing to pin down and characterize
- Let's go back to the user trying to solve problems…
  - User-centered versus system-centered characterizations

Another take



Toward a Deeper Understanding of the Role of Interaction in Information Visualization

Ji Soo Yi, Youn ah Kang, John T. Stasko, *Member, IEEE*, and Julie A. Jacko

Abstract—Even though interaction is an important part of information visualization (Infovis), it has garnered a relatively low level of attention from the Infovis community. A few frameworks and taxonomies of Infovis interaction techniques exist, but they typically focus on low-level operations and do not address the variety of benefits interaction provides. After conducting an extensive review of Infovis systems and their interactive capabilities, we propose seven general categories of interaction techniques widely used in Infovis: 1) Select, 2) Explore, 3) Reconfigure, 4) Encode, 5) Abstract/Elaborate, 6) Filter, and 7) Connect. These categories are organized around a user's intent while interacting with a system rather than the low-level interaction techniques provided by a system. The categories can act as a framework to help discuss and evaluate interaction techniques and hopefully lay an initial foundation toward a deeper understanding and a science of interaction.

Index Terms—Information visualization, interaction, interaction techniques, taxonomy, visual analytics

1 Introduction

Information visualization (Infovis) systems, at their core, appear to have two main components: representation and interaction. The representation component, whose roots lie in the field of computer graphics, concerns the mapping from data to representation and how that representation is rendered on the display. The interaction component involves the dialog between the user and the system as the user explores the data set to uncover insights. The interaction component's roots lie in the area of human-computer interaction (HCI). Although discussed as two separate components, representation and interaction clearly are not mutually exclusive. For instance, interaction with a system may activate a change in representation. Nonetheless, the two components seem to compose the two fundamental aspects of Infovis systems, and it seems reasonable to consider what each contributes to an end-user's and jotting down notes on the poster). Spence even suggests the notion of "passive interaction" through which the user's mental model on the data set is changed or enhanced [38]. Finally, through interaction, some limits of a representation can be overcome, and the cognition of a user can be further amplified (e.g., [15, 29]).

The importance of interaction and the need for its further study seem undisputed. For example, the recent book *Illuminating the Path: The Research and Development Agenda for Visual Analytics* calls for further research on interaction:

"**Recommendation 3.3: Create a new science of interaction to support visual analytics.** The grand challenge of interaction is to develop a taxonomy to describe the design space of interaction techniques that supports the

IEEE TVCG 13(6), '07

Study Methodology

- Survey
  - 59 papers
    - Papers introducing new interaction systems
    - Well-known papers in subareas of Infovis
  - 51 systems
    - Commercial Infovis Systems (SeeIT, Spotfire, TableLens, InfoZoom, etc.)
  - Collected 311 individual interaction techniques
- Affinity Diagram Method

Focus Emerged

User intent

"What a user wants to achieve through a specific interaction technique"

Main Idea

- Don't focus so much on particular interactive operations and how they work
- Interaction is ultimately being done by a person for a purpose
  - Seeking more information, solving a problem
  - Fundamental aspect of exploratory, analytic discourse

Results

7 categories

Select
Explore
Reconfigure
Encode
Abstract/Elaborate
Filter
Connect

1. Select

"Mark something as interesting"

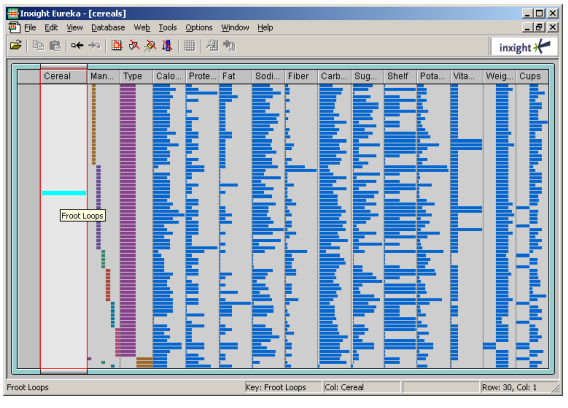
- Mark items of interest to keep track
- Seems to often work as a preceding action to subsequent operations.

e.g.,

- Selecting a placemark in Google Map
- The Focus feature in TableLens

Pop-up tooltips

- Hovering mouse cursor brings up details of item

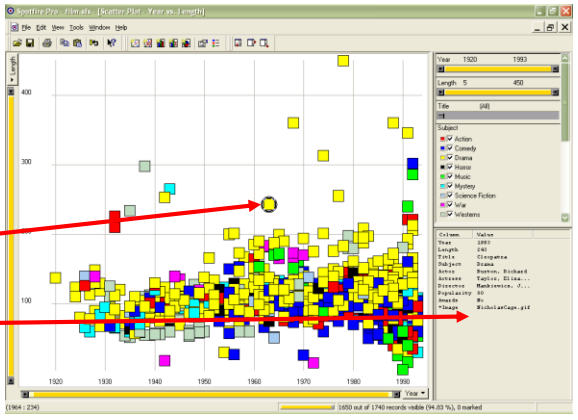


Mouse Selection

Clicking on an item selects it and attributes of the data point are shown

Selected item

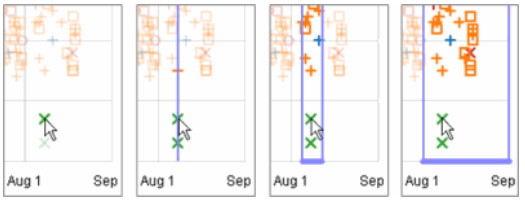
Attributes



Generalized Selection

- When you click on an item in a visualization, can we generalize the selection off the precise item?
  - Maybe you want to select items matching some attribute(s) of that item

Query Relaxation



As you dwell on your mouse pick, the selection criteria broaden and you can choose sets of items

Video

Heer, Agrawala, Willett
CHI '08

2. Explore

"Show me something different"

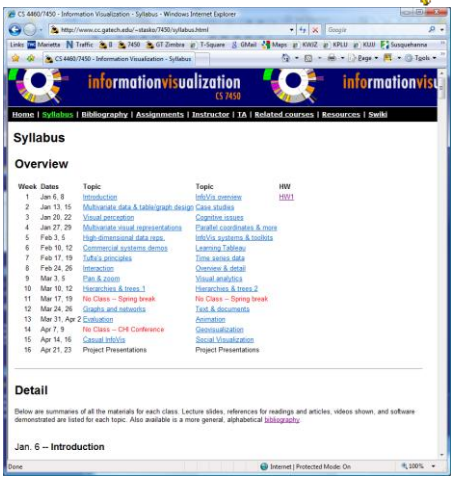
- Enable users to examine a different subset of data
- Overcome the limitation of display size

e.g.,

- Panning in Google Earth
- Direct Walking in Visual Thesaurus

Direct Walk

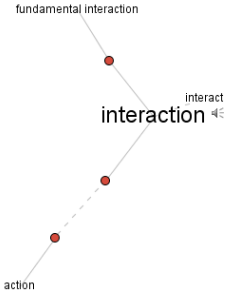
- Linkages between cases
- Exploring one may lead to another
- Example:
  - Following hyperlinks on web pages



Example

http://www.visualthesaurus.com

Visual Thesaurus



3. Reconfigure

"Show me a different arrangement"

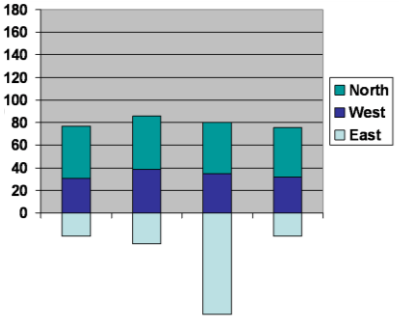
- Provide different perspectives by changing the spatial arrangement of representation

e.g.,
- Sorting and rearranging columns in TableLens
- Changing the attributes in a scatter plot
- The baseline adjustment feature in Stacked Histogram
- The "Spread Dust" feature in Dust & Magnet

Rearrange View

- Keep same fundamental representation and what data is being shown, but rearrange elements
  - Alter positioning
  - Sort

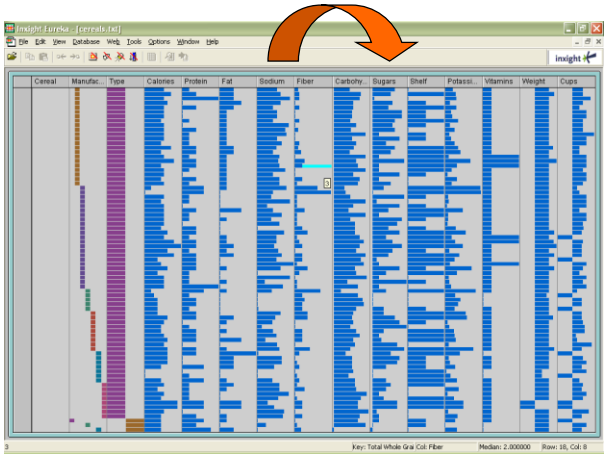
Example



Stacked Histogram

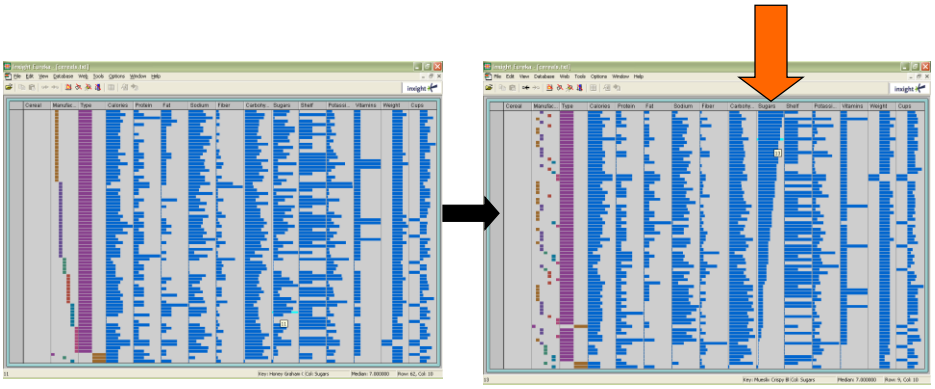
Rearrange

In TableLens you can move columns (attributes) left and right



Sorting

Can sort data with respect to a particular attribute in Table Lens



4. Encode

"Show me a different representation"

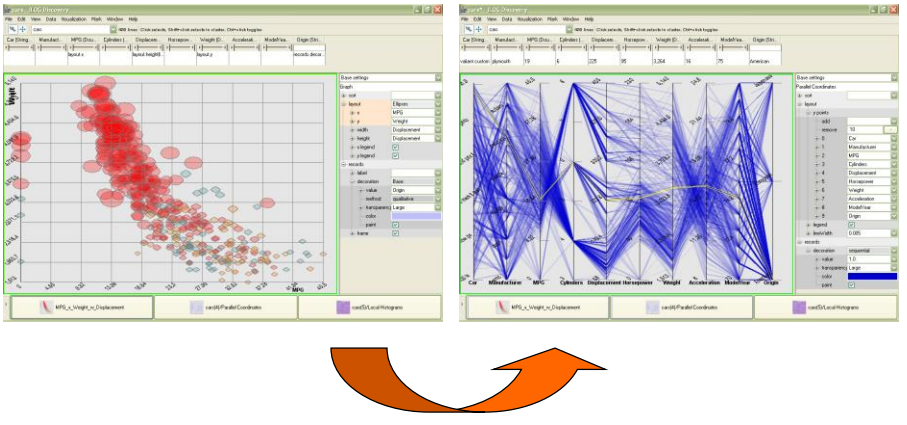
- Change visual appearances

e.g.,
- Changing color encoding
- Changing size
- Changing orientation
- Changing font
- Changing shape

Changing Representation

- May interactively change entire data representation
  - Looking for new perspective
  - Limited real estate may force change

Example



Selecting different representation from options at bottom

5. Abstract/Elaborate

"Show me more or less detail"

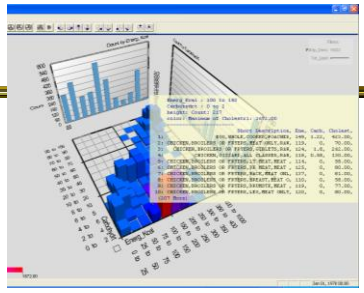
- Adjust the level of abstraction (overview and details)

e.g.,
- Unfolding sub-categories in an interactive pie chart
- Drill-down in Treemap
- Details-on-demand in Sunburst
- The tool-tip operation in SeeIT
- Zooming (geometric zooming)

Details-on-Demand

- Term used in infovis when providing viewer with more information/details about data case or cases
- May just be more info about a case
- May be moving from aggregation view to individual view
  - May not be showing all the data due to scale problem
  - May be showing some abstraction of groups of elements
  - Expand set of data to show more details, perhaps individual cases

Examples



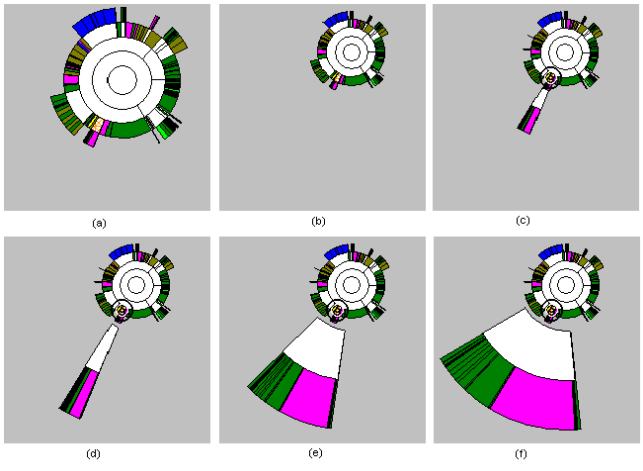
SeeIT

Google Earth

Table Lens

Example

Animated SunBurst



6. Filter

"Show me something conditionally"

- Change the set of data items being presented based on some specific conditions.

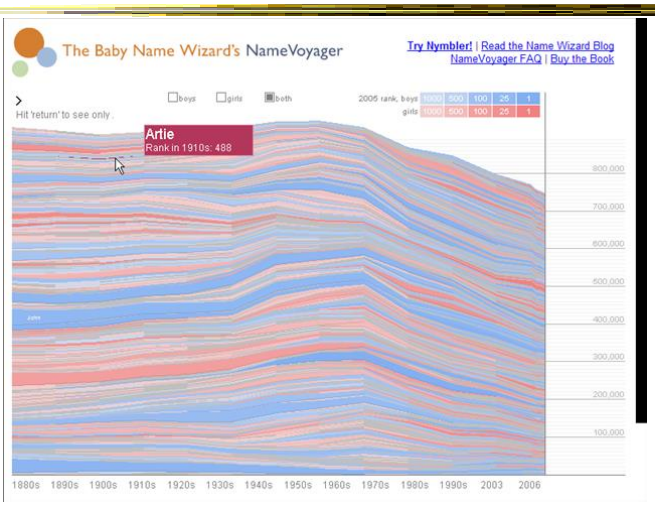
e.g.,
- Dynamic query
- Attribute Explorer
- Keystoke based filtering in NameVoyager
- QuerySketch

Filtering/Limiting

- Fundamental interactive operation in infovis is changing the set of data cases being presented
  - Focusing
  - Narrowing/widening

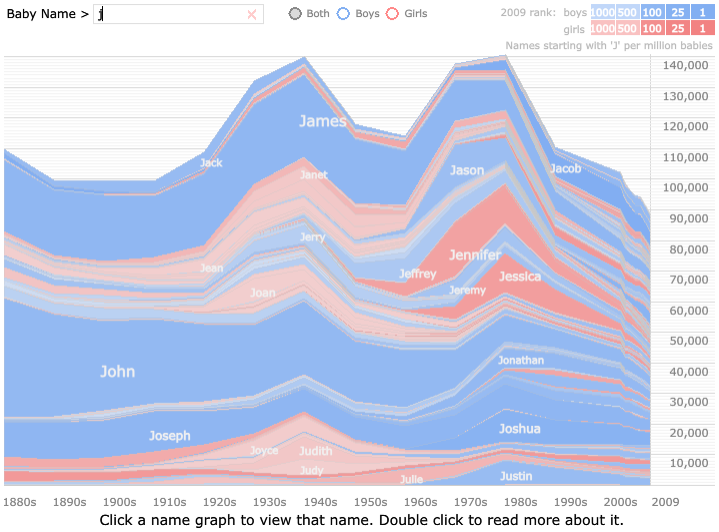
Example

NameVoyager



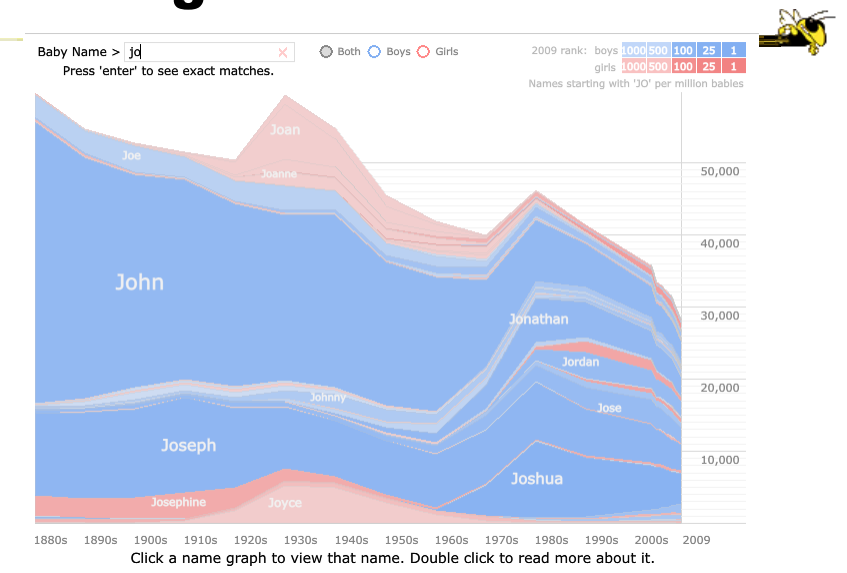
http://www.babynamewizard.com/namevoyager.html/

Filtering

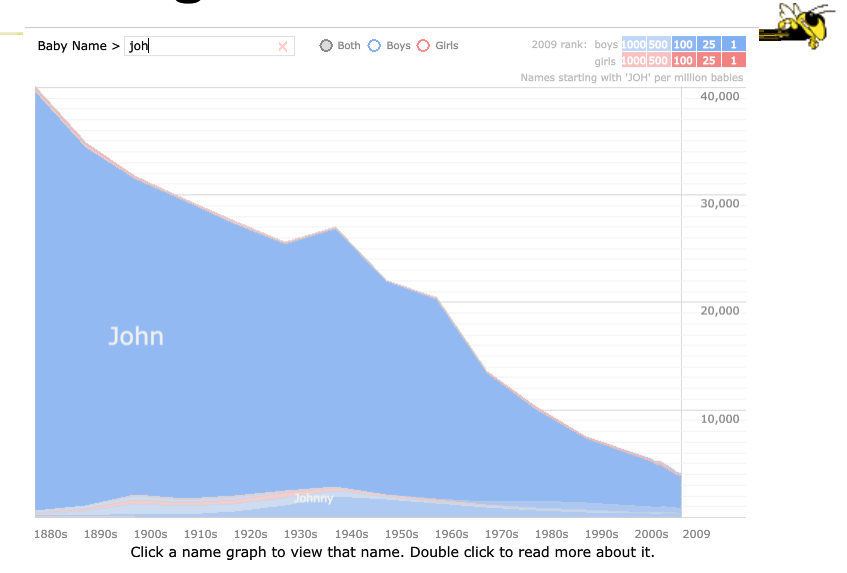


Click a name graph to view that name. Double click to read more about it.

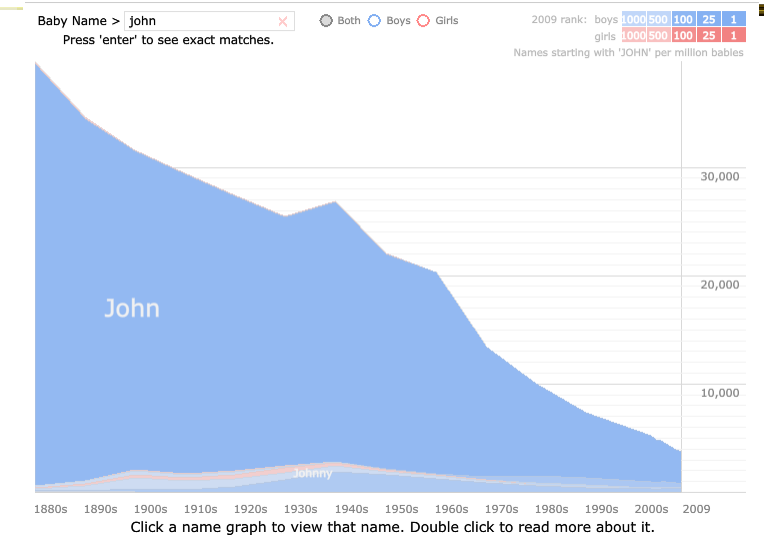
Filtering



Filtering



Filtering



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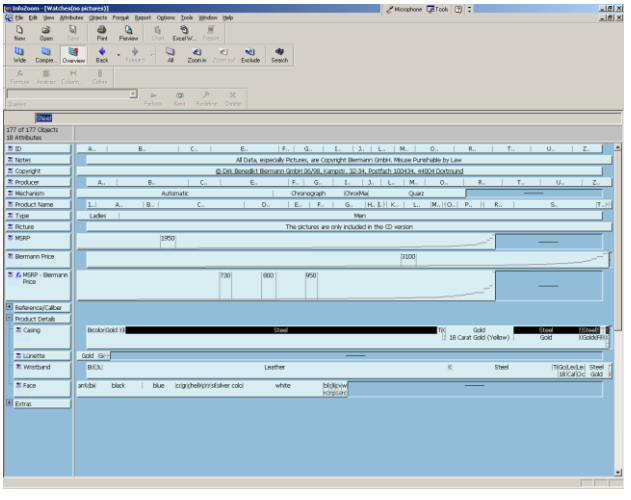
Example



InfoZoom

Example

- Faceted metadata
  - Attributes of datasets are grouped into multiple orthogonal categories
  - Selecting a value from one filters on that value and updates the items in other categories
  - User explores data collection by series of selections

FacetMap

Video

Smith et al
TVCG '06

Dynamic Query

- Probably best-known and one of most useful infovis techniques
- Let's explore more details...

DB Queries

- Query language
  - **Select** house-address
    From atl-realty-db
    Where price >= 200,000 **and**
    price <= 400,000 **and**
    bathrooms >= 3 **and**
    garage == 2 **and**
    bedrooms >= 4

DB Queries

- Pros?
  - Powerful, flexible
- Cons?

Typical Query Response

- 124 hits found
  - 1. 748 Oak St. - a beautiful …
  - 2. 623 Pine Ave. -
  - …
- 0 hits found

Further Cons

- Must learn language
- Only shows exact matches
- Don't know magnitude of results
- No helpful context is shown
- Reformulating to a new query can be slow
- …

Dynamic Query

- Specifying a query brings immediate display of results
- Responsive interaction (< .1 sec) with data, concurrent presentation of solution
- "Fly through the data", promote exploration, make it a much more "live" experience
  - Timesharing vs. batch

Dynamic Query Constituents

- Visual representation of world of action including both the objects and actions
- Rapid, incremental and reversible actions
- Selection by pointing (not typing)
- Immediate and continuous display of results

Shneiderman
IEEE Software '94

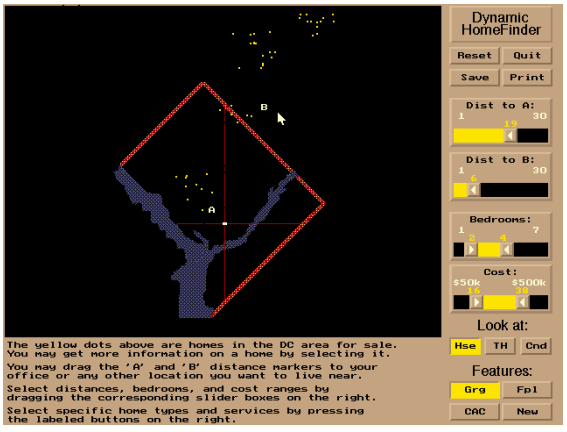
Ahlberg & Shneiderman
CHI '94

Imperfection

- Idea at heart of Dynamic Query
  - There often simply isn't one perfect response to a query
  - Want to understand a set of tradeoffs and choose some "best" compromise
  - You may learn more about your problem as you explore

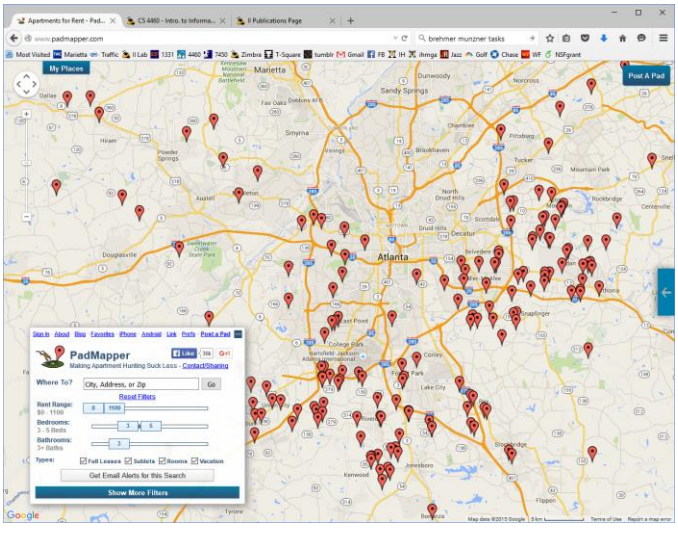
DQ Examples

- HomeFinder - Univ. of Maryland



http://www.padmapper.com

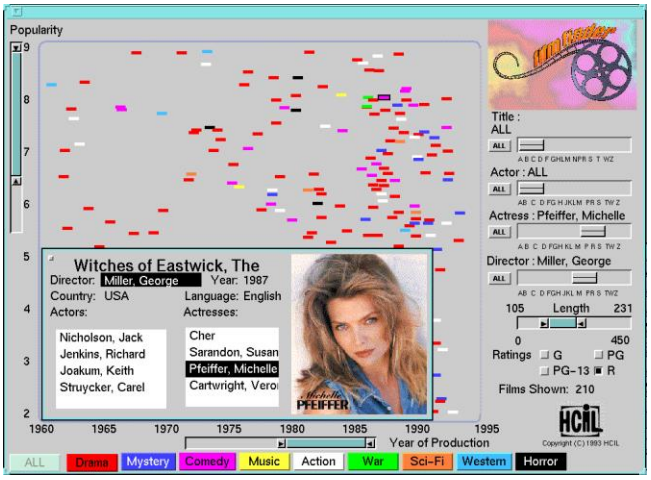
PadMapper



FilmFinder

C. Ahlberg
Maryland

Video



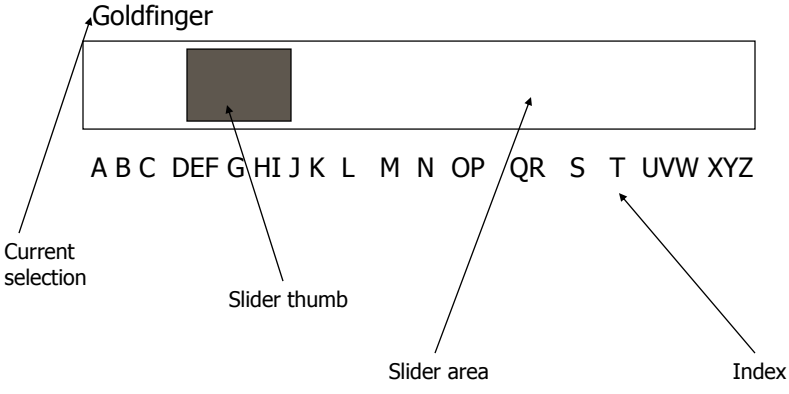
What Do They Show?

- Interface
  - buttons
  - sliders (nominal --> ordinal)
  - alphasliders

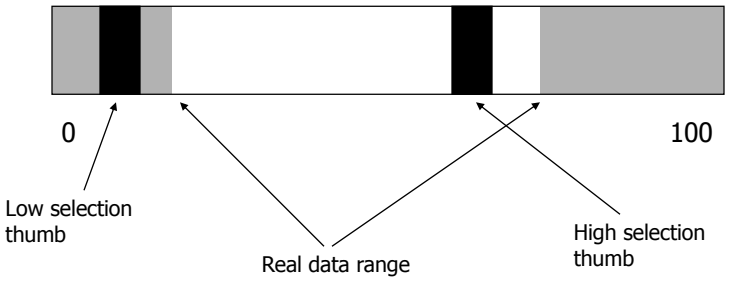
Query Controls

- Variable types
  - Binary nominal - Buttons
  - Nominal with low cardinality - Radio buttons
  - Ordinal, quantitative - sliders

Alphaslider

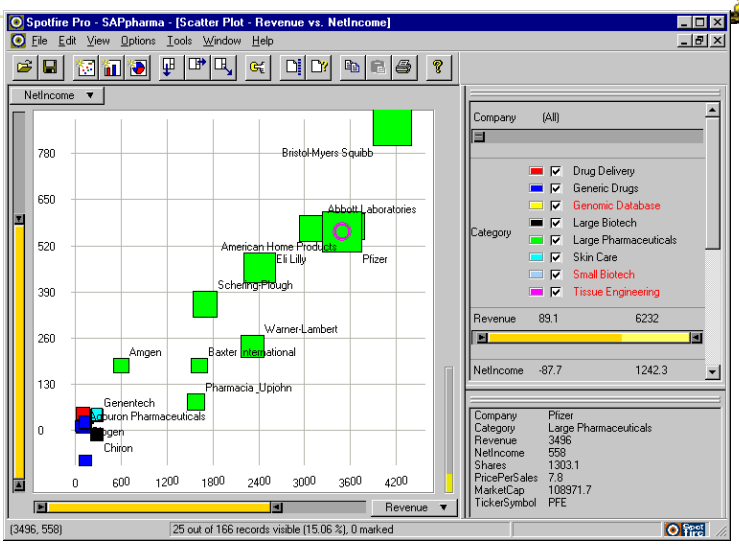


Rangeslider



Spotfire

(old version)

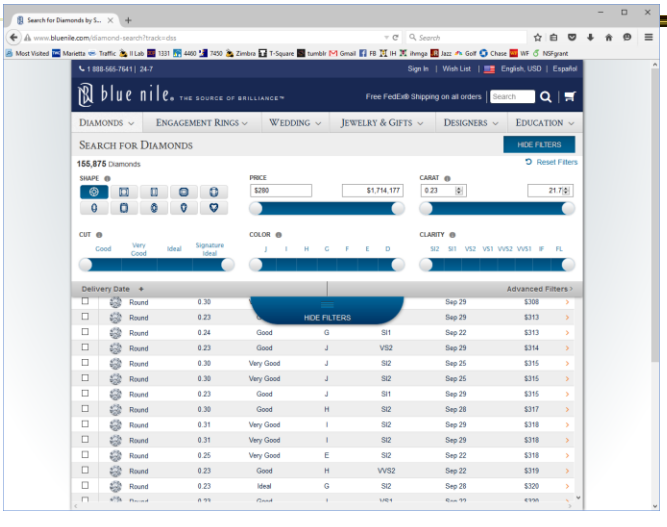


Spotfire Features

- Starfield display
- Tight coupling
  - features to guide the user
  - rapid, incremental, reversible interactions
  - display invariants
  - continuous display
  - progressive refinement
  - details on demand

An Example

Note quite DQ though



http://www.bluenile.com/diamond-search?track=dss

DQ Pros

- ?

DQ Pros

- Work is faster
- Promote reversing, undo, exploration
- Very natural interaction
- Shows the data

DQ Cons

- ?

DQ Cons

- Operations are fundamentally conjunctive
- Can you formulate an arbitrary boolean expression?
  - !(A1 V A2) ^ A3 V (A4 V A5 ^ A6) V …
- But do people really do this often?

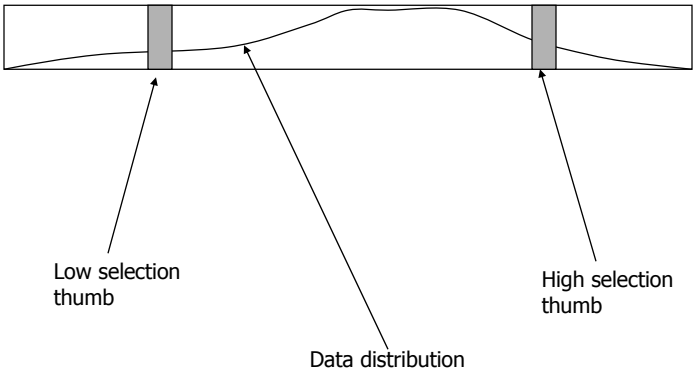
DQ Cons

- Controls are global in scope
  - They affect everything
- Controls must be fixed in advance

DQ Cons

- Controls take space!
  - How much in Spotfire?
- Put data in controls...

Data Visualization Sliders



Eick
UIST '94

DQ Cons

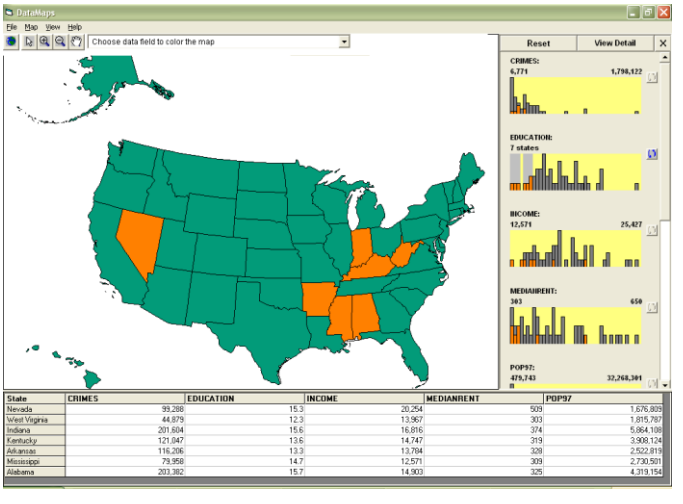
- As data set gets larger, real-time interaction becomes increasingly difficult
- Storage - Data structures
  - linear array
  - grid file
  - quad, k-d trees
  - bit vectors

Tanin et al
InfoVis '97

Brushing Histograms

- Special case of brushing
- Data values represented in histograms that can be clicked on and selected (controls region)
- When items selected there, the corresponding item(s) are highlighted in main view windows

BH Example



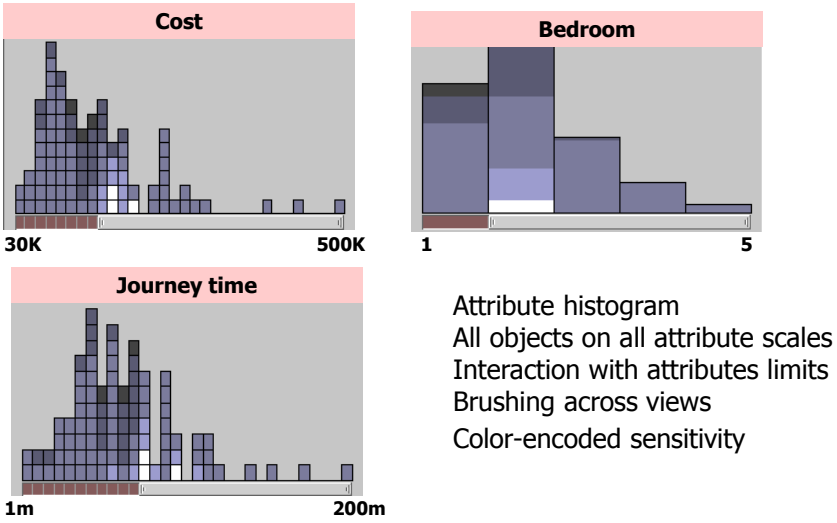
DataMaps

Maryland
&
Va Tech

Demo

Attribute Explorer

Spence & Tweedie
Inter w Computers '98

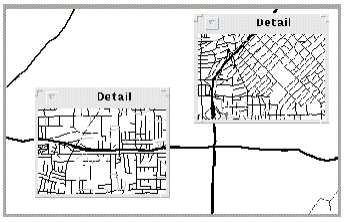


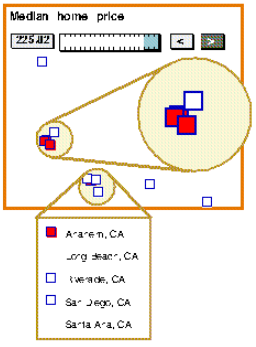
Attribute histogram
All objects on all attribute scales
Interaction with attributes limits
Brushing across views
Color-encoded sensitivity

DQ Disadvantage

- Operations are global in scope
- Can we do something to fix that…?

Magic Lenses





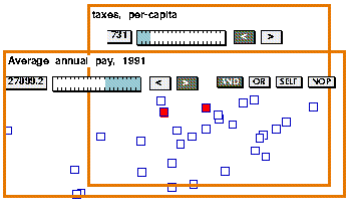


Figure 1(a) High salaries AND low taxes.

Video

Fishkin & Stone
CHI '95

7. Connect

"Show me related items"

- Highlight associations and relationships
- Show hidden data items that are relevant to a specified item

e.g.,

- Highlighting directly connected nodes in Vizster
- Brushing in InfoScope

Highlighting Connections

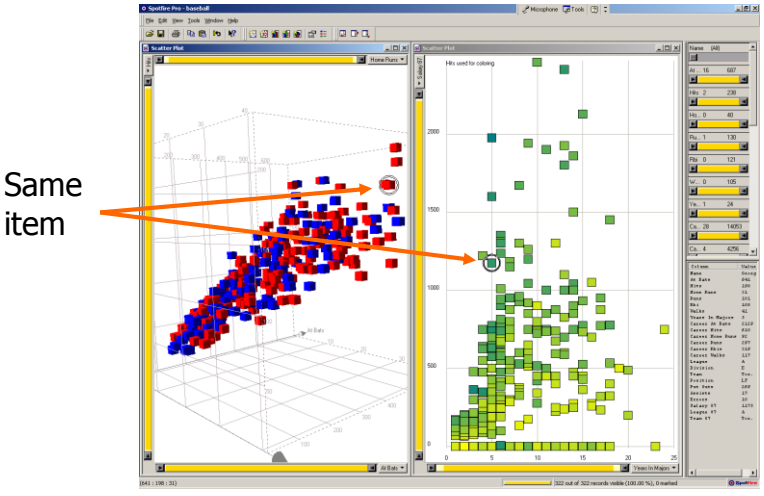
- Viewer may wish to examine different attributes of a data case simultaneously
- Alternatively, viewer may wish to view data case under different perspectives or representations

- But need to keep straight where the data case is

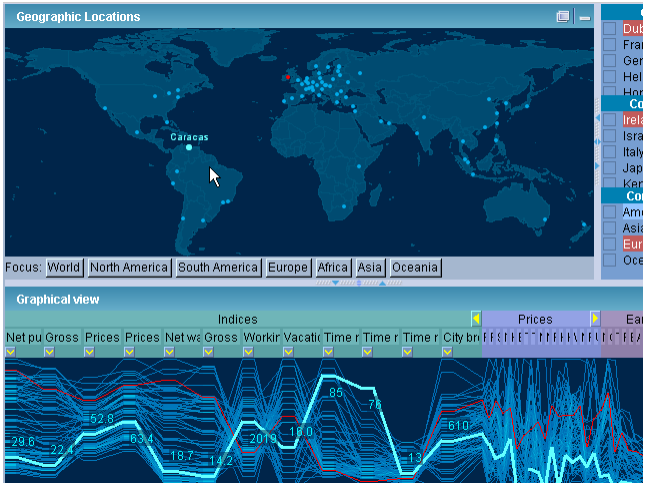
Brushing

- Applies when you have multiple views of the same data
- Selecting or highlighting a case in one view generates highlighting the case in the other views
- Very common technique in InfoVis

Brushing



Example



InfoScope

Interaction Characteristics

- Fluidity a key
  - Promotes "flow"
    - Balanced challenge
    - Concentration
    - Loss of self-consciousness
    - Transformation of time
    - Prompt feedback
    - Sense of control
    - Intrinsically rewarding
  - Supports direct manipulation
  - Minimizes the gulfs of action

Elmqvist et al
Information Visualization '11


Fluid interaction for information visualization

Fluidity Design Guidelines

- Use smooth animated transitions between states
- Provide immediate visual feedback on interaction
- Minimize indirection in the interface
- Integrate user interface components in the visual representation
- Reward interaction
- Ensure that interaction never 'ends'
- Reinforce a clear conceptual model
- Avoid explicit mode changes

Animation for Transitions

- Principles
  - Animation can help "soften the blow" when a view changes
  - Preserve context, allow the viewer to track where things went
- Project overview
  - Developed variety of different transitions and applications
  - Performed experiments to see how these are perceived

Heer & Robertson
TVCG (InfoVis) '07

Transition Types

- View transformation
- Substrate transformation
- Filtering
- Ordering
- Timestep
- Visualization change
- Data schema change

Key Component

- Staging
  - Animation proceeds in stages, not all at once
  - Varies by animation type and view

DynaVis

- Implemented in C# and Direct3D graphics
- Let's see it!

Video

OK

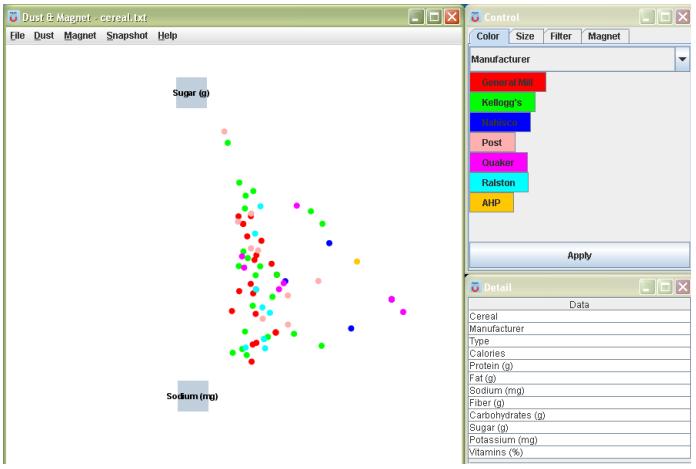
- Let's take a step back and think about representation & interaction again

Supporting Representation

- Interaction in many cases is vital to representation
  - Provides useful perspective
    - Many, many examples:
    - Parallel coords, InfoZoom, anything 3D
  - Necessary for clarifying representation
    - Dust & Magnet

Dust & Magnet

Must interact to gain any value

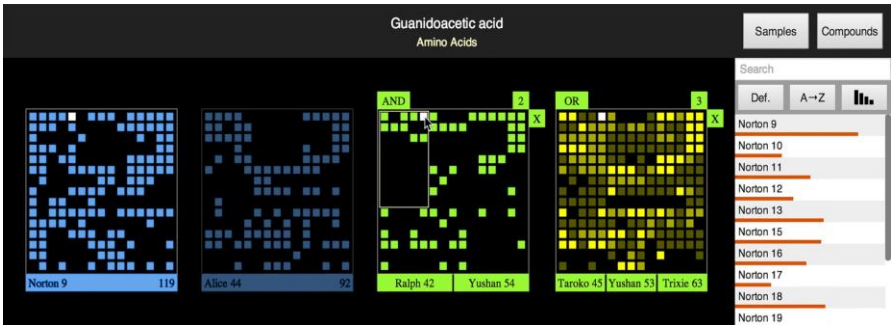


Demo

Yi et al
Information Visualization '05

OnSet

Perform union & intersection via interaction



Represent set as a box, elements are spots in that box
Use interaction to do set union, intersection

Sadana, Major, Dove & Stasko
TVCG (InfoVis) '14

Moving Past WIMP

- WIMP metaphor on desktop machines assumes certain input devices
  - Keyboard and mouse centric
- How does interaction change when we move to a more mobile platform?
  - Tablet, phone, etc.

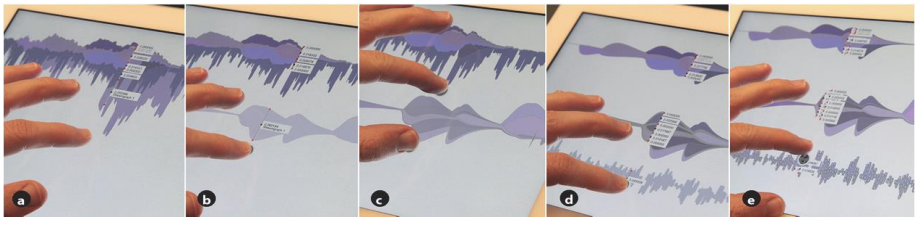
Multi-touch InfoVis

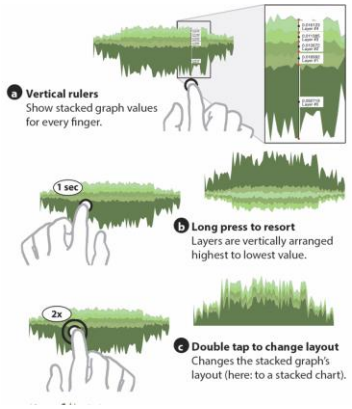
- What will it be like to interact with visualizations on a (touch) tablet computer?
  - Lots of UI controls in vis applications
  - Lots of small data objects to manipulate
- Many touch gestures possible, but what are the right ones?

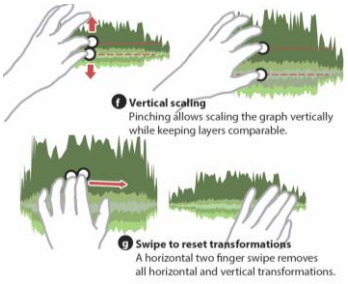
TouchWave

- Interactions for a stacked graph on a tablet
  - For temporal, hierarchical data
  - Uses multi-touch interactions
  - Seeks to avoid complex gestures

Baur et al
ITS '12







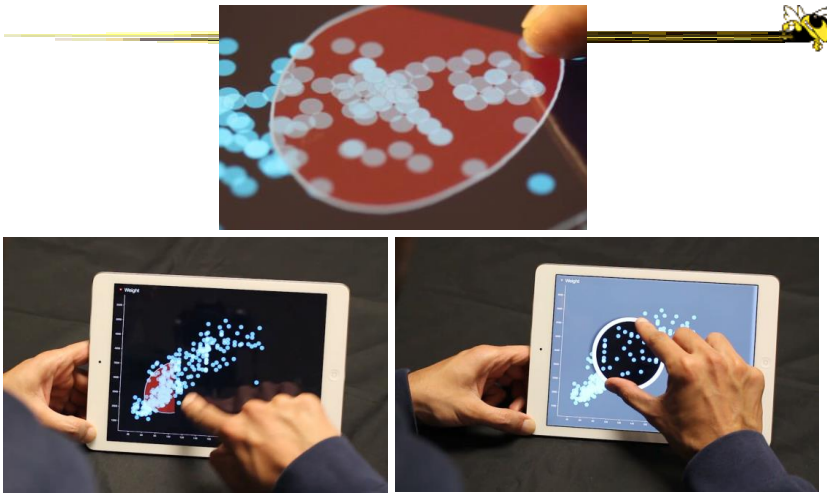
Multitouch Vis on Tablet

- Design interactive scatterplot for a tablet
- Identify operations to be supported
- Consider different feasible gestures for each operation
  - Draw upon existing research
  - Consider new gestures (a remarkable amount possible!)
- Prototype ideas with users

Constraints

- One hand holding the tablet
- Not much screen real estate
- Fat finger problem
- Simpler gestures (1 or 2 finger) probably better
- Leverage gestures from other applications

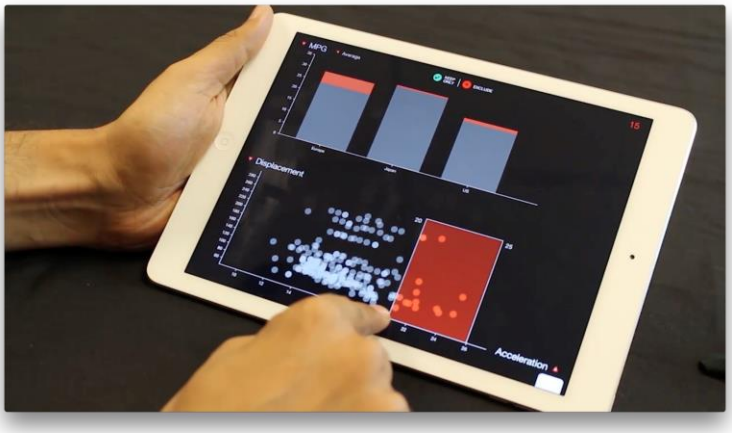
http://www.cc.gatech.edu/gvu/ii/touch/



Video

Sadana & Stasko
AVI '14

Multi-Coordinated Views

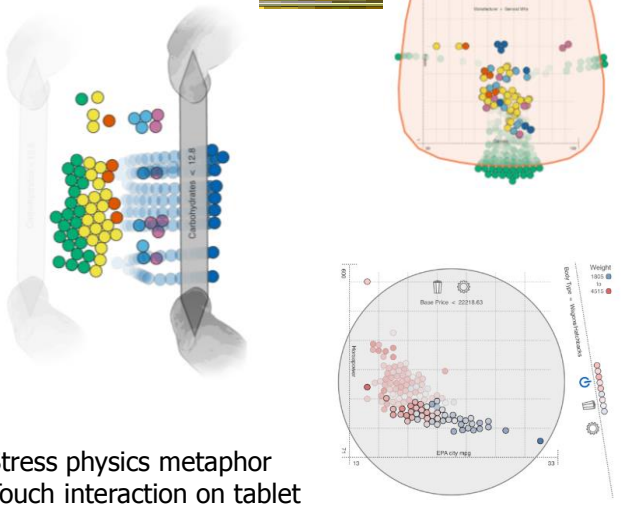


Video

Sadana & Stasko
Computer Graphics Forum (EuroVis) '16

Kinetica

Video



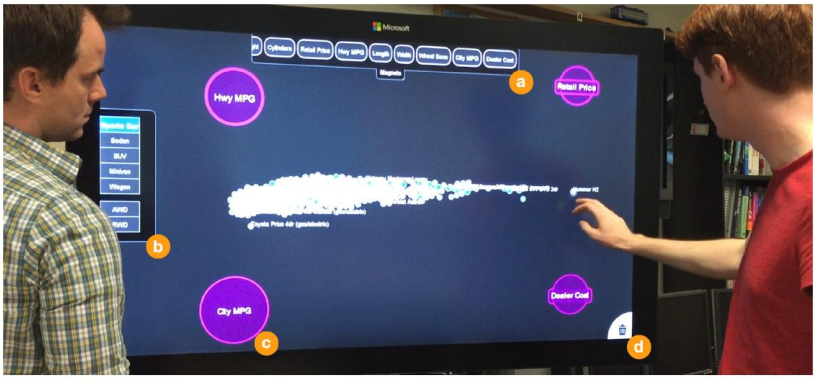
Stress physics metaphor
Touch interaction on tablet

Rzeszotarski & Kittur
CHI '14

Go Big

Video

Dust & Magnet on a large multitouch display



Dai, Sadana, Stolper & Stasko
InfoVis '15 Poster

Key Points

- Interaction facilitates a dialog between the user and the visualization system
- Multiple views amplify importance of interaction
- Interaction often helps when you just can't show everything you want

Learning Objectives

- Understand how interaction can be used to address fundamental challenges in infovis that cannot be handled through representation
- List and give examples from 7 interaction categories of Yi's framework
  - Explain how each is employed for analytic benefit
- Describe the following types of interaction and how each is used
  - Drill down, Generalized selection, Details on demand, Filtering, Faceted browsing, Brushing histograms, Magic lenses
- Explain what dynamic queries are, and list their benefits as well as their limitations/weaknesses
- Explain what brushing & linking is
- Describe different ways that animation is used for benefit
- Give examples of systems/techniques where interaction is fundamental and vital to the technique
- Understand challenges in moving from keyboard/mouse to finger/pen touch interaction

Quizzes

- John S. will keep them
- Scores in t-square

HW 4

- Experience with commercial systems
- Pick 2 of 3 systems
  - Tableau, Spotfire, Qlik
- Use 2 of 5 data sets
  - Nutrition one mandatory
- Become familiar, explore data
- Write report about your experience
  - Focus on vis capabilities, not UI quirks
- Due on Oct. 12
  - Start early!!!

Reading

- Yi et al, 2007
- Watch videos from webpage

Upcoming

- Overview and Detail
- User Tasks & Analysis