

# Information Visualization

## Interaction, Distortion & Multiple-View Methods

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# Goal of this Lecture

Overview about the “Science of interactions”,  
challenges and limitations

Overview about multiple-view methods,  
challenges and limitations

Focus+Context techniques,  
challenges and limitations



# Content

Introduction & Motivation

Science of Interaction

Modeling Interaction

Focus+Context

Conclusion – Lessons Learned

# INTRODUCTION & MOTIVATION

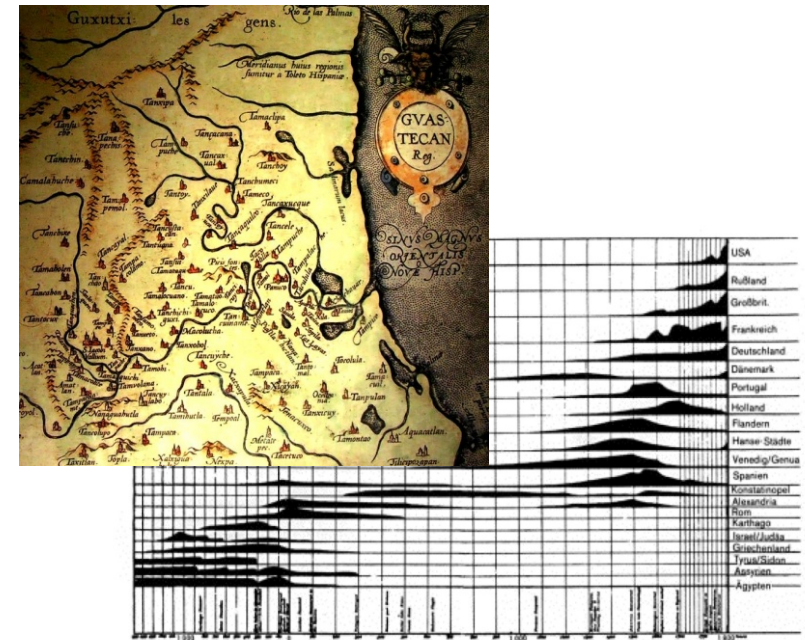
# Interactions

## Past

Only passive observations

Representation not changeable

“one fits all”

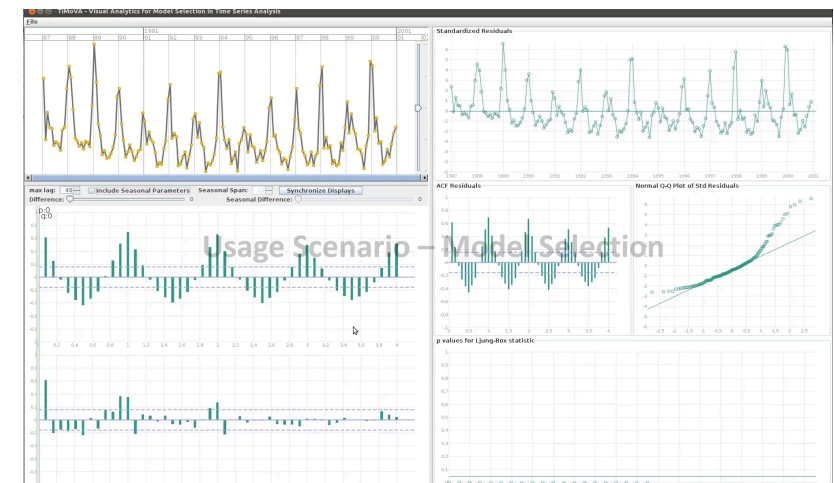


## Today

Active examination with visualizations

Dynamically adaptable and modifiable

→ Different users, tasks, and aims



# SCIENCE OF INTERACTION

## Main components

Visual representation

Interaction technique(s)

Research focus:

**Develop novel visual representations**

Recently:

**Growing interest in interaction — Evaluation of**

Related fields: Human-Computer Interaction (HCI),  
Interaction Design

# Research Focus

Very challenging to come up with **innovative, new** visual representations

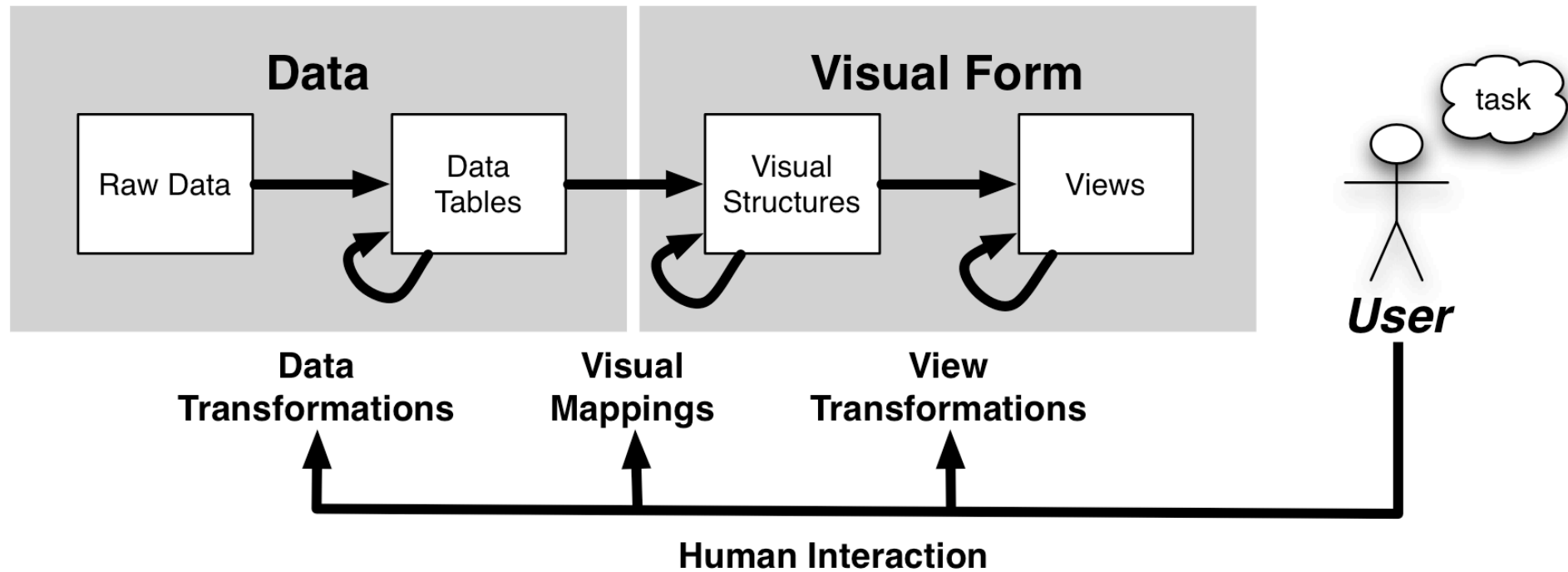
But can do interesting work with **how** users **interact** with visualizations

It's what distinguishes InfoVis from static visual representations on paper and Infographics

Analysis is a **process**, often iterative with branching and side activities

# InfoVis Reference Model

[Card et al., 1999]



*User interaction can and needs to feed back into any level*

# Interaction ...

How do you define “interactive”?

.1 sec

Animation, visual continuity, sliders

1 sec

System response, conversation break

10 sec

Cognitive response



# Interaction Levels

## Physical Level

How does the user physically interact?

*E.g., Mouse Wheel, Touch Screen*

→ **Interaction Devices**

## Control Level

How can it be carried out by the user?

*E.g., Move Scrollbar*

→ **User Interface**

## Conceptual Level

What to be done?

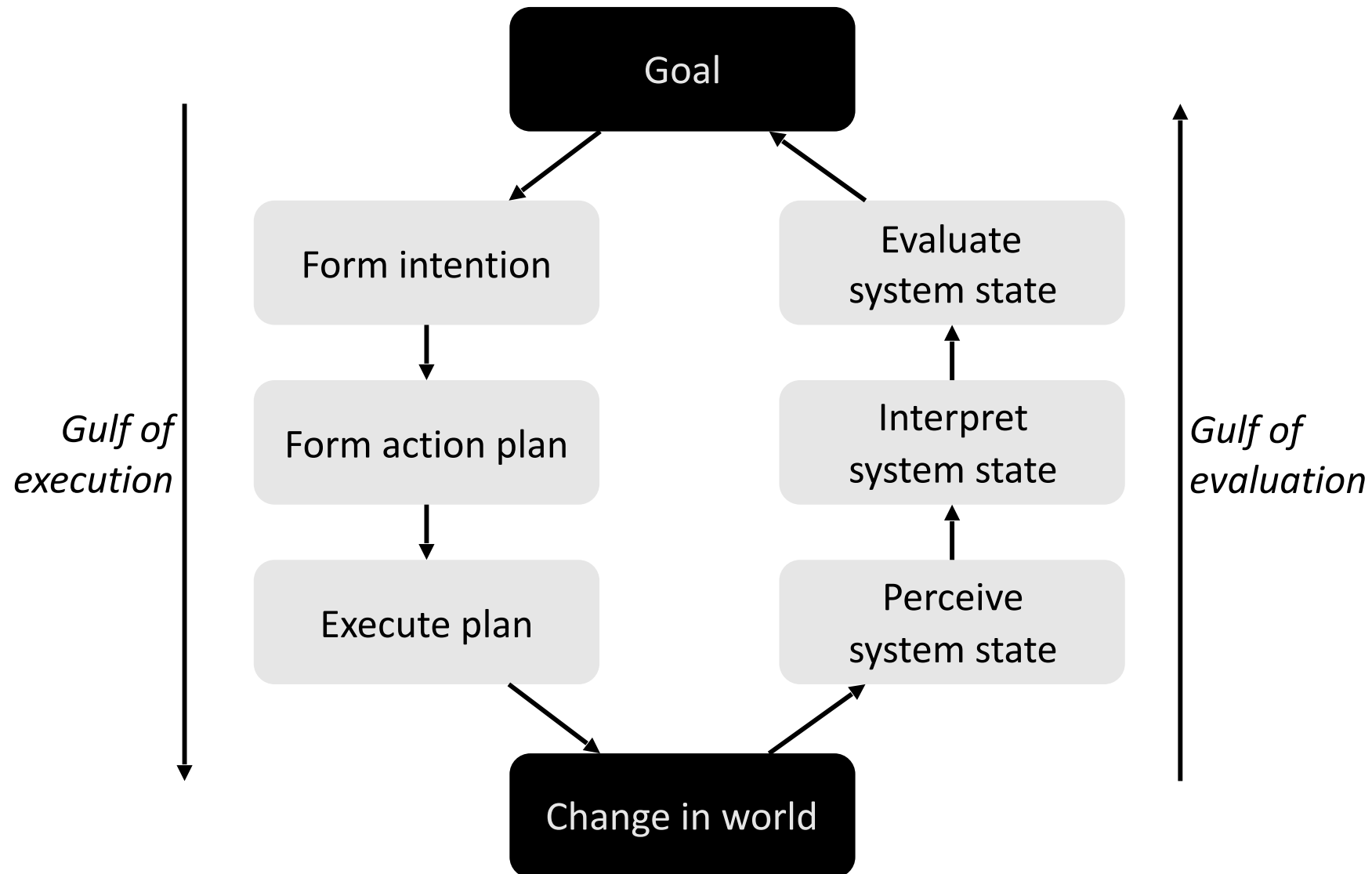
*E.g., Scrolling / Navigating*

→ **Task**

**All three levels: discussed further outside scope of interaction**

# Norman's Execution-Evaluation Cycle

[Norman, 1988]



# Norman's Execution-Evaluation Cycle

[Norman, 1988]

## **Gulf of Execution**

The difference between the user's view of the system and the allowable actions in the system.

## **Gulf of Evaluation**

The difference between what the user wants to do, and what was actually changed.

# Visual Information Seeking Mantra... again

[Shneiderman, 1996]

***Overview first, zoom and filter,  
then details-on-demand.***

**Overview:** Gain an overview of the entire collection.

**Zoom:** Zoom in on items of interest.

**Filter:** Filter out uninteresting items.

**Details on demand:** Select an item or group and get details when needed.

**Relate:** View relationships among items.

**History:** Keep a history of actions to support undo, replay, and progressive refinement.

**Extract:** Allow extraction of sub-collections and of the query parameters.

# Interaction Taxonomy: User-centered

[Yi, Kang, Stasko 2007]

## 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

## Aggregate interaction techniques by user intent

*“What a user wants to achieve”*

... rather than how techniques work

# Interaction :: User Intents by Yi et al.

Based on [Yi, Kang, Stasko 2007]

**Select:** mark something as interesting

**Explore:** show me something else

**Reconfigure:** show me a different arrangement

**Encode:** show me a different representation

**Abstract/Elaborate:** show me more or less detail

**Filter:** show me something conditionally

**Connect:** show me related items

---

**Undo/Redo:** go backward or forward to pre-existing system states

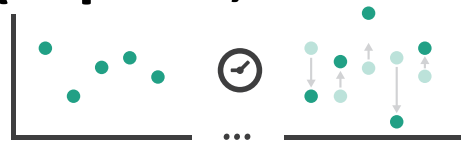
**Change configuration:** change various configurations and settings of a system

# Interaction :: User Intents by Munzner

Based on [Munzner, 2014]

## Manipulate (Explore, Reconfigure)

Change



Select



Navigate

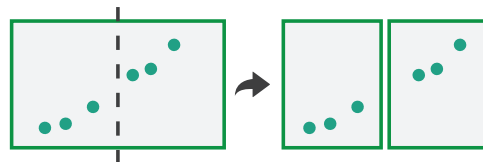


## Facet (Encode, Connect)

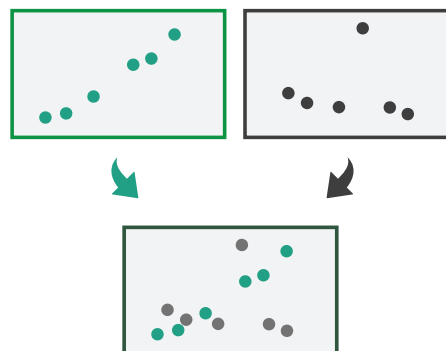
Juxtapose



Partition



Superimpose

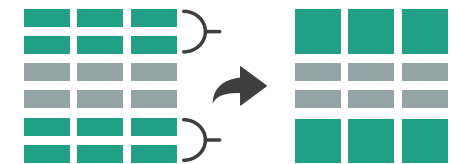


## Reduce (Abstract/Elaborate)

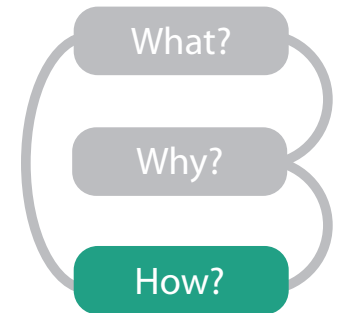
Filter



Aggregate



Embed





# ThermalPlot :: An Exposition

## Current InfoVis & Visual Analytics Approaches

Incorporate multitude of interaction techniques

Growing complexity – Target user intents should be supported through interaction

### Recent example:

Holger Stitz, Samuel Gratzl, Wolfgang Aigner, and Marc Streit

*ThermalPlot: Visualizing Multi-Attribute Time-Series Data Using a Thermal Metaphor*, IEEE Transactions on Visualization and Computer Graphics, Issue 99, 2016

# Select: mark something as interesting

Adapted [Aigner, Presentation 2010]

<https://thinkh.github.io/thermalplot/>

E.g., Selecting, Highlighting



Degree-of-Interest (DoI)

ΔClose 75%

EPS. Ret. ...

LineUp

Details

Select one or more items to see details here.

[ThermalPlot, 2016]

# Select: mark something as interesting

## E.g., Brushing

Adapted [Aigner, Presentation 2010]

[Becker & Cleveland, 1987, Hauser et al., 2002]

More complex than simple selection

Brush is an interactive interface tool to select / mark subsets of data in a single view

e.g., by sweeping a virtual brush across items of interest

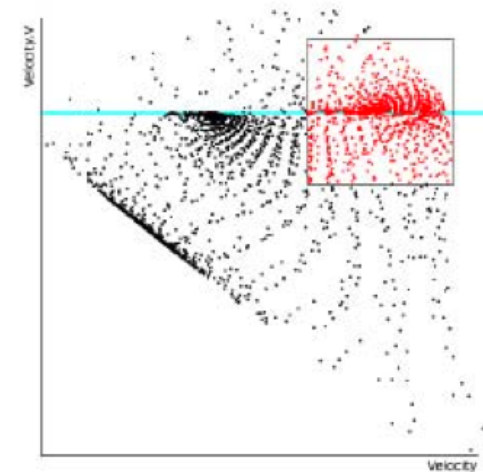
Usually used to visually filter data (via highlighting)

Additional manipulation / operations may be performed on the subsets

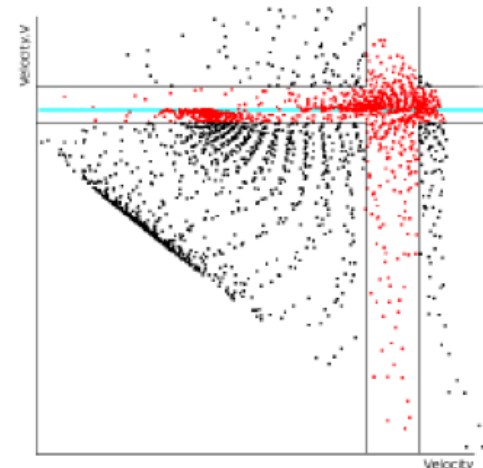
e.g., masking, magnification, labelling etc.

Different types of brushes [Hauser et al. 2002]

e.g., simple brush, composite brush, angular brushing, smooth brushing



AND-brush



OR-brush

[Hauser et al., 2002]

# Select: mark something as interesting

Adapted [Aigner, Presentation 2010]

[Becker & Cleveland, 1987, Hauser et al., 2002]

## E.g., Brushing

## More cor

Brush is a  
subsets c

e.g.,  
interc

Usually u

## Additional performance

e.g.,

## Different

e.g.,  
smoc



, 2016]

# Explore: show me something else

## **Zooming + Panning,** **Overview + Detail**

e.g., Size + Position of Viewport  
... in Space, Time

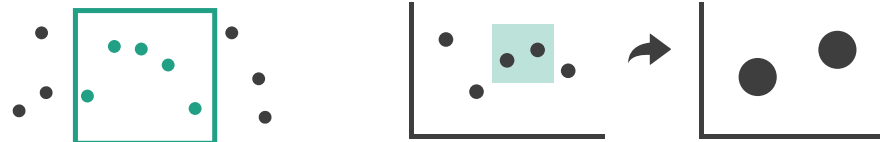


## **Geometric Zoom**

e.g., Photoshop

## **Semantic Zoom**

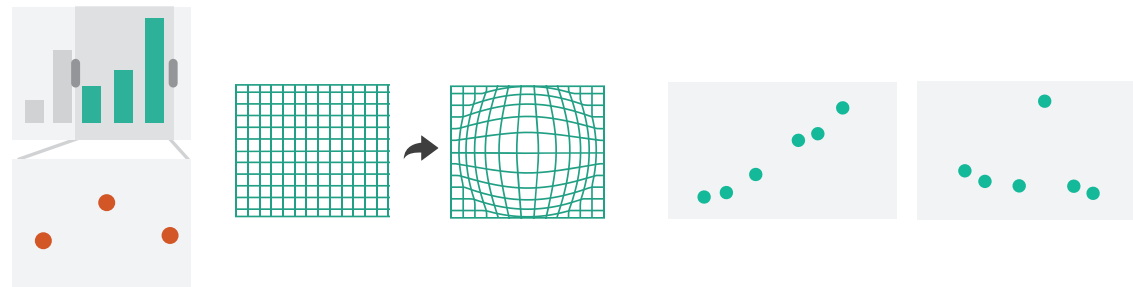
e.g., Google Maps



## **Overview+Detail** **Focus+Context**

e.g., Fisheye Zoom

## **Small Multiples**



[Stitz et al., 2016]

# Explore: show me something else

## **Zooming + Panning, Overview + Detail**

e.g., Size + Position of Viewport  
... in Space, Time

## **Geometric Zoom**

e.g., Photoshop

## **Semantic Zoom**

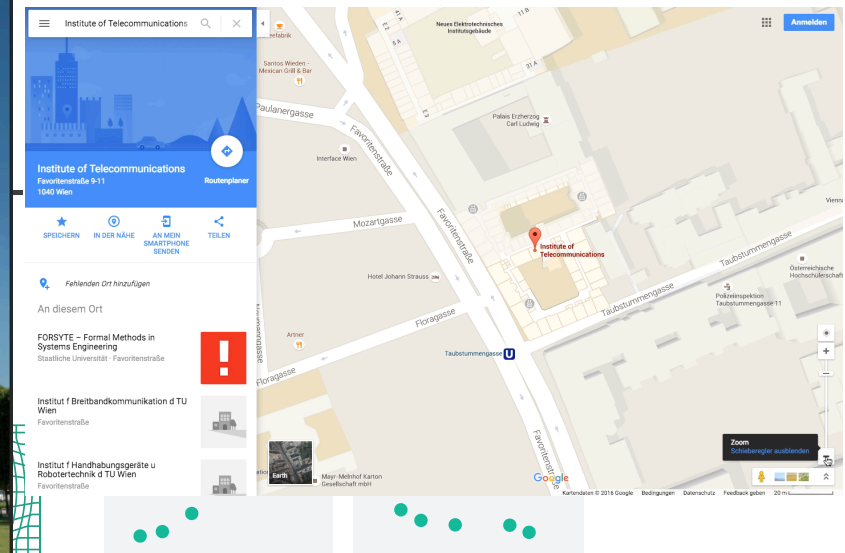
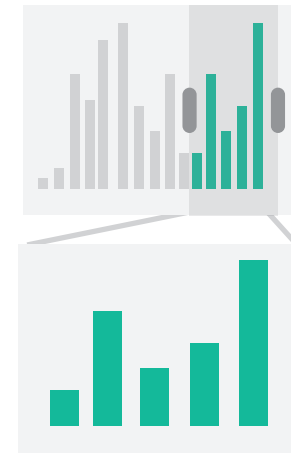
e.g., Google Maps

## **Overview+Detail Focus+Context**

e.g., Fisheye Zoom

## **Small Multiples**

Based on [Munzner, 2014]

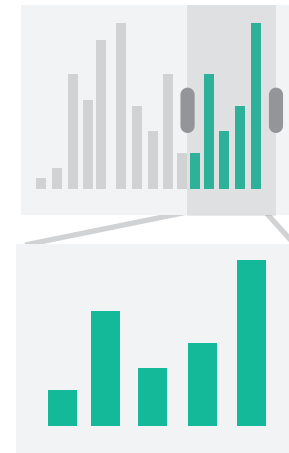


[Stitz et al., 2016]

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## **Zooming + Panning, Overview + Detail**

e.g., Size + Position of Viewport  
... in Space, Time



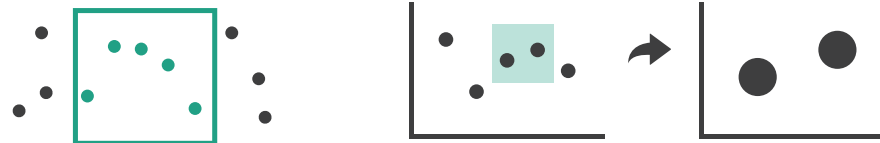
Based on [Munzner, 2014]

## **Geometric Zoom**

e.g., Photoshop

## **Semantic Zoom**

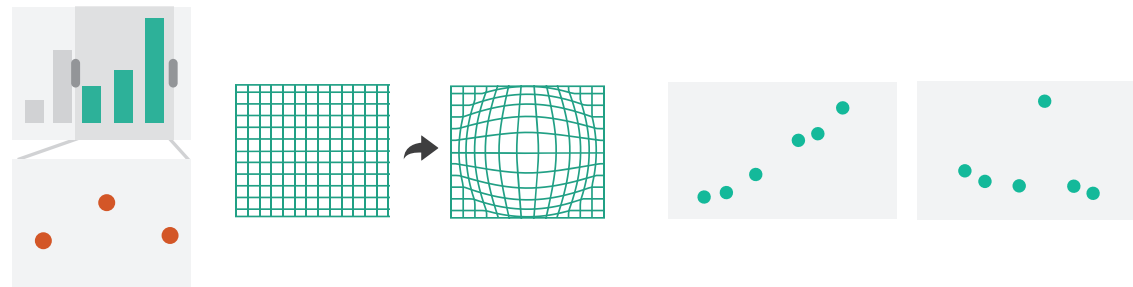
e.g., Google Maps



## **Overview+Detail Focus+Context**

e.g., Fisheye Zoom

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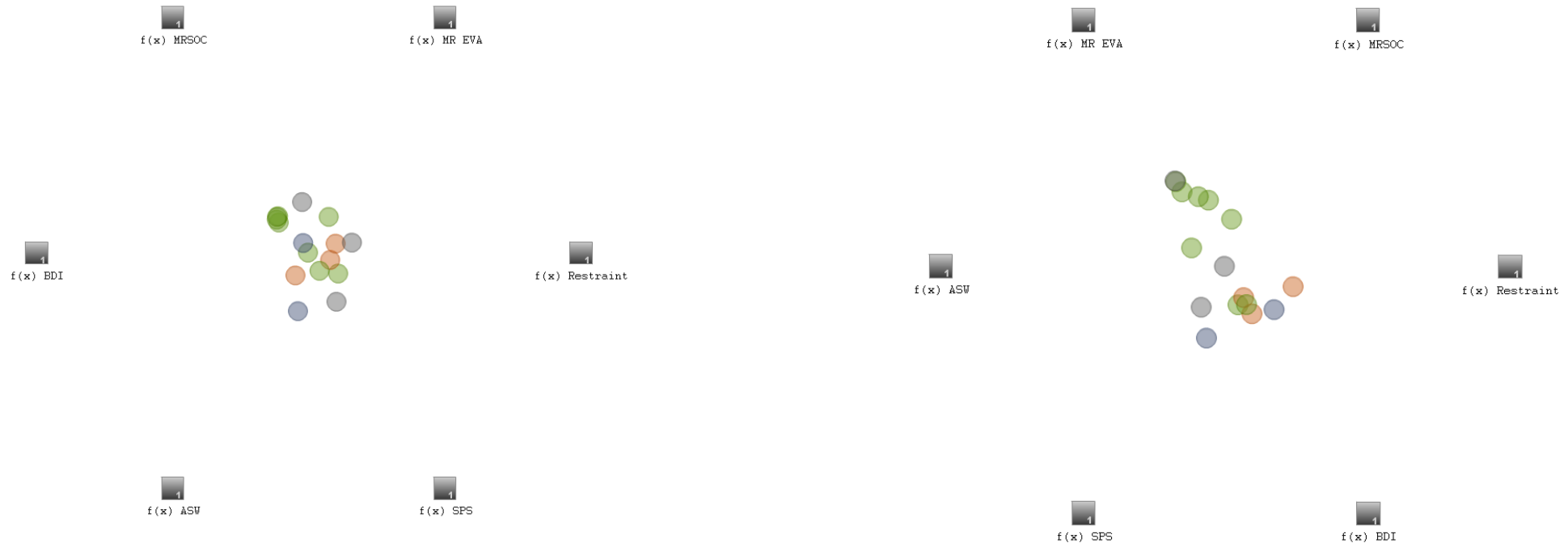


[Stitz et al., 2016]

# Reconfigure: show me a different arrangement

Adapted [Aigner, Presentation 2010]

E.g., Swap x and y Axis of a Scatter Plot; Axis of Parallel Coordinates; **Rearrange View**, Move View Position, Sorting Items in a Table, Switch Scale on Axes



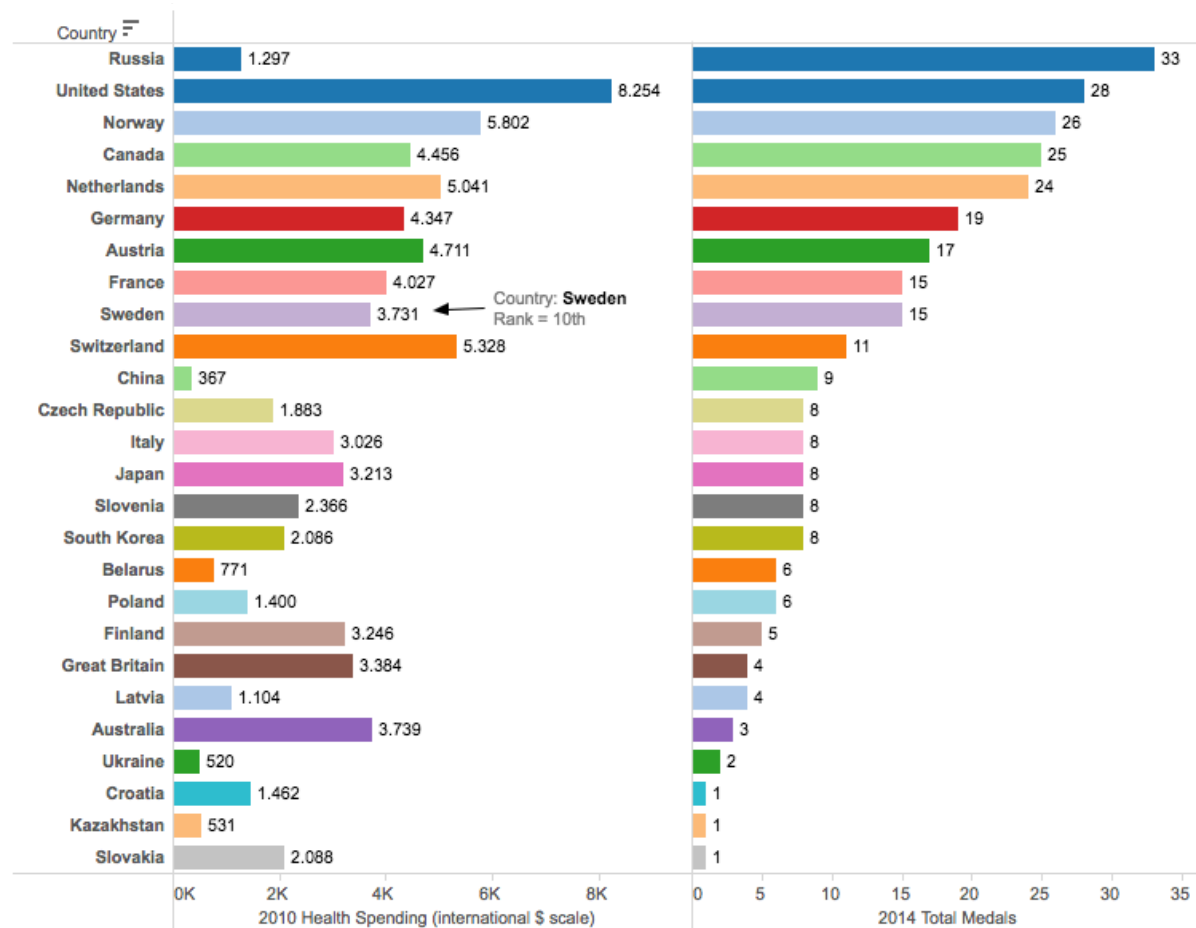
[gravi++, 2006]



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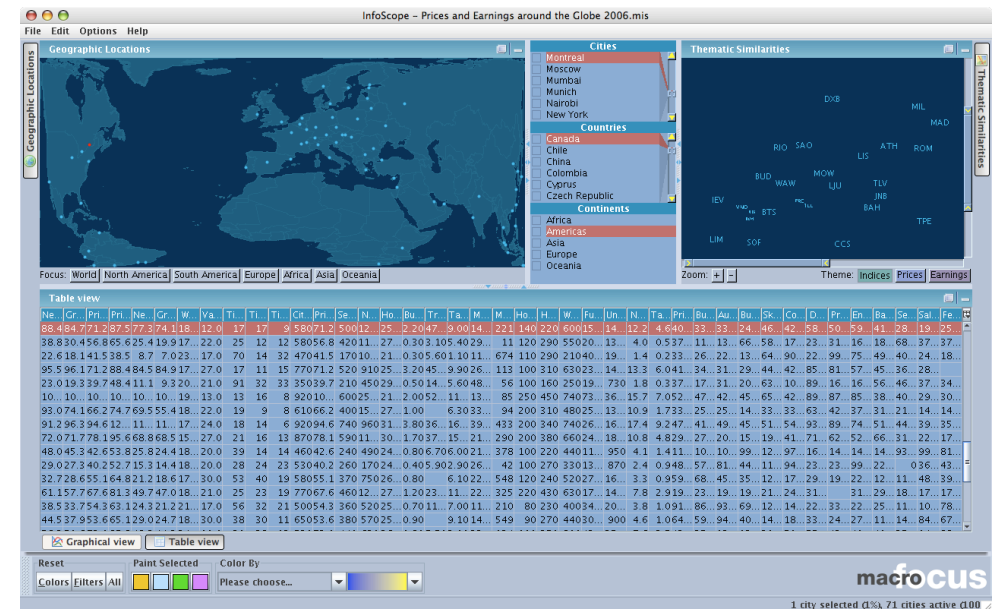
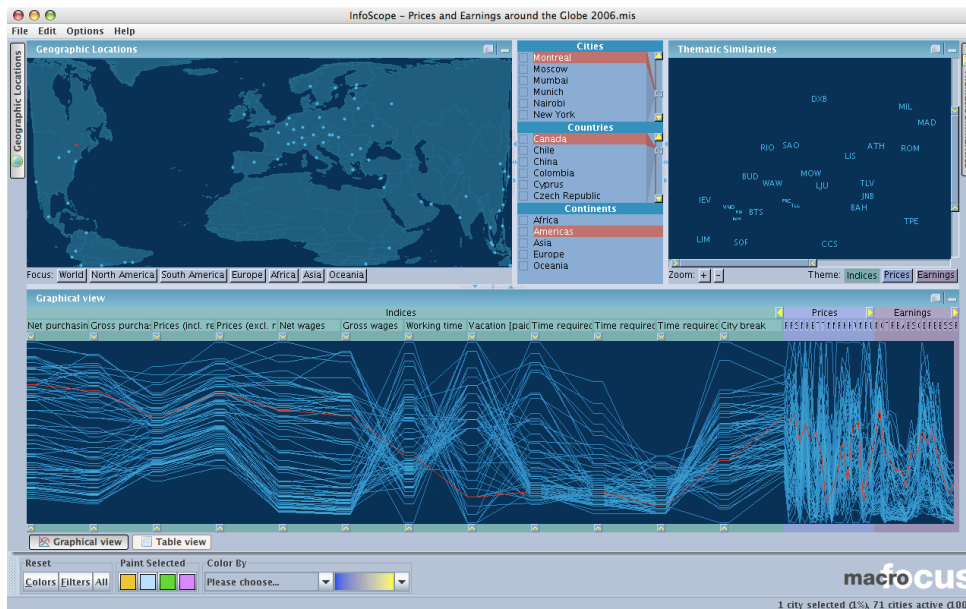
[Stitz et al., 2016]

# Encode: show me a different representation

Adapted [Aigner, Presentation 2010]

## Change representation

e.g., from parallel coordinates to tabular data

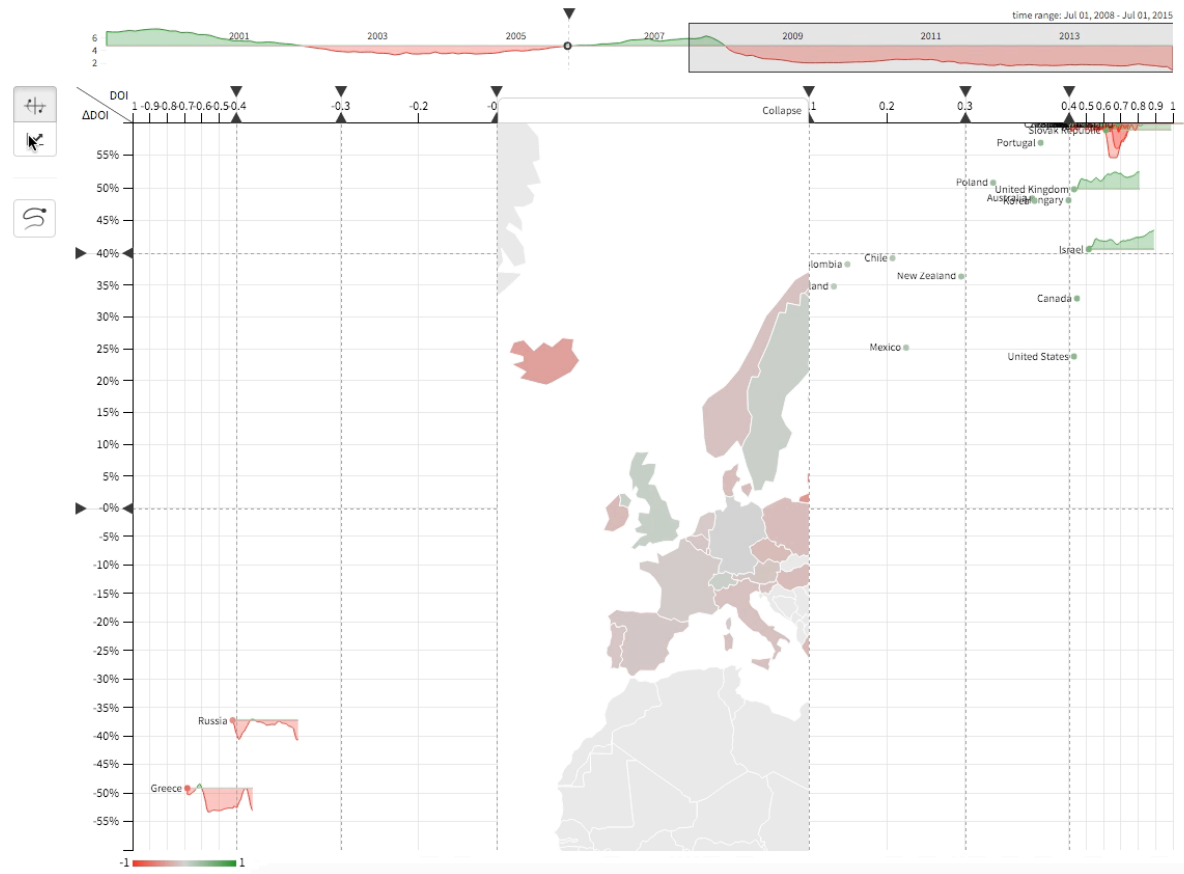


[InfoScope, 2007]

# Encode: show me a different representation

## Change representation

e.g., from scatterplot to linechart



[Stitz et al., 2016]

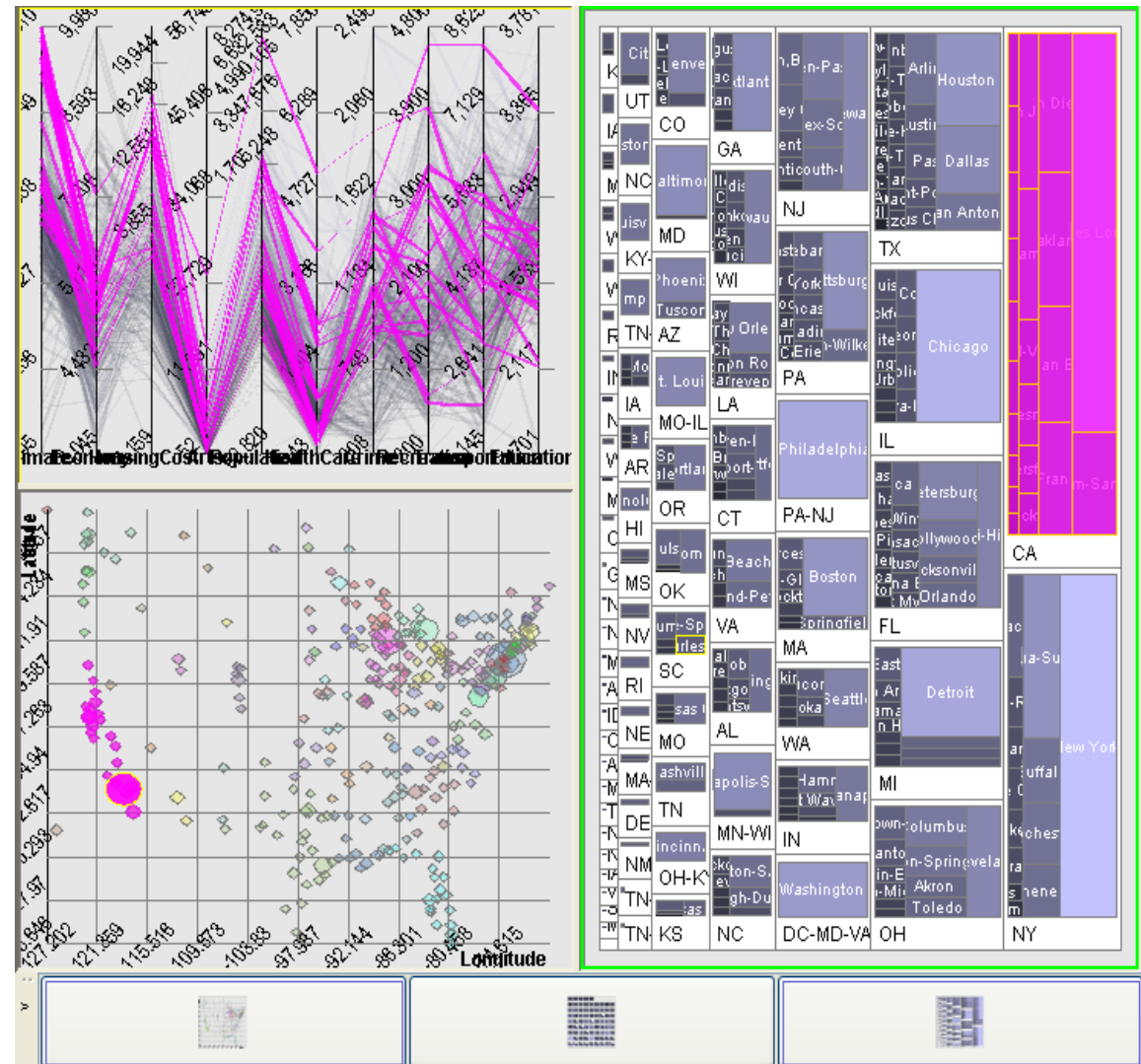
# Encode: show me a different representation

Adapted [Aigner, Presentation 2010]

Same data,  
different encoding

## Multiple Views: Brushing & Linking

*A multiple view–system  
uses two or more  
distinct views to support  
the investigation of a  
single conceptual entity*



[Baldonado et al., 2000]

# Encode: show me a different representation

Adapted [Aigner, Presentation 2010]

Same data,  
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## Multiple Views: Brushing & Linking

*A multiple view–system  
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[Stitz et al., 2016]

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Adapted [Aigner, Presentation 2010]

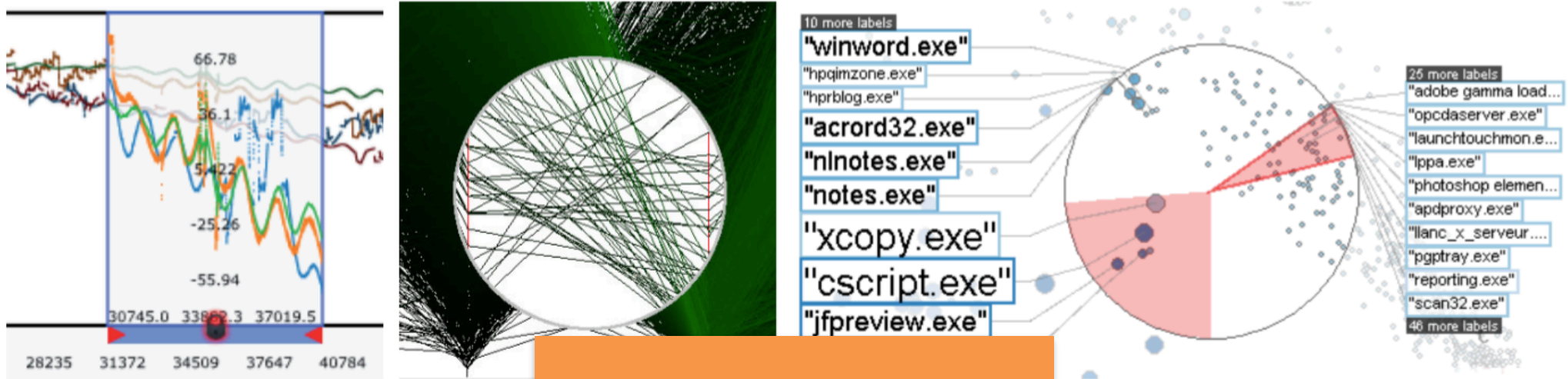
## E.g., Interactive Lenses, Movable Filters

Arbitrarily shaped area of an object and to manipulate this area with specific operators

Cover only a part of the object

Can be overlaid and combined

Combination with Dynamic Queries [Fishkin & Stone 1995]



More on that later

[Tominski et al., 2014]

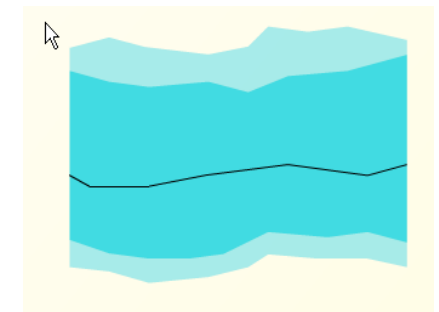
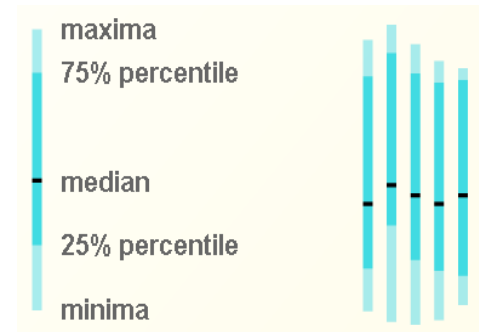
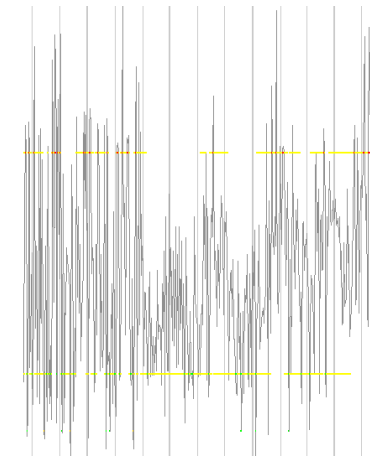
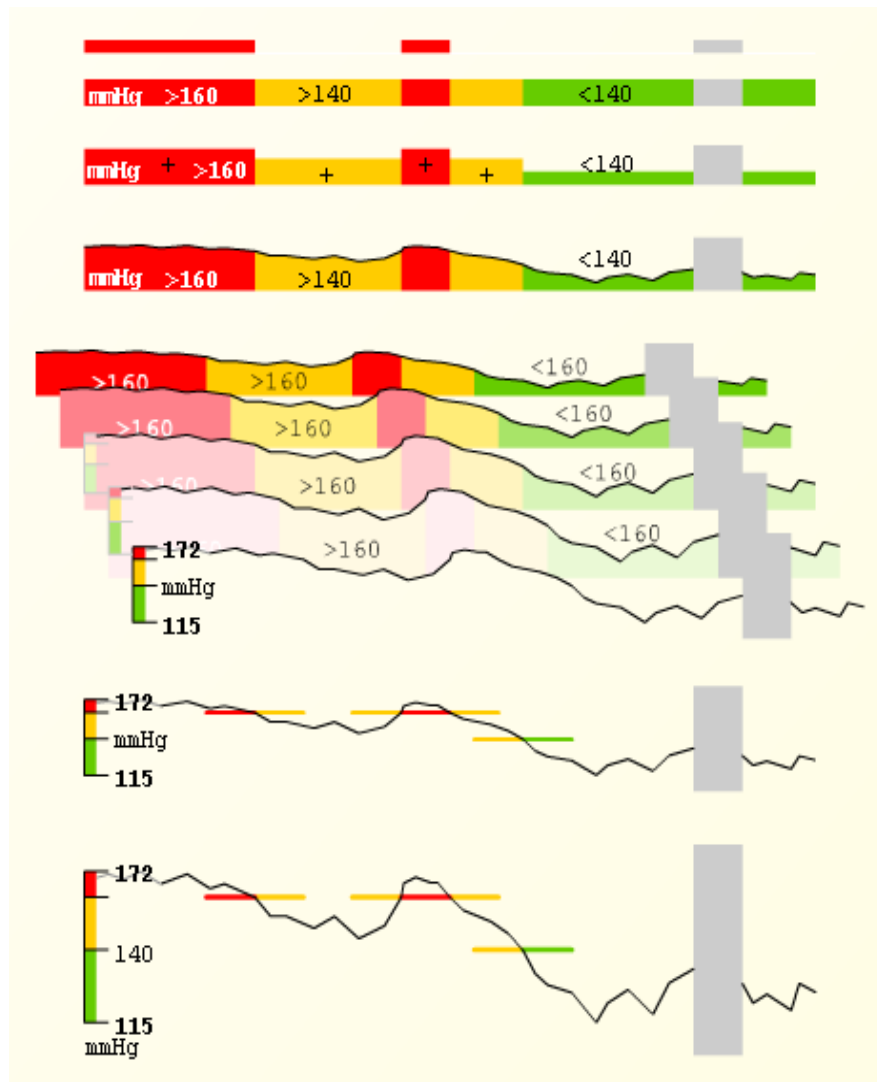


# Encode: show me a different representation

## E.g., Midgaard - Semantic Zoom

Quantitative/Qualitative hybrids

High-frequency data



[Bade et al., 2004]



# Abstract/Elaborate: show me more or less detail

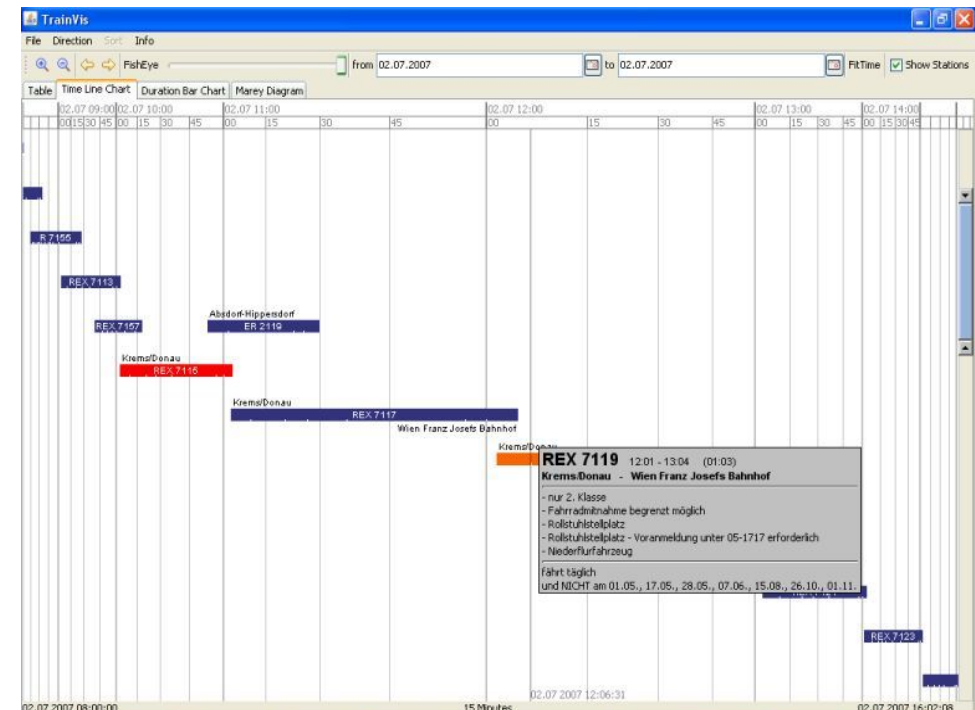
Adapted [Aigner, Presentation 2010]

## E.g., Details on Demand

Displaying detailed information about data case(s) on demand to the user

May just be more info about a case

May be moving from aggregation view to individual view



[TrainVis, Weishapl, Aigner, 2007]

# Abstract/Elaborate: show me more or less detail

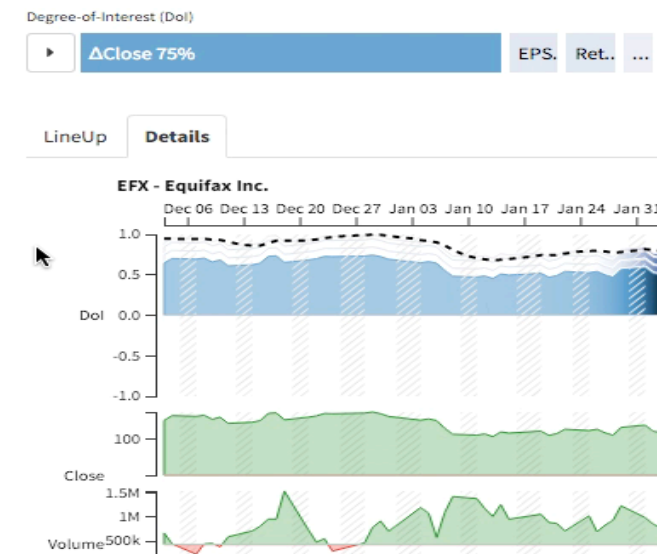
Adapted [Aigner, Presentation 2010]

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[Stitz et al., 2016]

# Filter: show me something conditionally

Adapted [Aigner, Presentation 2010]

## E.g., Dynamic Queries

Selecting value ranges of variables via controls with real time feedback in the display.

### Principles:

Visual Presentation of  
Query's Components

Visual Presentation of  
Results

Rapid, Incremental, and  
Reversible Control

Selection by Pointing,  
not Typing

Immediate and  
Continuous Feedback

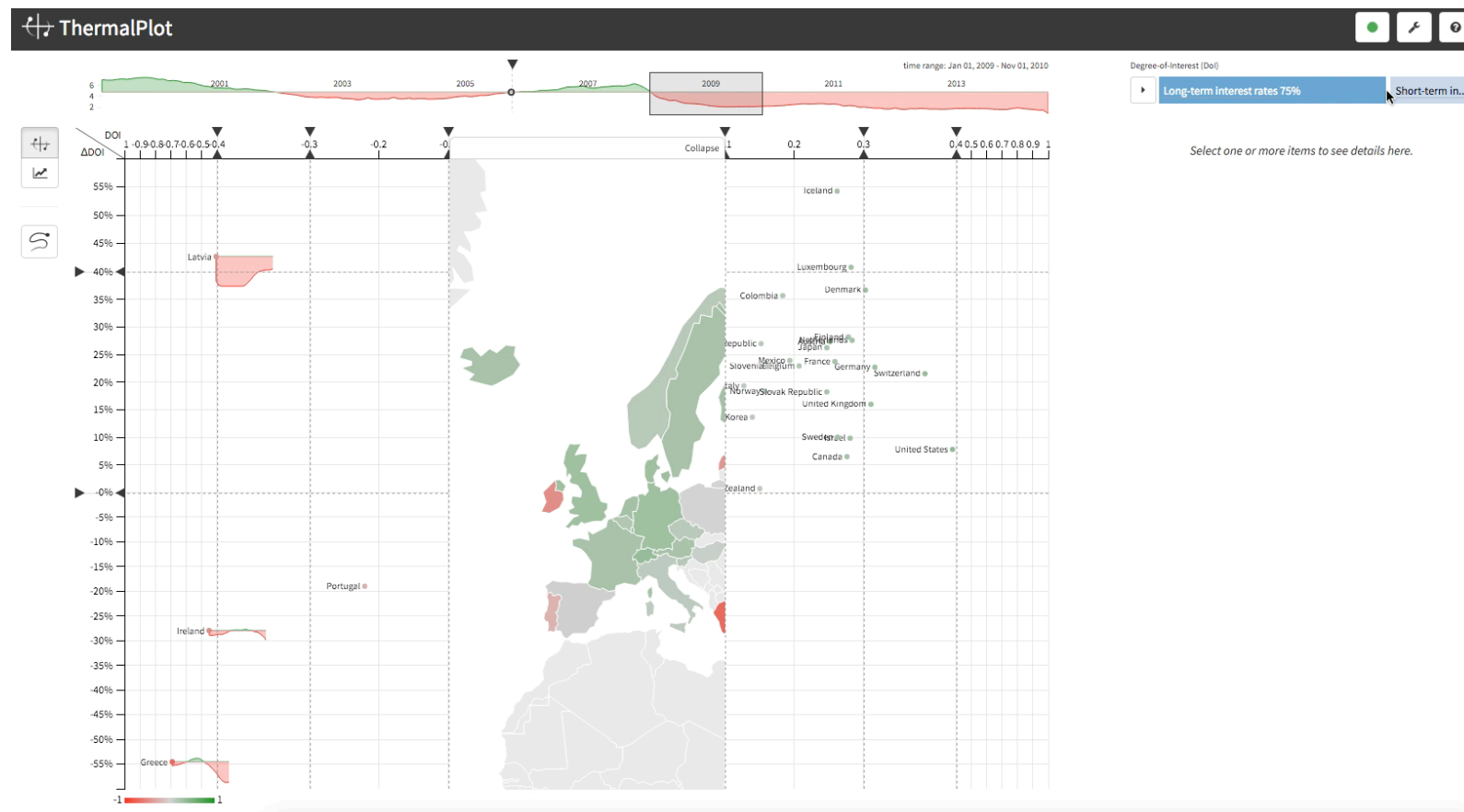
Encourage Exploration

# Filter: show me something conditionally

Adapted [Aigner, Presentation 2010]

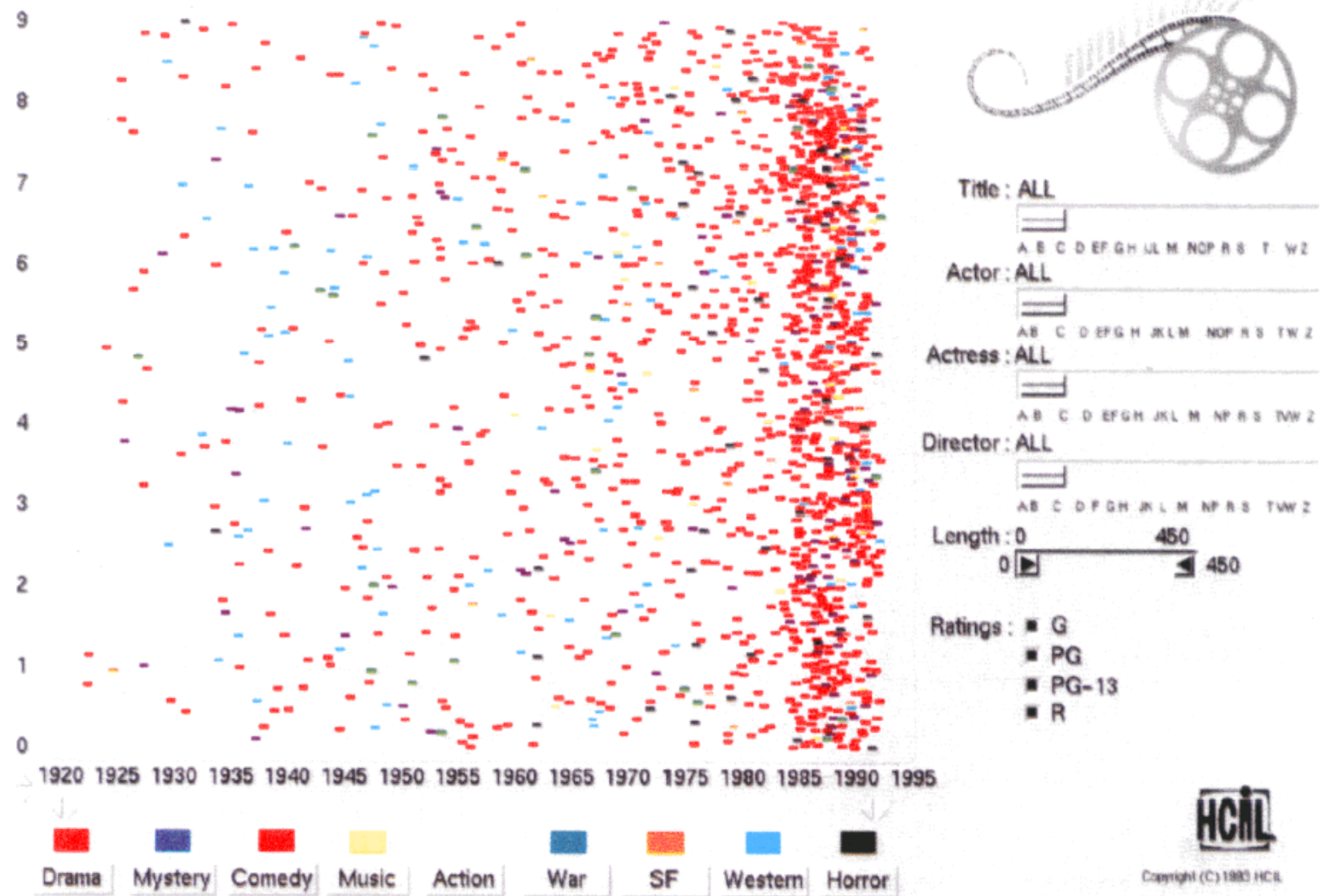
## E.g., Dynamic Queries

Selecting value ranges of variables via controls with real time feedback in the display.



# Filter :: Dynamic Queries

## Interactive Search

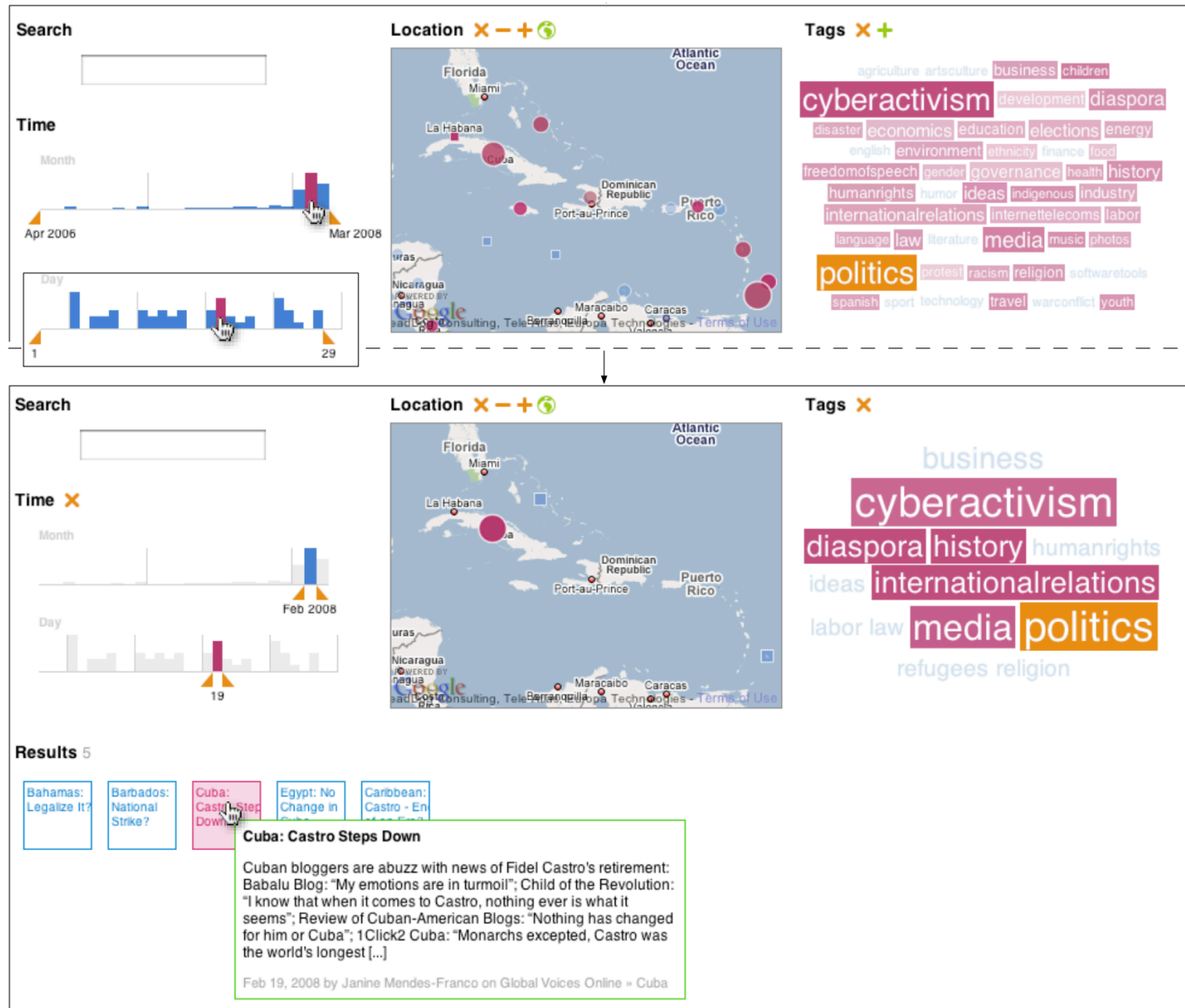


Farbabbildung 22: Der *FilmFinder* [Ahlberg94].

# Filter :: Dynamic Queries

Adapted [Aigner, Presentation 2010]

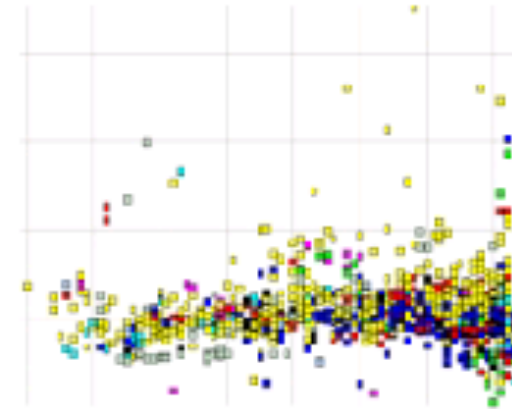
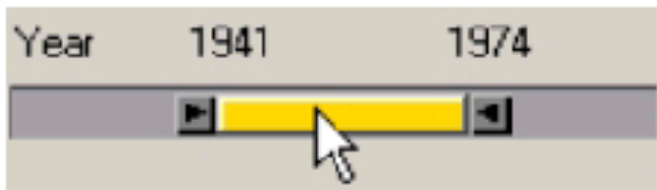
## E.g., Dynamic Queries



Doerk et al., 2008]

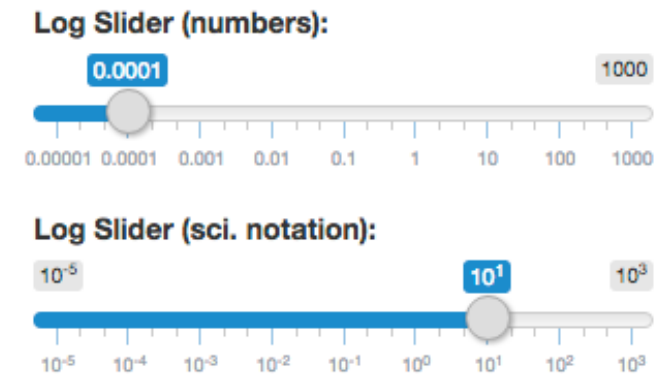
# Filter :: Semantic Sliders: Range Slider

[Shneiderman, 1994 ff]



# Filter :: Semantic Sliders: AlphaSlider

[Ahlberg and Shneiderman, 1994]



Used to rapidly scan through and select from lists of alphanumeric data

- Small-sized widget to search sorted lists

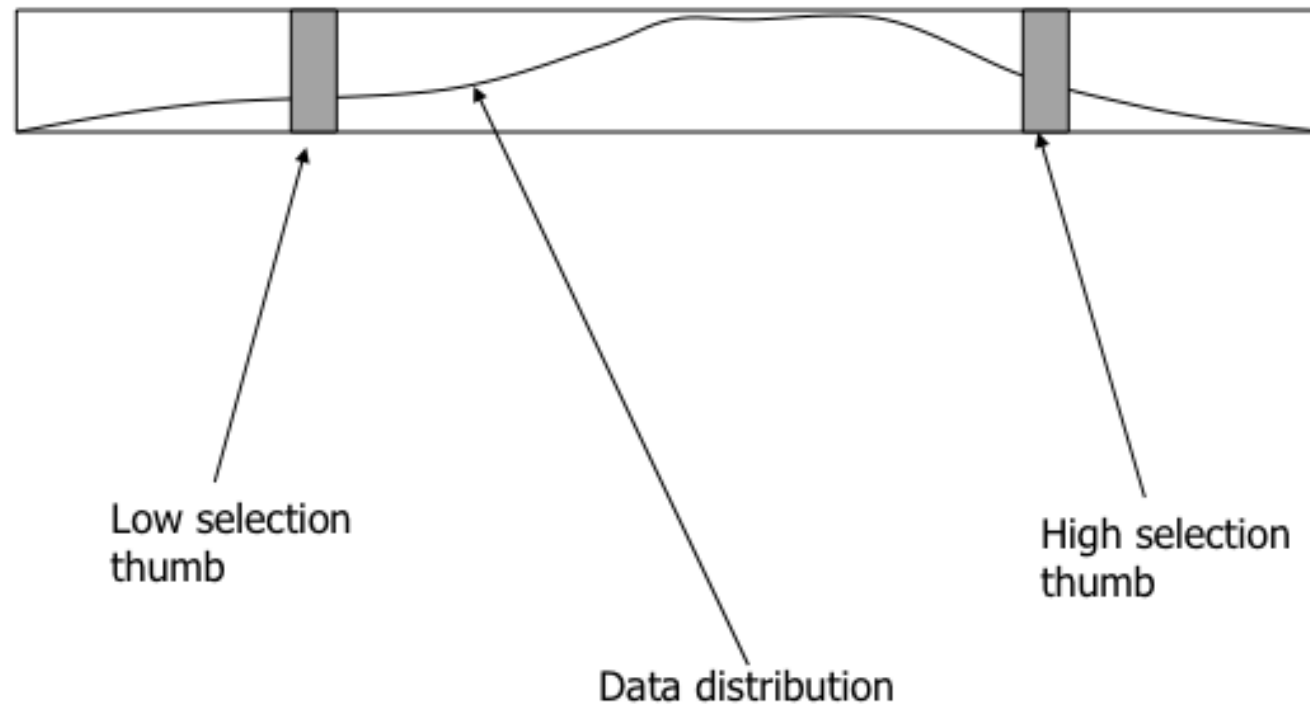
- Letter index visualizing the distribution of initial letters - jump to a position in the slider

- Locating an items out of a list of 10,000 items ~ 28s for novice users



# Filter :: Data Visualization Sliders

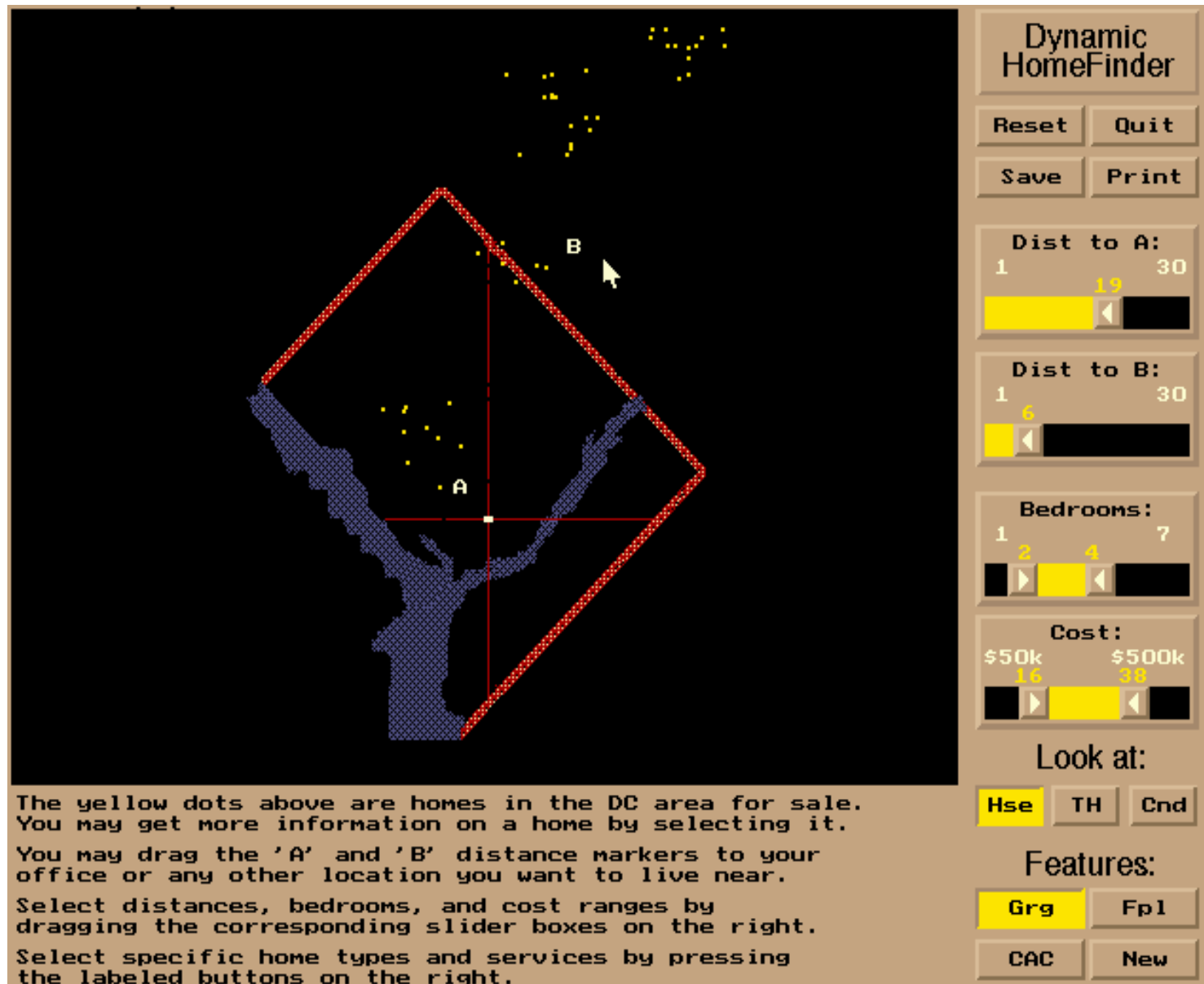
[Eick, 1994]



Data distribution is shown within control

# Filter :: Dynamic HomeFinder

[Shneiderman, 1994 ff]



[Video](#)

# Filter :: Multiple Linked Views

**Christopher Ahlberg**

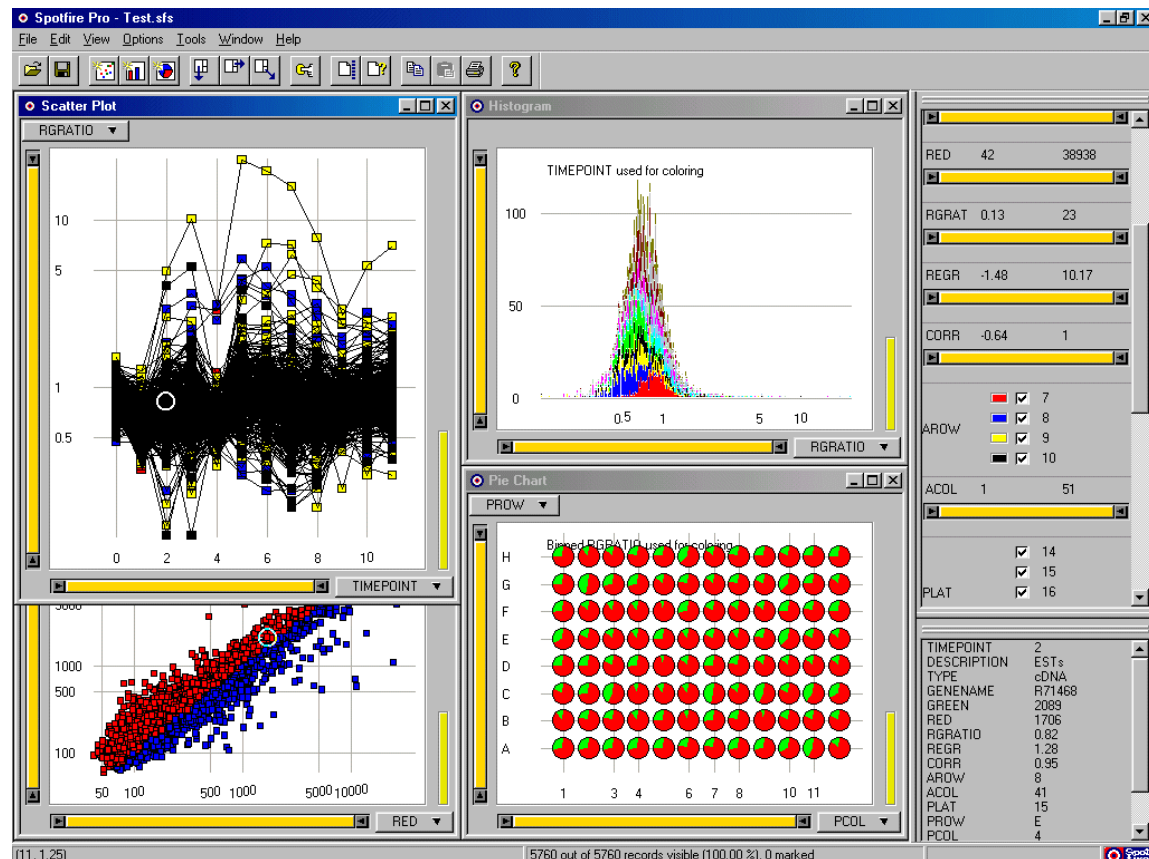
Adapted [Aigner, Presentation 2010]

**1991: Visiting student from Sweden at the HCIL University of Maryland**

**1996: Founder of Spotfire**

**2007: Spotfire was sold for 195 Mio. \$**

**2017: Spotfire TIBCO - Big Data Analytics, Data Wrangling, ...**



# Filter :: Node-Link Representations

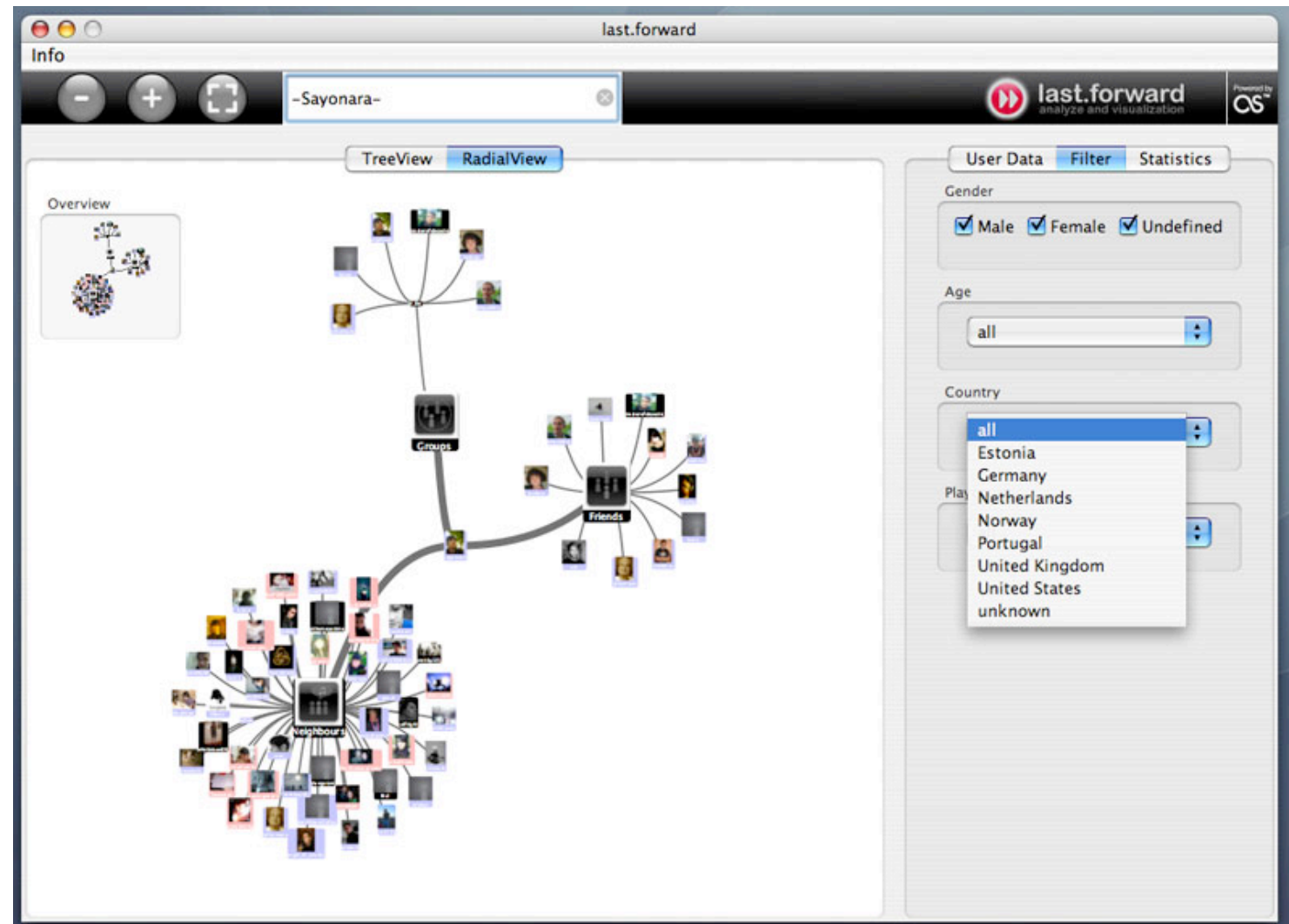
Adapted [Aigner, Presentation 2010]

Images as nodes

Weighted edges

Overview + Detail

Filtering



# Filter :: Dynamic Queries Summary

[Büring lect., 2007]

## Users can explore data - **no false input possible**

- generate new queries based on incidental learning

- Visual representation of data supports data exploration

- continuously develop and test hypotheses (detect clusters, outliers, trends in multivariate data)

- undo and reversing of actions

## Potential **drawbacks**

- Limit of query complexity – filters are always conjunctive

- Performance is limited for very large data sets

- Controls require valuable display space

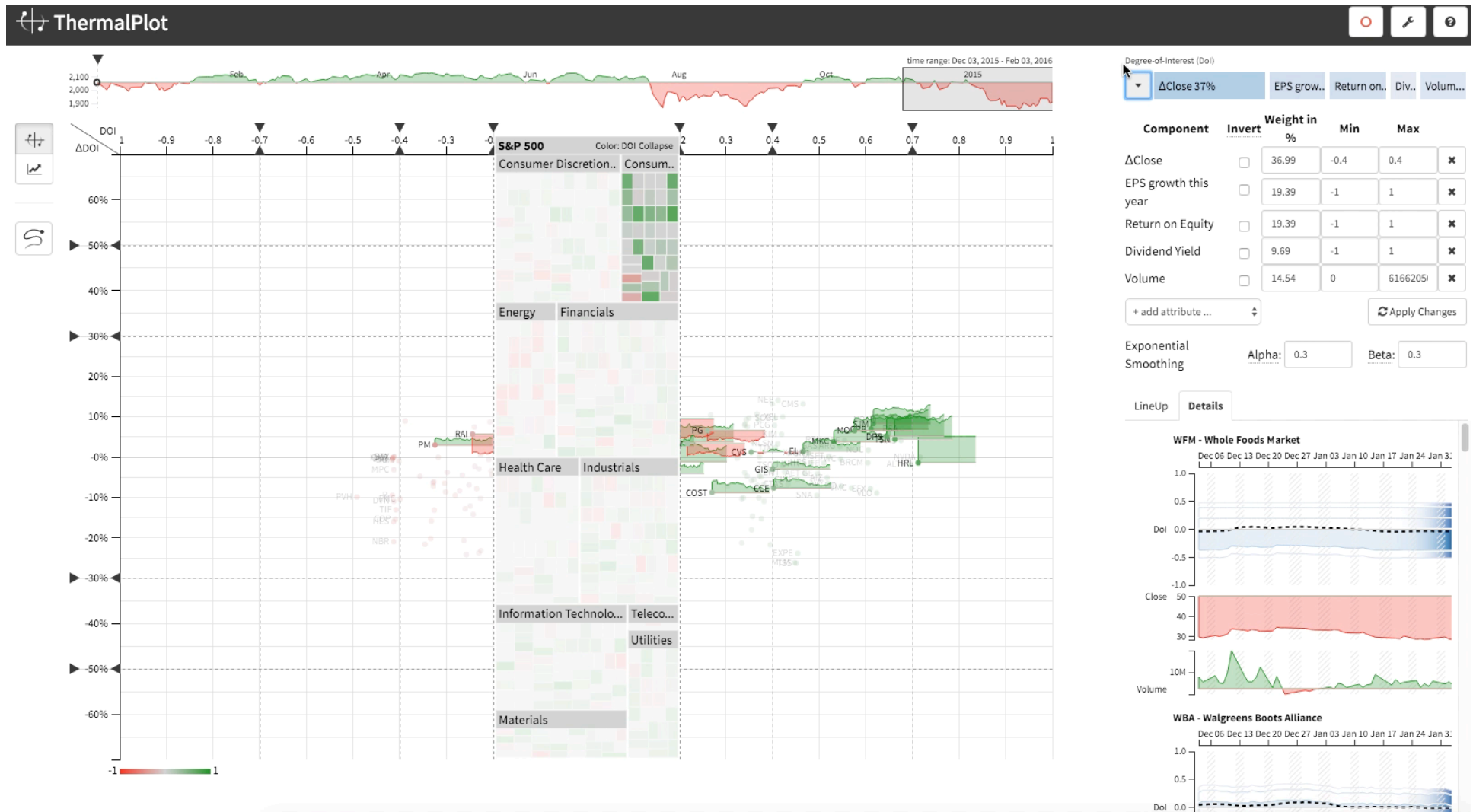
- Information is pruned – User can lose focus

- Only single range queries and single selection in the Alphaslides

- Operations are global in scope

# Filter :: Dynamic Queries Summary

Users can explore data - no false input possible



# Connect: show me related items

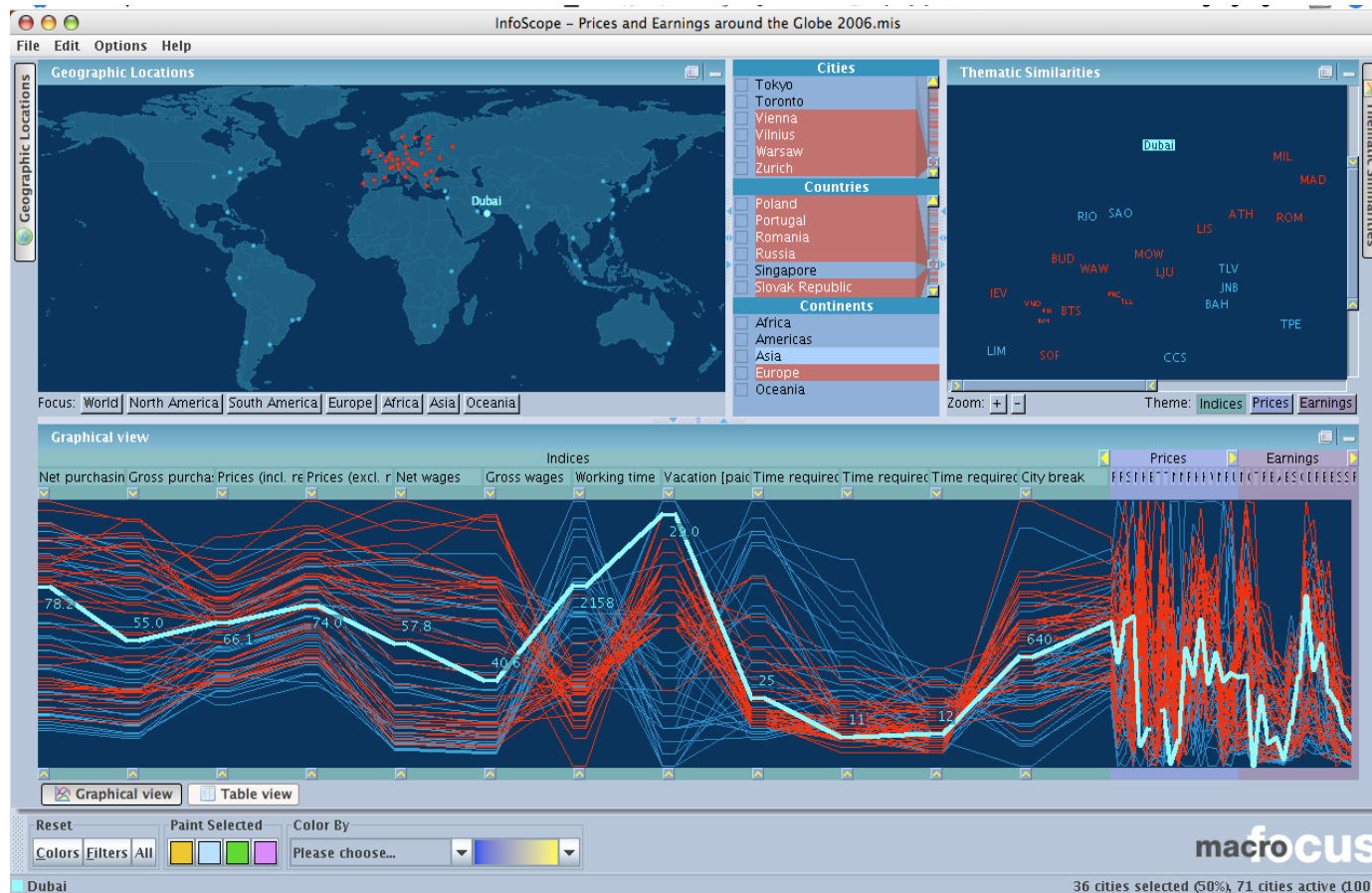
Adapted [Aigner, Presentation 2010]

## E.g., Linking

Connection between multiple views of the same dataset

Updating one view means updating all

Often mentioned in conjunction with “brushing” (Linking + Brushing)



# Connect: show me related items

Adapted [Aigner, Presentation 2010]

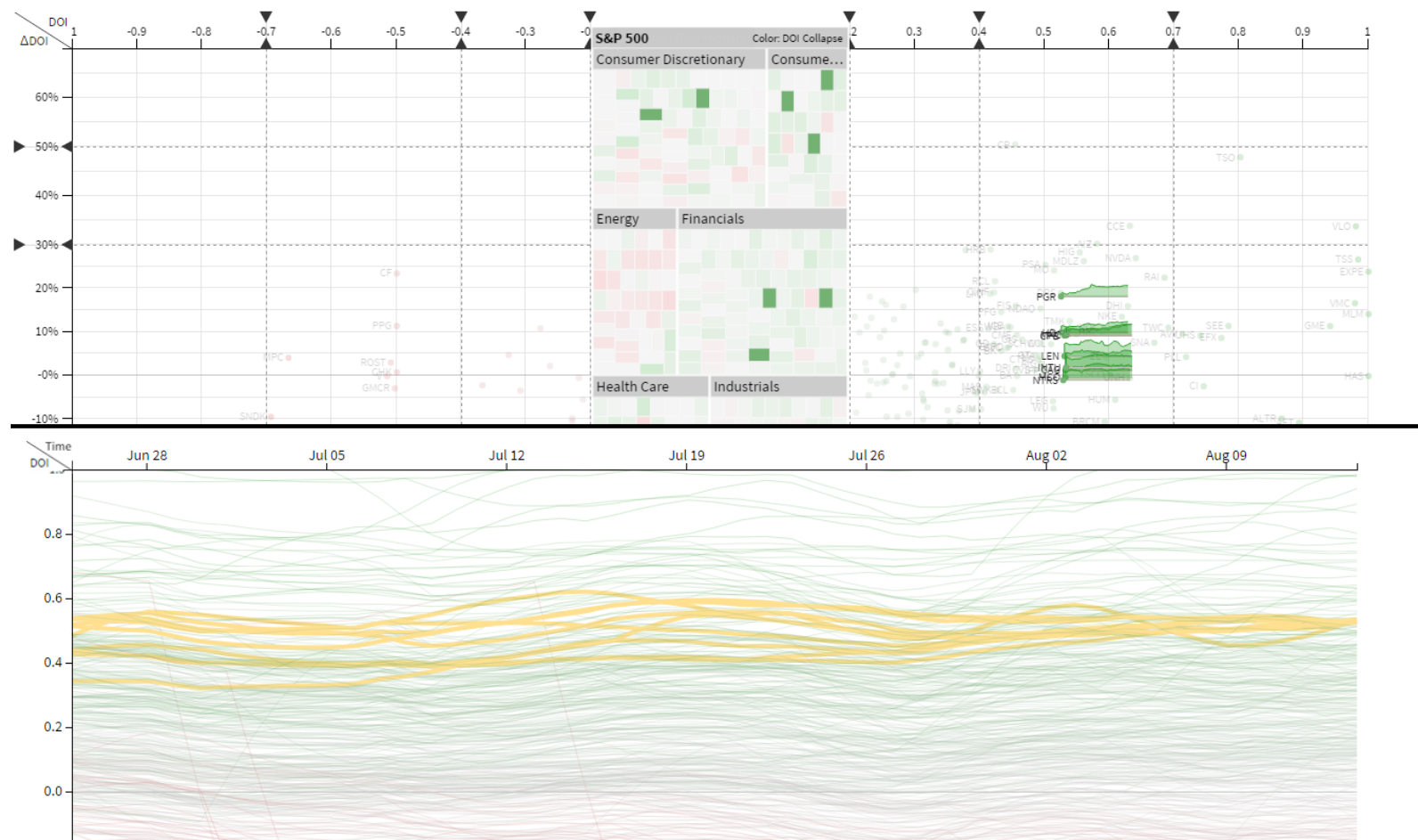
<https://thinkh.github.io/thermalplot/>

## E.g., Linking

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# ALTERNATIVE TYPES OF INTERACTION

“The user interface has to **bridge the gap** between the technical aspects of a visualization approach and the users’ mental models of the problems to be solved.”

*[TimeViz, Aigner, et al., 2011p. 110]*

“[...] user interfaces that are **consistent with users’ mental models** are vastly superior to those that are merely reflections of the implementation model.”

*[Cooper, et al., 2007, p. 30]*

## Visualization Views

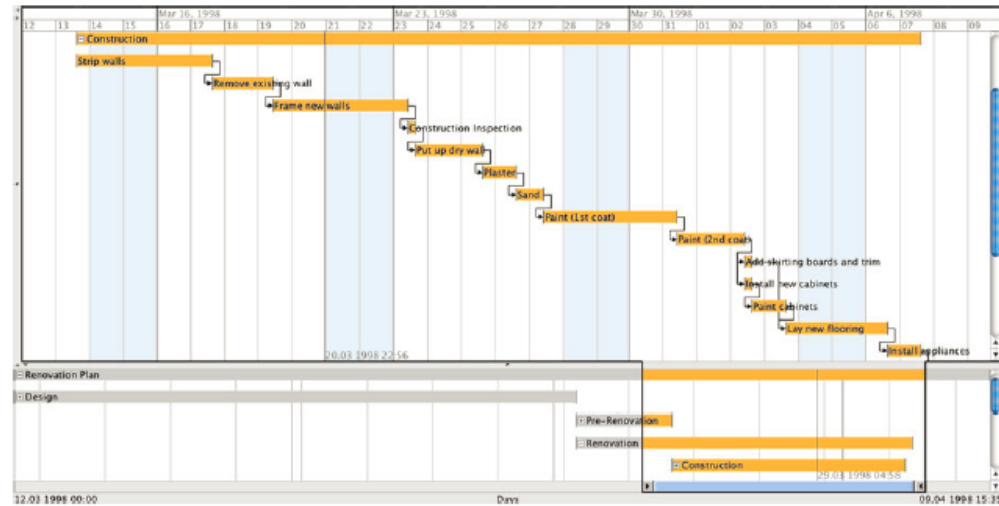
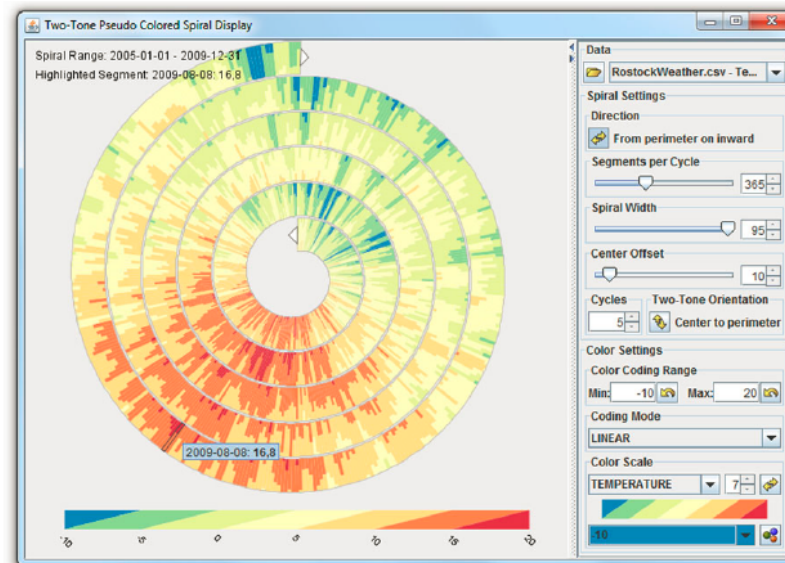


Fig. 5.2: Overview+detail. The detail view at the top shows individual steps of the construction phase of a renovation plan. In the overview at the bottom, the entire project is shown, including the design, pre-renovation, renovation, and construction phases.

## Interaction Controls

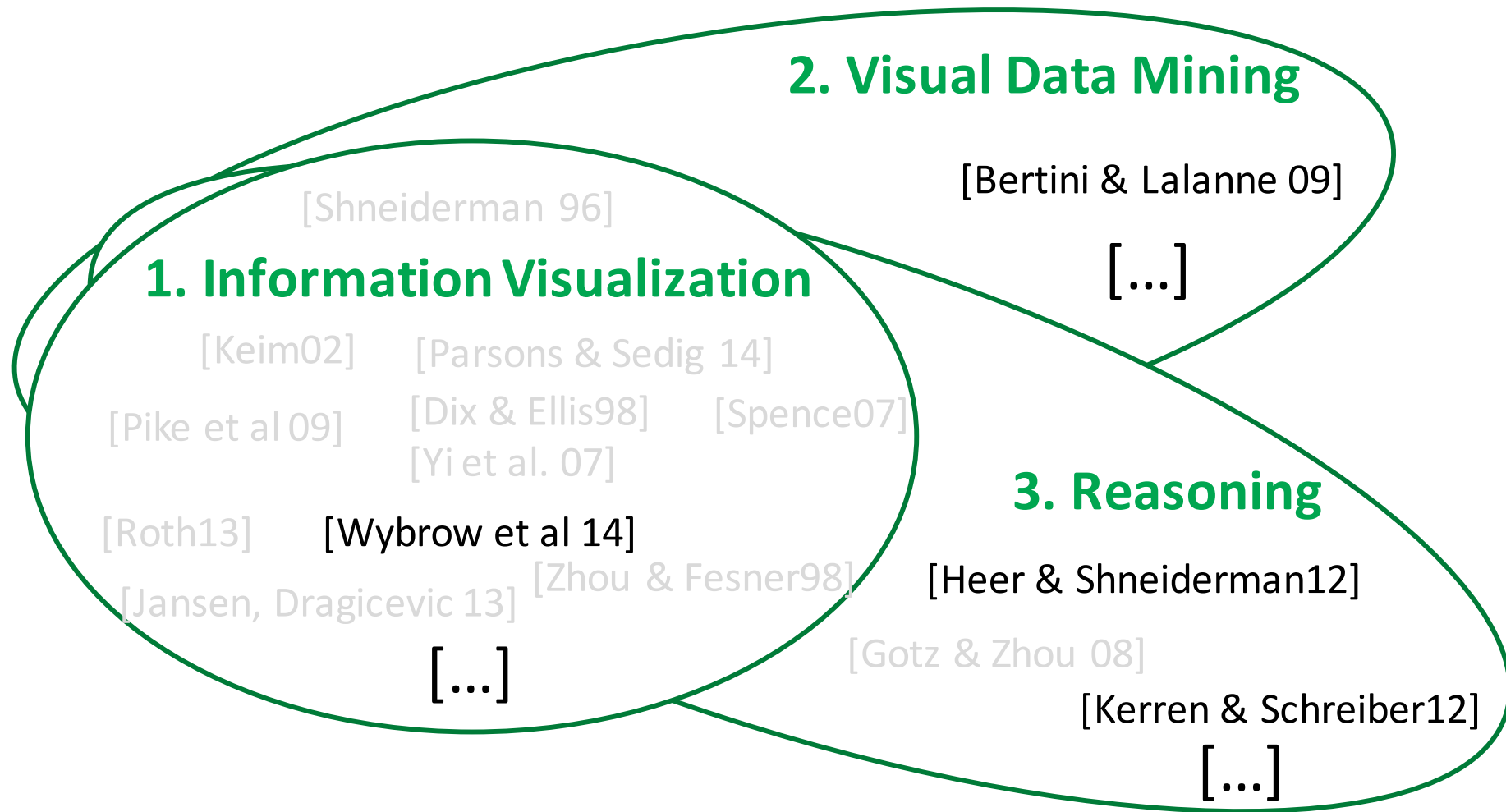


[Video](#)

Fig. 5.5: User interface for a spiral visualization. The interface consists of one spiral view and one control panel, which in turn consists of various controls to adjust visualization parameters.

# Pipeline-Focused Interaction Systematization

[BlackBox, Schulz, v. Landesberger, Baur, 2014]



# Taxonomies :: Low-Level Interactions

[Yi, Kang, Stasko, 2007]

## *Taxonomies of low-level interaction techniques*

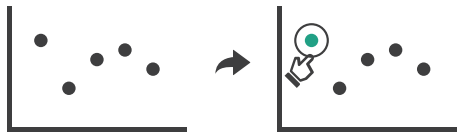
Shneiderman (1996) [37]	Overview, zoom, filter, details-on-demand, relate, history, and extract
Buja, Cook, and Swayne (1996) [9]	Focusing (choice of [projection, aspect ratio, zoom, pan], choice of [variable, order, scale, scale-aspect ratio, animation, and 3-D rotation]), linking (brushing as conditioning / sectioning / database query), and arranging views (scatter plot matrix and conditional plot)
Chuah and Roth (1996) [13]	Basic visualization interaction (BVI) operations: graphical operations (encode data, set graphical value, manipulate objects), set operations (create set, delete set, summarize set, other), and data operations (add, delete, derived attributes, other)
Dix and Ellis (1998) [15]	Highlighting and focus, accessing extra information – drill down and hyperlinks, overview and context, same representation / changing parameters, same data / changing representation, linking representation – temporal fusion
Keim (2002) [24]	Dynamic projections, interactive filtering, interactive zooming, interactive distortion, interactive linking and brushing
Wilkinson (2005) [54]	Filtering (categorical/continuous/multiple/fast filtering), navigating (zooming/panning/lens), manipulating (node dragging/categorical reordering), brushing and linking (brush shapes/brush logic/fast brushing), animating (frame animation), rotating, transforming (specification/assembly/display/tap/2 taps/3 taps)

# Interaction Types

[TimeViz, Aigner, et al., 2011]

[Munzner, 2014]

## Direct Manipulation

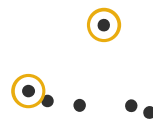


## Brushing & Linking



## Dynamic Querying

→ Present → Locate → Identify



# Interaction Types

[Stasko, 2011, Lecture Slides]

[Dix & Ellis, AVI 1998]

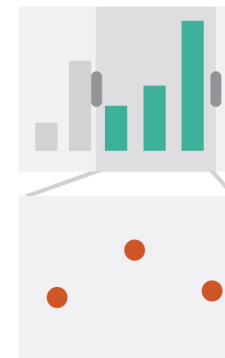
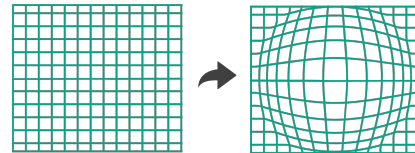
[Munzner, 2014]

**Highlighting and focus** – discover links in multiple views

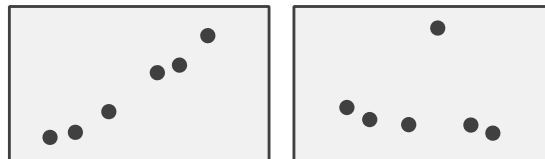


**Accessing extra info** – drill down and hyperlinks

**Overview and context** – zooming and fisheyes



**Same representation** – changing parameters



**Linking representations** – temporal fusion, superimposition



## **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



# Few's Interaction Types

[Few, Ch 4, 2009]

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

# Taxonomies :: Dimensions, Operators, & User Tasks

[Yi, Kang, Stasko, 2007]

## *Taxonomical dimensions of interaction techniques*

Tweedie (1997) [47]	Interaction types (manual, mechanical, instructable, steerable, and autonomous), directness (direct and indirect manipulation), and interaction space (2D and 3D)
Spence (2007) [38]	Interaction modes (continuous, discrete, and composite interaction)

## Additional task taxonomies

[McEachren 1995]

[Andrienko & Andrienko 2006]

## *A taxonomy of interaction operations*

Ward and Yang (2004) [50]	interaction operators (navigation, selection, distortion), interaction spaces (screen-space, data value-spaces, data structure-space, attribute-space, object-space, and visualization structure-space), and interaction parameters (focus, extents, transformation, and blender)
---------------------------	---

## *Taxonomies of user tasks*

Zhou and Feiner (1998) [56]	Relational visual tasks (associate, background, categorize, cluster, compare, correlate, distinguish, emphasize, generalize, identify, locate, rank, reveal, switch) and direct visual organizing and encoding tasks (encode)
Amar, Eagan, and Stasko (2005) [4]	Retrieve value, filter, compute derived value, find extremum, sort, determine range, characterize distribution, find anomalies, cluster, and correlate

# Interaction Devices

Adapted [Aigner, Presentation 2010]  
[Shneiderman and Plaisant, 2005]

Keyboard devices

Pointing devices

Direct control devices

easy to learn and use, but hand may obscure display

*e.g., Lightpen; Touchscreens; Stylus*

Indirect control devices

takes time to learn

*e.g., Mouse; Touchpad; Drawing tablet*

Novel devices and strategies

special purposes

*e.g. Foot controls; Eye tracking; 3D trackers; DataGloves; Boom Chameleon; Haptic*

*feedback; Tangible user interfaces; Digital paper; Virtual Reality interfaces; Augmented Reality devices*

Speech and auditory interfaces

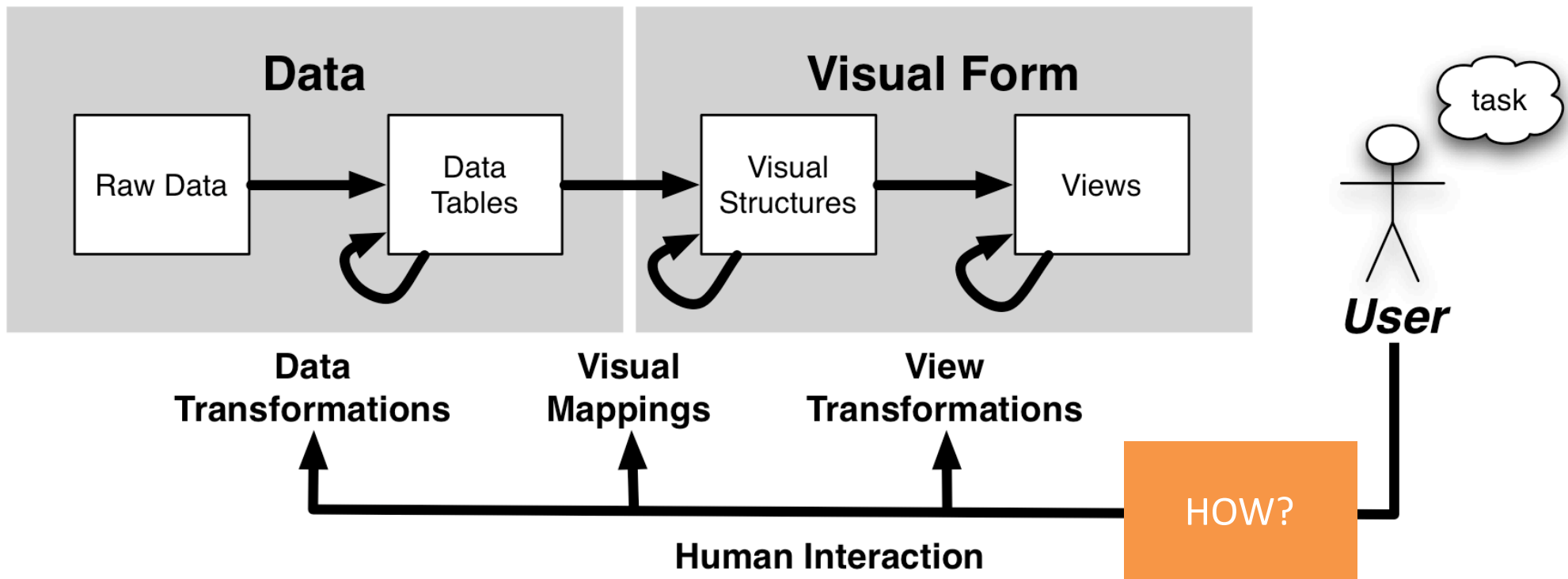
Displays – Headsets, ...

Printers – 3D printers, 3D printing stylus, ...

# MODELING INTERACTION

# InfoVis Reference Model

[Card et al., 1999]



*User interaction can feed back into any level*

# Integrating Interaction in Visualizations

Adapted [Schulz, v. Landesberger, Presentation 2014]

Formalizing interactions to

- Derive information from interaction

- Recreate visualization pipelines/states

- Formulate visual histories

Metaphors in interaction design:

- Mental model that both designers and users adhere to

- Users can rely on knowledge about how one thing works to operate the other

- Shortcut towards understanding and memorizing an interface

## **Why do we need to model interaction?**

To capture requirements (when the user does this,  
then the system should do that)

- ... to develop by

- ... to evaluate against

To build workflows for passing on interaction  
knowledge and providing user guidance

To automatically generate UIs

# Interaction Models :: Types

Adapted [Schulz, v. Landesberger, Presentation 2014]

## **What is modeled?**

Extent: Single action or whole workflow

Granularity: Concrete events or general task

## **How is it modeled?**

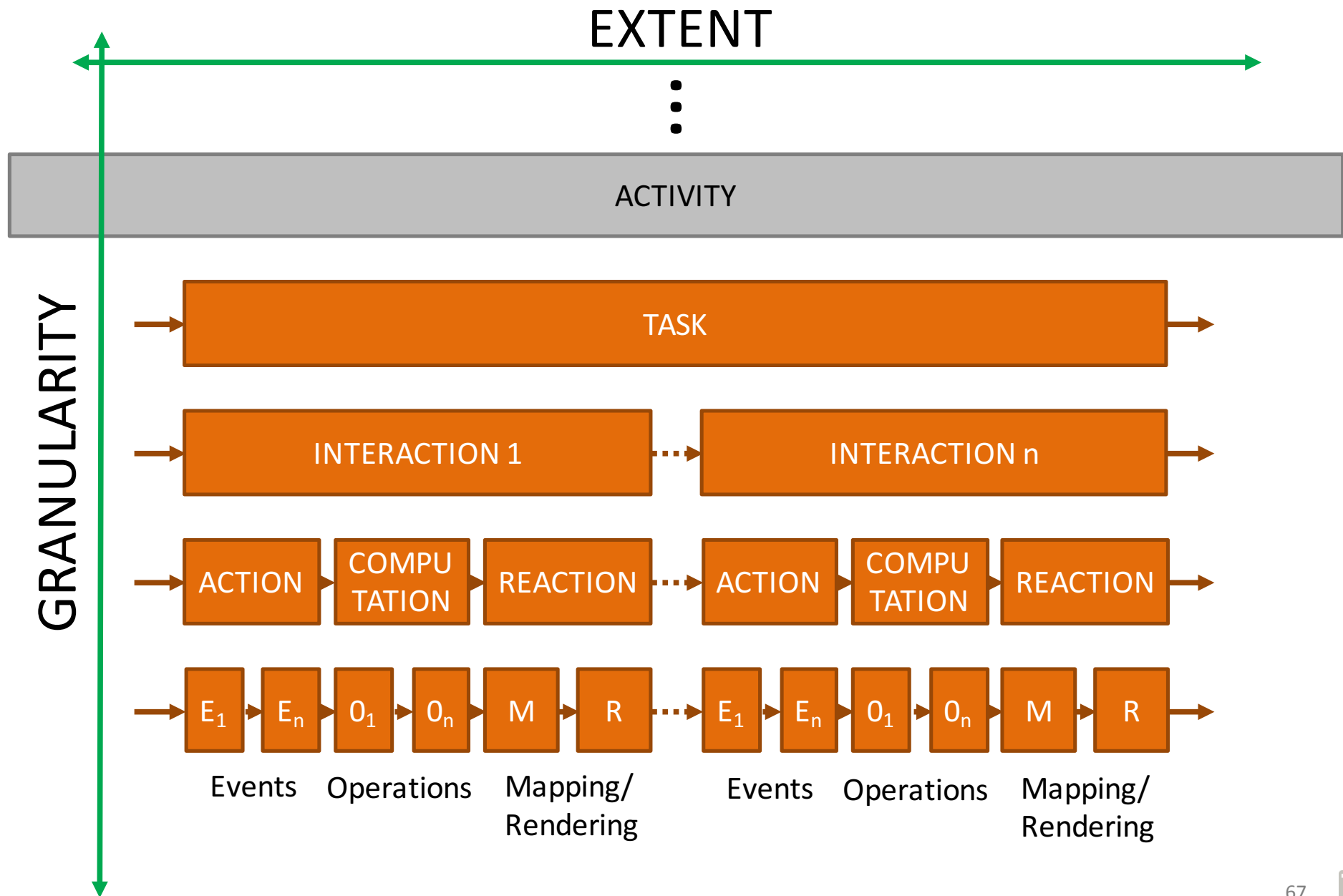
Diagrammatically: Sequence/Activity diagram

Symbolically: Notations



# Interaction Models

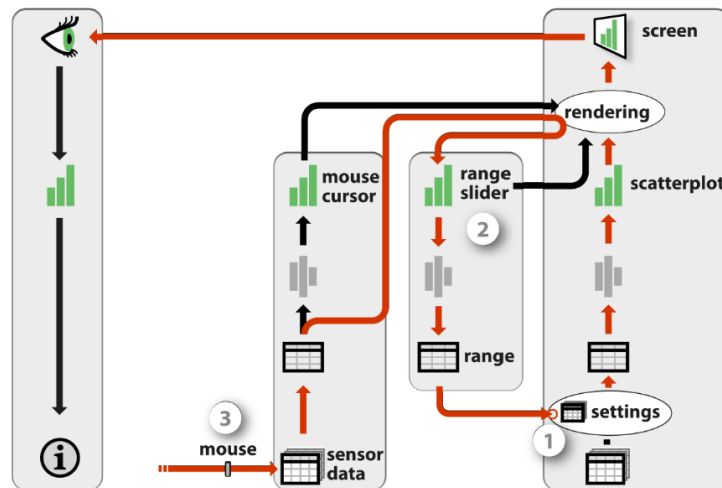
Adapted [Schulz, v. Landesberger, Presentation 2014]



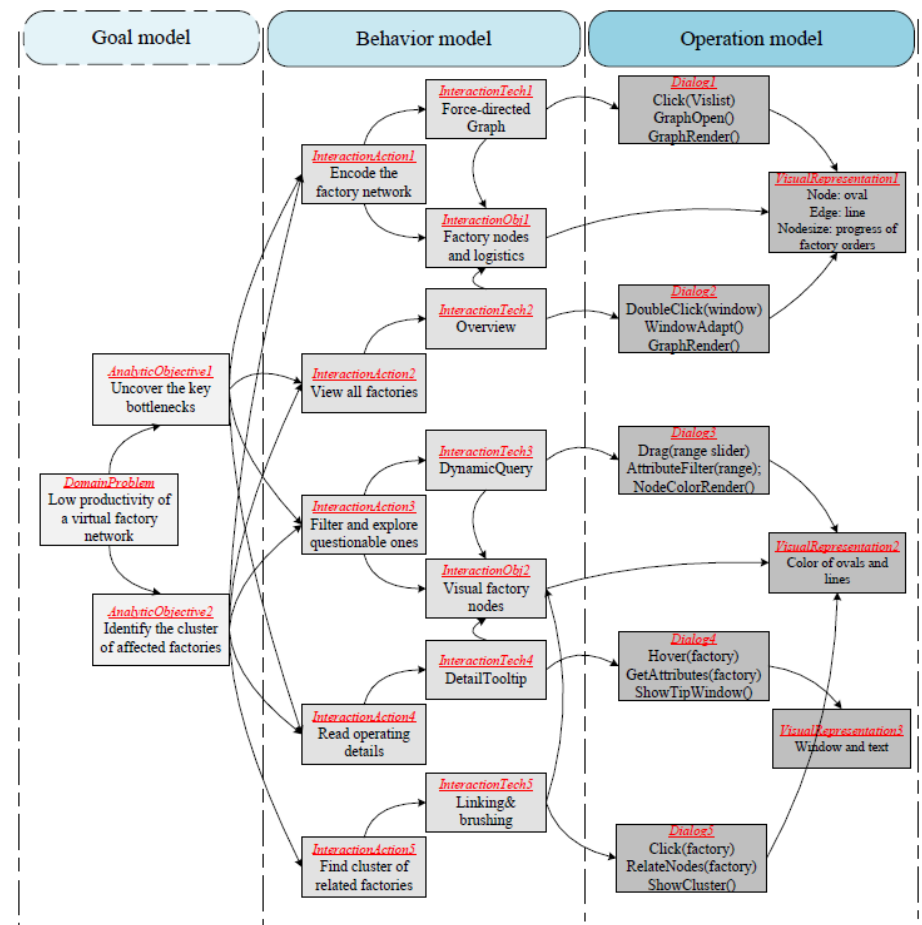
# Interaction Models :: Utilization

Adapted [Schulz, v. Landesberger, Presentation 2014]

## Integration into InfoVis Pipeline



## Multi-level Interaction Model Stored Interaction states



# Interaction History

Adapted [Schulz, v. Landesberger, Presentation 2014]

Recording user interaction history

Utilize interaction history and feed back to user:

- Undo / Redo

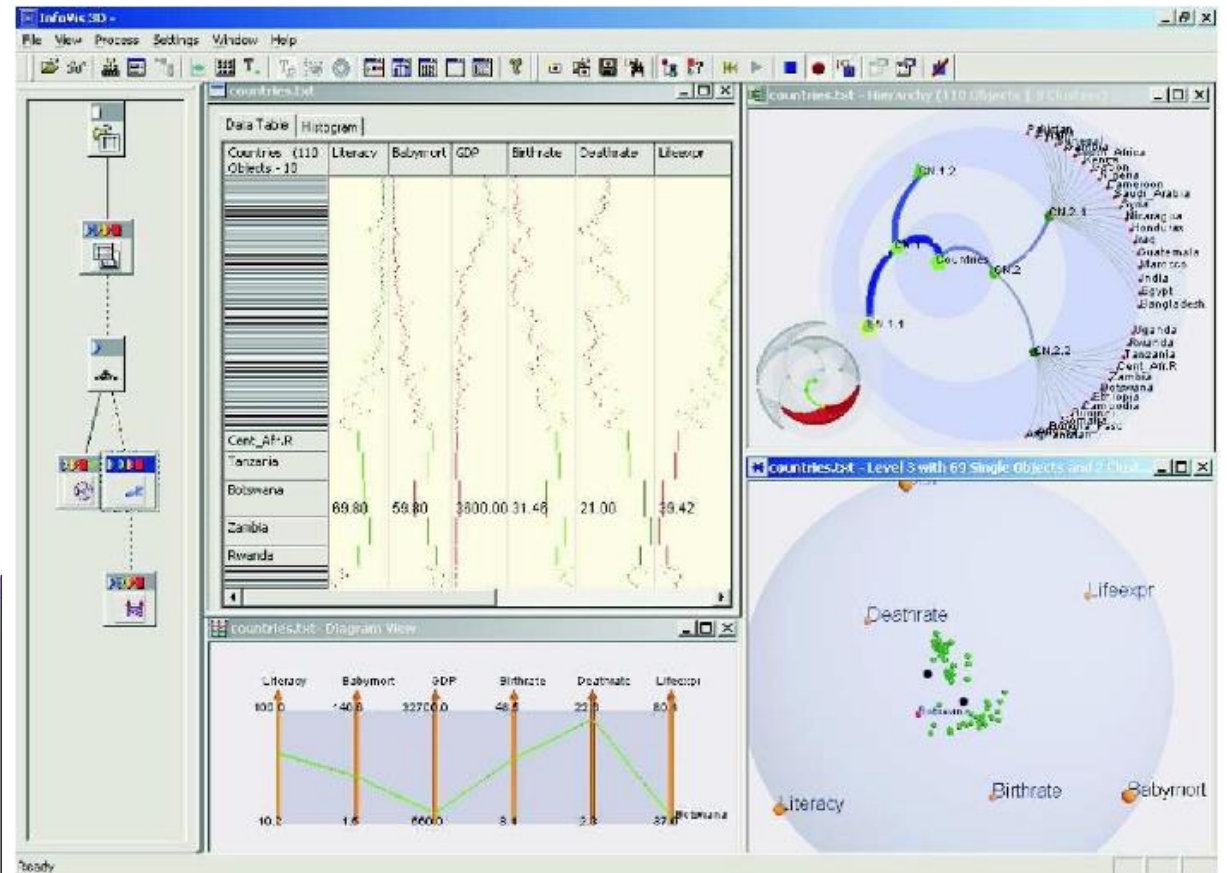
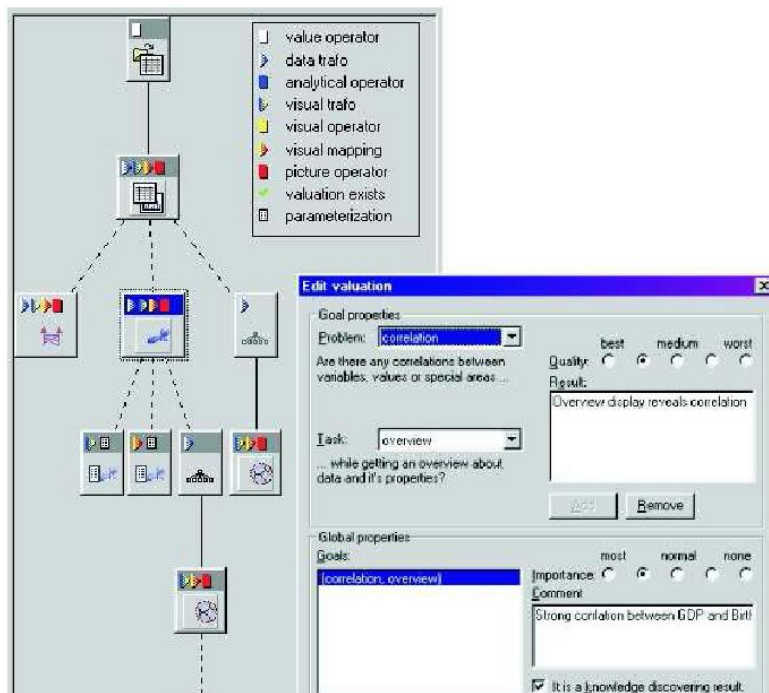
- Utilizing collection of history to provide users with guidance in further analysis

# Recording Interaction History

Adapted [Schulz, v. Landesberger, Presentation 2014]

What and how is interaction recorded and how is this information presented to the user?

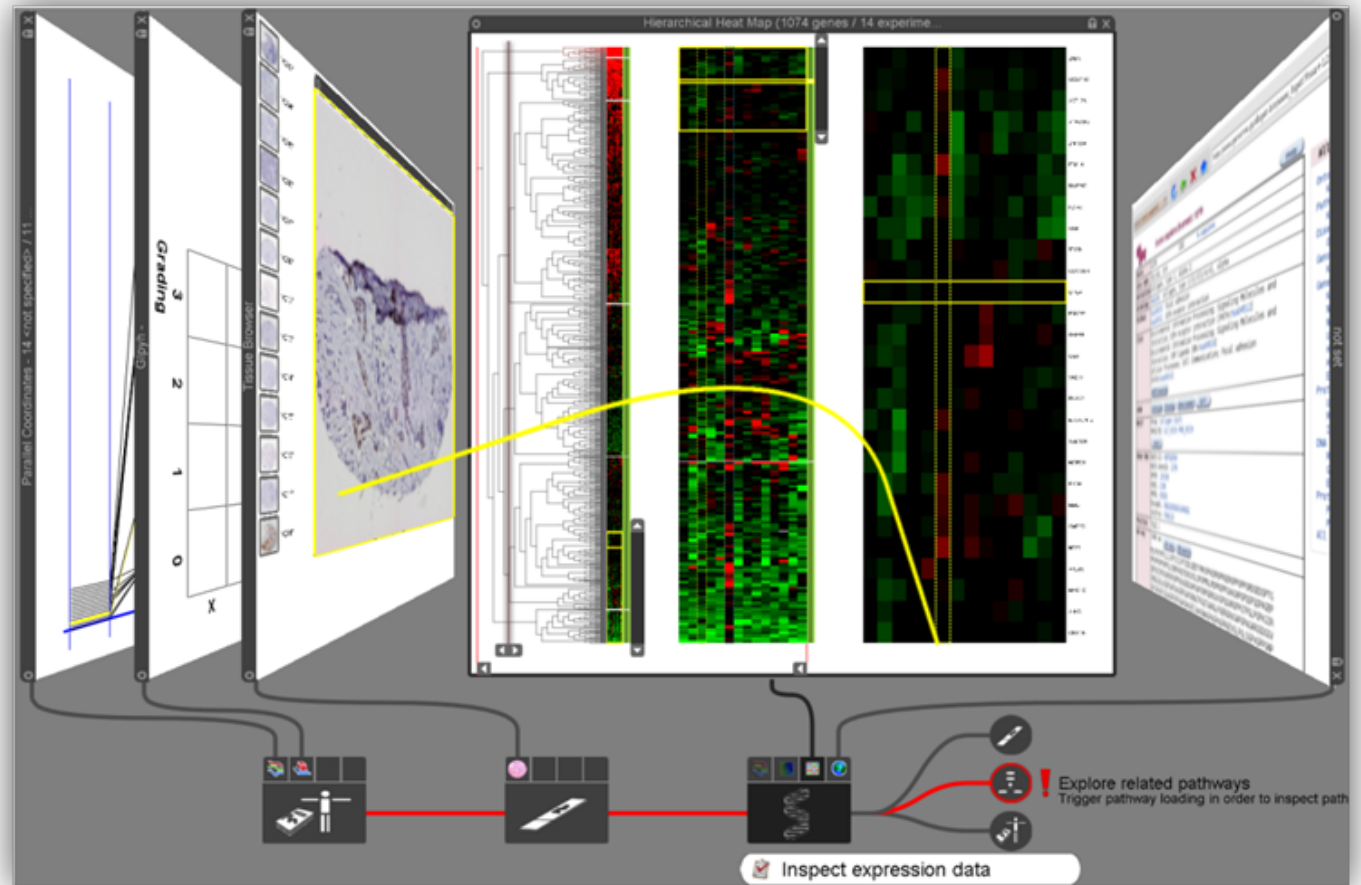
Multiple Levels of detail  
Scope - global vs. local



# Utilizing Collections of Histories

Analyze past interaction histories to provide:

- Guidance context
- Guidance domain
- Guidance target
- Guidance degree



[Streit et al. 2012]

# Design Guidelines for Fluid Interaction

[Elmqvist et al., 2011]

DG1: Use smooth animated transitions between states.

DG2: Provide immediate visual feedback on interaction.

DG3: Minimize indirection in the interface.

DG4: Integrate user interface components in the visual representation.

DG5: Reward interaction.

DG6: Ensure that interaction „never ends“.

DG7: Reinforce a clear conceptual model.

DG8: Avoid explicit mode changes.

# INTERACTION LIBRARIES

# Incorporating Interactions

Visualization libraries started incorporating interaction models

Explicit interactivity

Vega-Lite - grammar of interactive graphics

Implicit interactivity

d3fc, d3panels — d3 based, implicitly wrapped interactions

bokeh — python



## Interaction through property description

```
{
  "encoding": {
    "color": {
      "condition": {
        "field": "weather",
        "title": "Weather",
        "scale": {
          "domain": ["sun", "fog", "drizzle", "rain", "snow"],
          "range": ["#e7ba52", "#a7a7a7", "#aec7e8", "#1f77b4", "#9467bd"]
        },
        "selection": "click",
        "type": "nominal"
      },
      "value": "lightgray"
    },
    "x": {"aggregate": "count", "type": "quantitative"},
    "y": {"field": "weather", "type": "nominal"}
  },
  "width": 600,
  "mark": "bar",
  "selection": {"click": {"encodings": ["color"], "type": "multi"}},
  "transform": [{"filter": {"selection": "brush"}}]
}
```

Seattle Weather - Interactive

# FOCUS+CONTEXT

## DISTORTION, OVERVIEW AND DETAIL, ETC.

## Scale

### **Many Data Sets are too Large to Visualize on one Screen**

May Simply be too many cases

May be too many variables

May only be able to highlight particular cases or particular variables, but viewer's focus may change from time to time

## Potential solutions lie in

**Representation**

**Interaction**

**Both**

# From Problems to Goals

## Problems

- Scale : Large Data Sets

- Small Window as Single Access-Point

- Difficult to Interpret Single Information Items when Viewing it Outside of its Context

## Goals

- Allow the User to Examine a Local Area in Detail without loss of overall context Information

- Facilitate Navigation

# Focus and Context (F+C)

## Usually

Either Detail or Full Picture

Lose Context When Zooming

⇒ Zoom In and Out a Lot

## Focus+Context

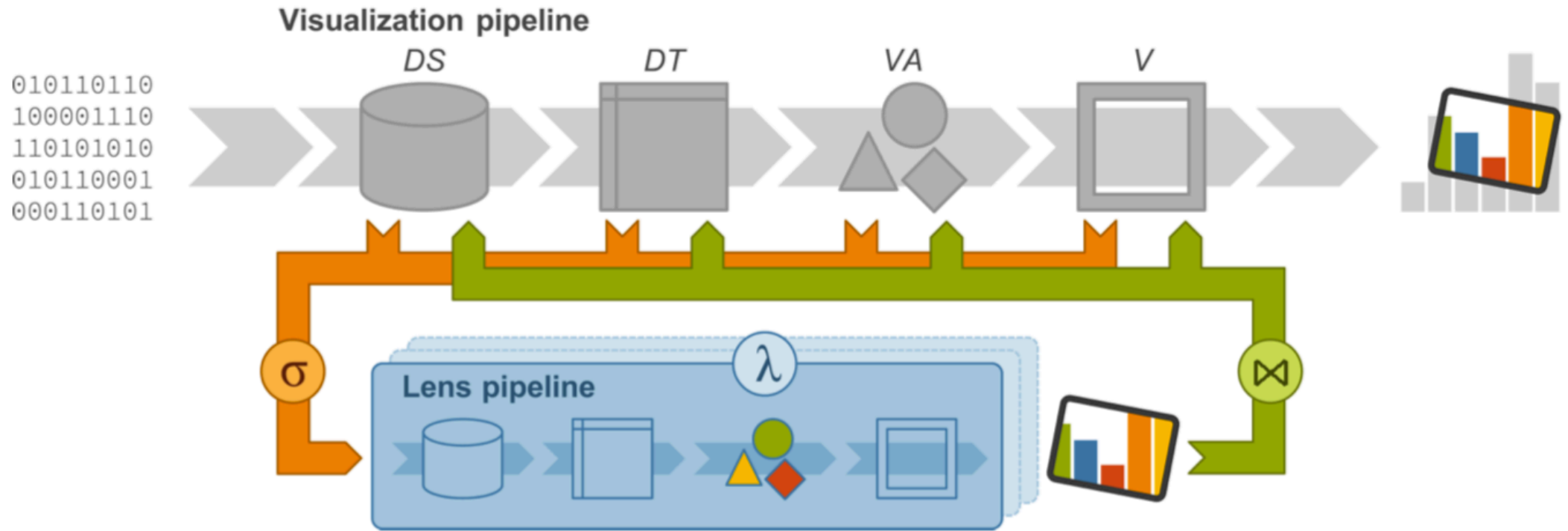
Integrate Detail and  
Big Picture

Make Better Use of  
Available Screen Space



# Lens Pipeline

[Tominski et al., 2017]



lens function  $\lambda$  to generate a lens effect.

Attached to a standard visualization pipeline via a selection  $\sigma$  and join  $\bowtie$ .

# Focus+Context Techniques

## Elide Data

Omit items from view completely

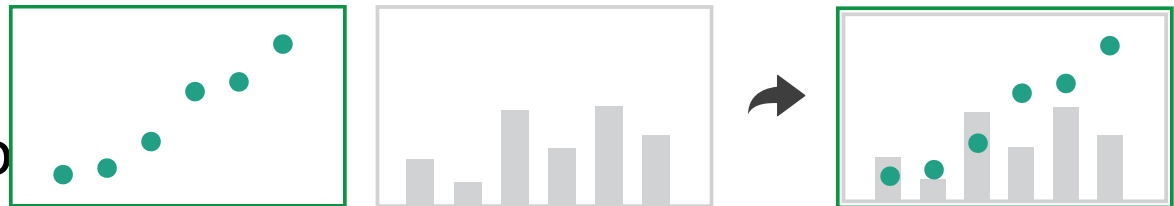
Summarize items using dynamic aggregation

Focused items shown in detail



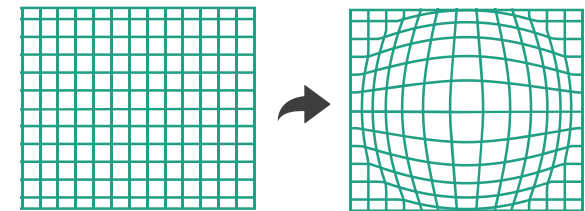
## Superimpose Layers

Focus layer(s) limited to local region(s)



## Distort Geometry

Single view using geometric distortion on focus regions



# Focus+Context :: Elide

## Elide Data

Omit items from view completely

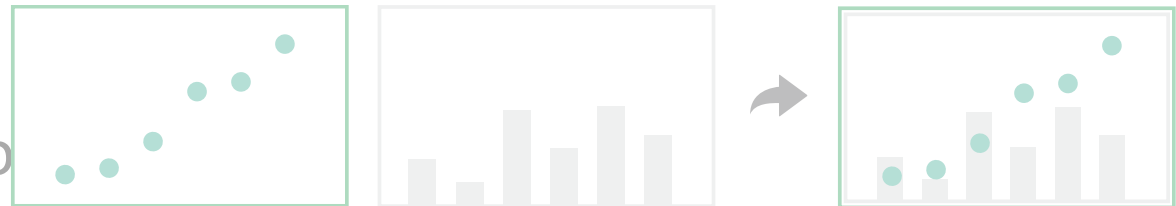
Summarize items using dynamic aggregation

Focused items shown in detail



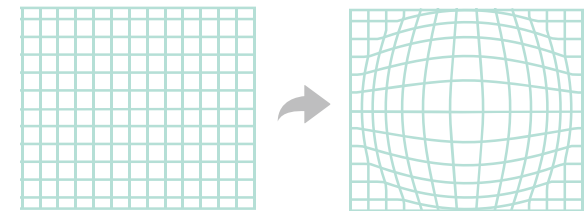
## Superimpose Layers

Focus layer(s) limited to local region(s)



## Distort Geometry

Single view using geometric distortion on focus regions



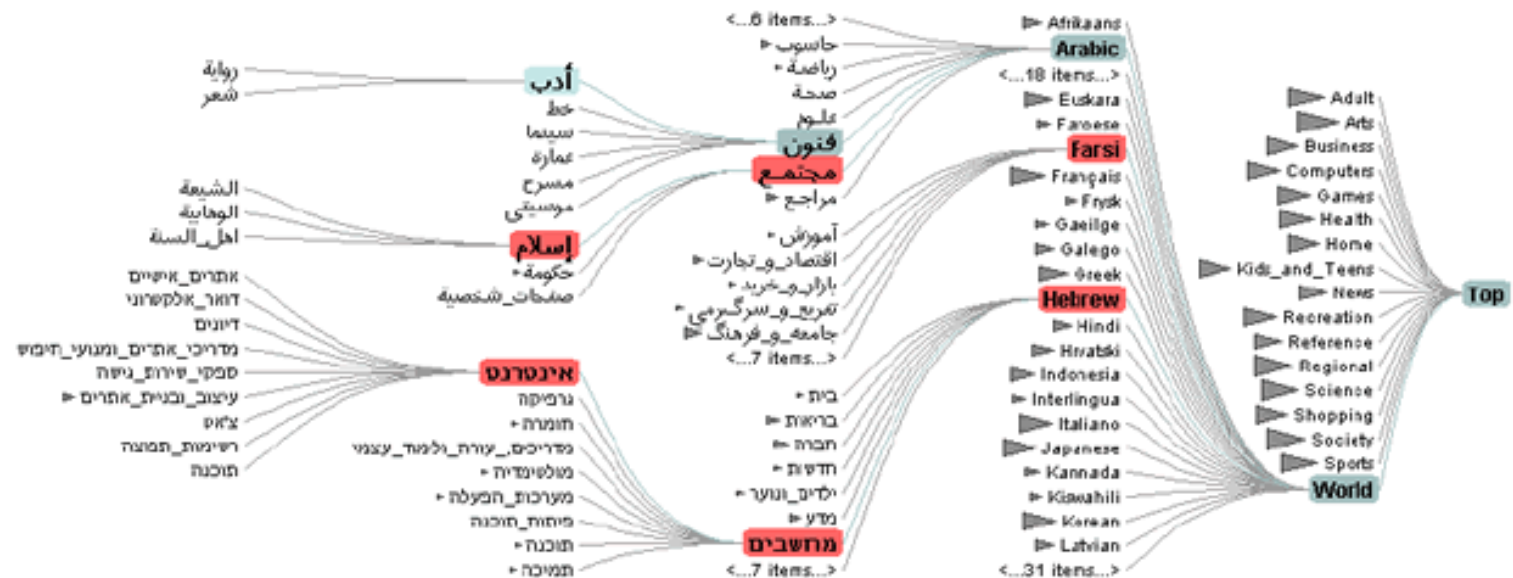


# Focus+Context :: Elide

Degree of interest (DOI) function

One or more focus points

Inherent functions determine aggregation degree, not the DOI function itself (based on parameters)



[Heer and Card, 2004]

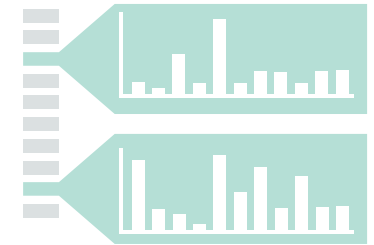
# Focus+Context :: Superimpose

## Elide Data

Omit items from view completely

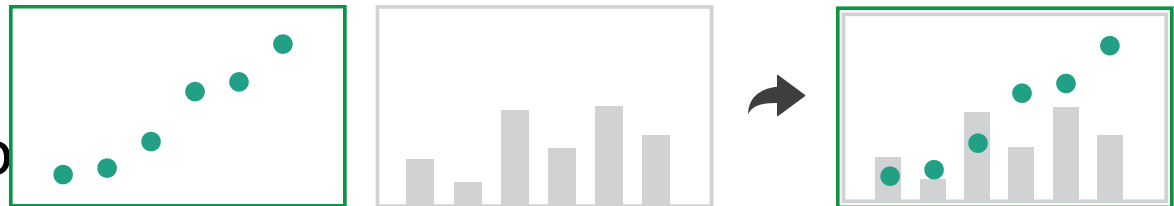
Summarize items using dynamic aggregation

Focused items shown in detail



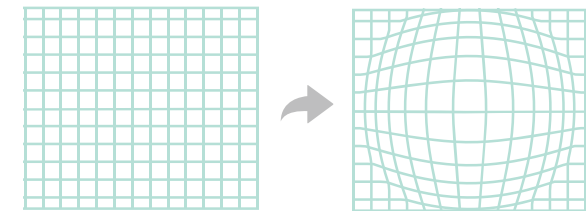
## Superimpose Layers

Focus layer(s) limited to local region(s)



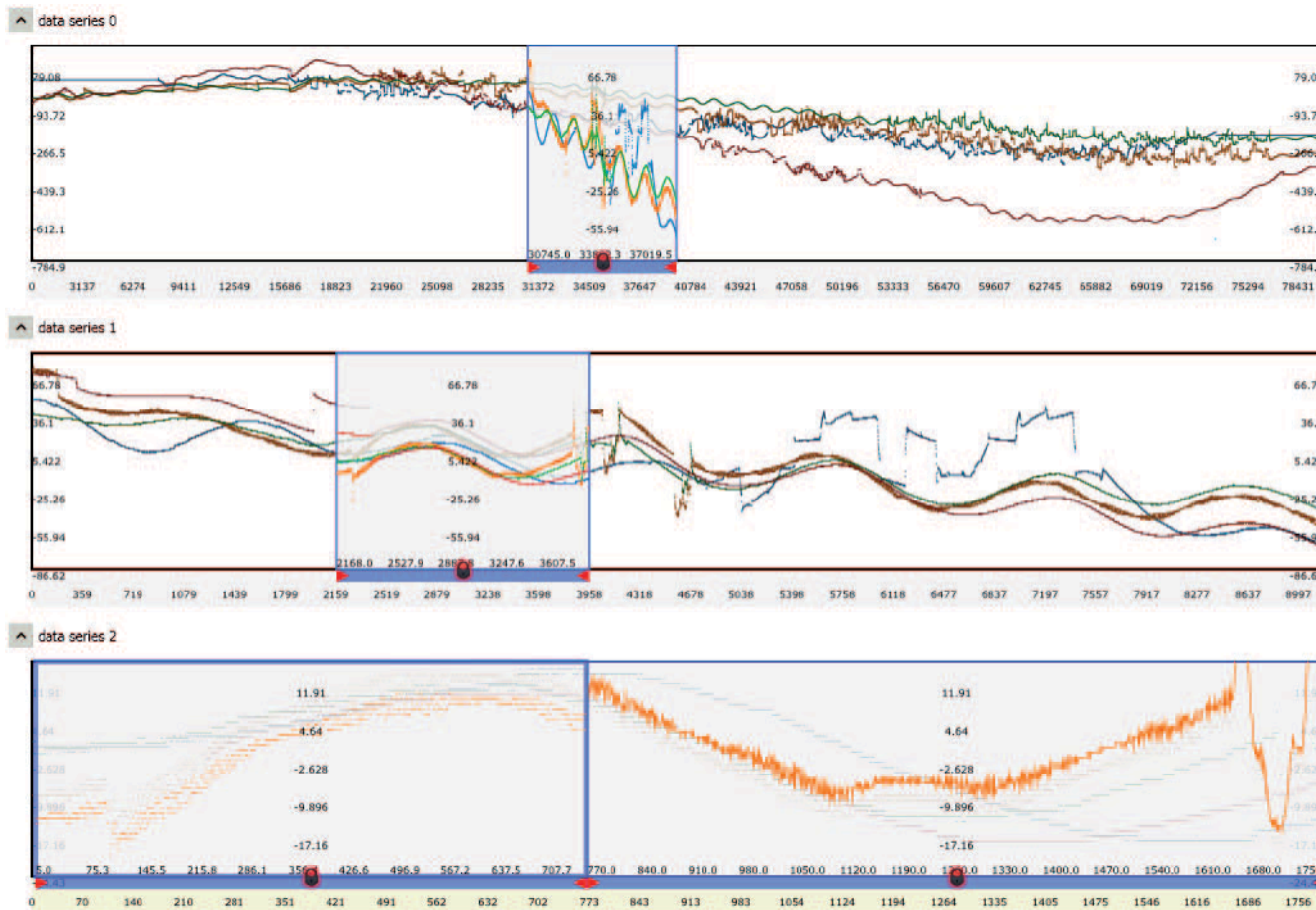
## Distort Geometry

Single view using geometric distortion on focus regions



# Focus+Context :: Superimpose

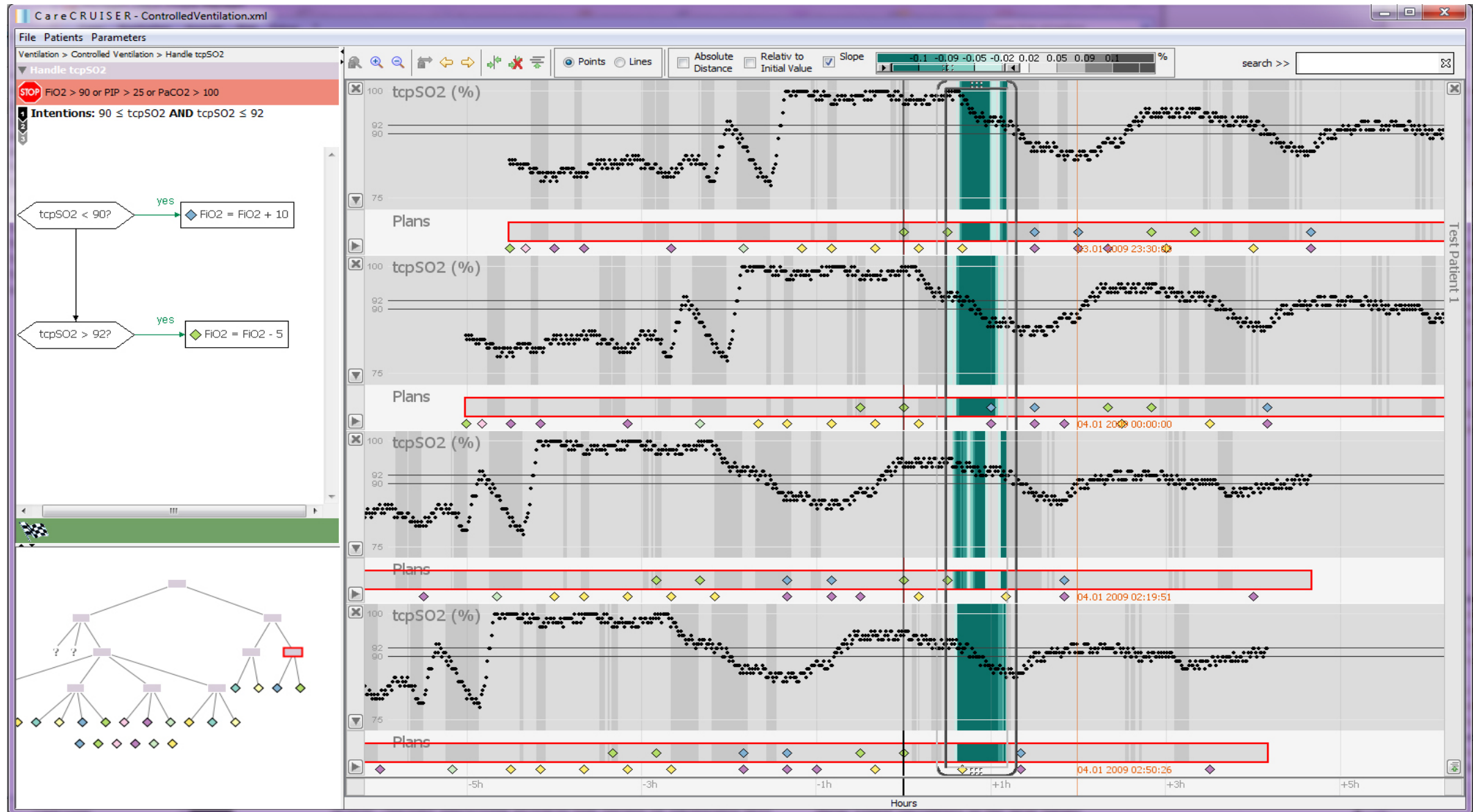
Utilize zoom glasses or magic lenses for limited local regions



[Zhao et al., 2011]

# Focus+Context :: Superimpose

CareCruiser [Gschwandtner, et al., 2010-2011]



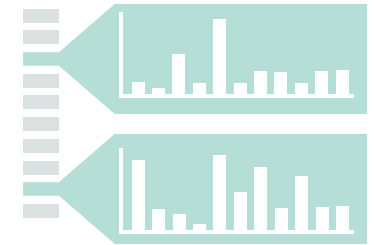
# Focus+Context :: Distort Geometry

## Elide Data

Omit items from view completely

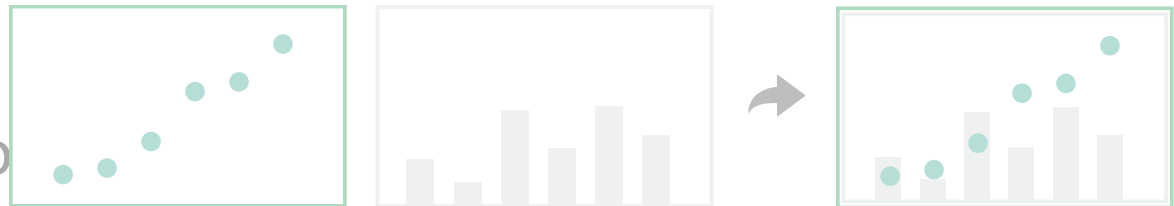
Summarize items using dynamic aggregation

Focused items shown in detail



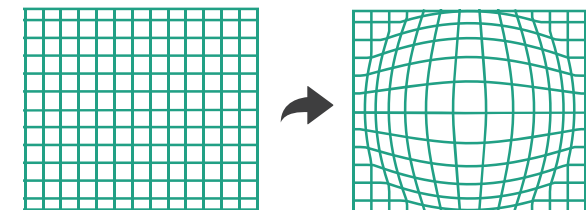
## Superimpose Layers

Focus layer(s) limited to local region(s)



## Distort Geometry

Single view using geometric distortion on focus regions



# Focus+Context :: Distort Geometry

## Basic Idea

Distortion of an Image to Allow the Visualization of Larger Amounts of Data

Polyfocal Display

[Kadmon & Shlomi 1978]

Bifocal Display

[Spence & Apperley 1982]

Fisheye View

[Furnas, 1981/1986]

Perspective Wall

[Mackinlay et al. 1991]

Graphical Fisheye View

[Sarkar & Brown, 1992]

***Abstract*** the Data

to Ensure Information Visibility

Apply a ***Transformation Function***

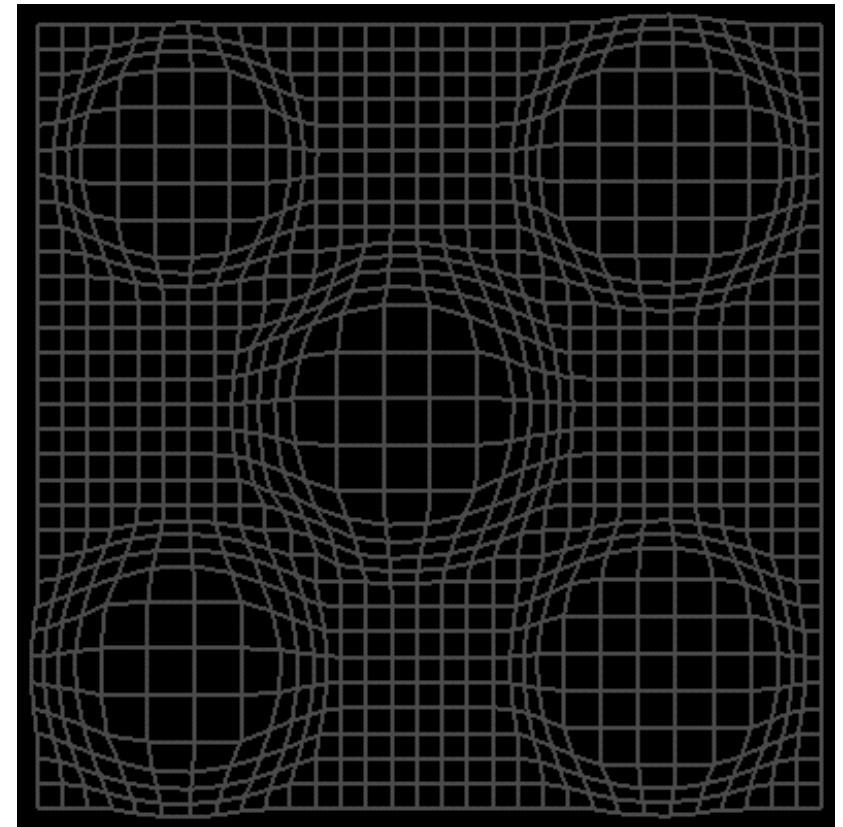
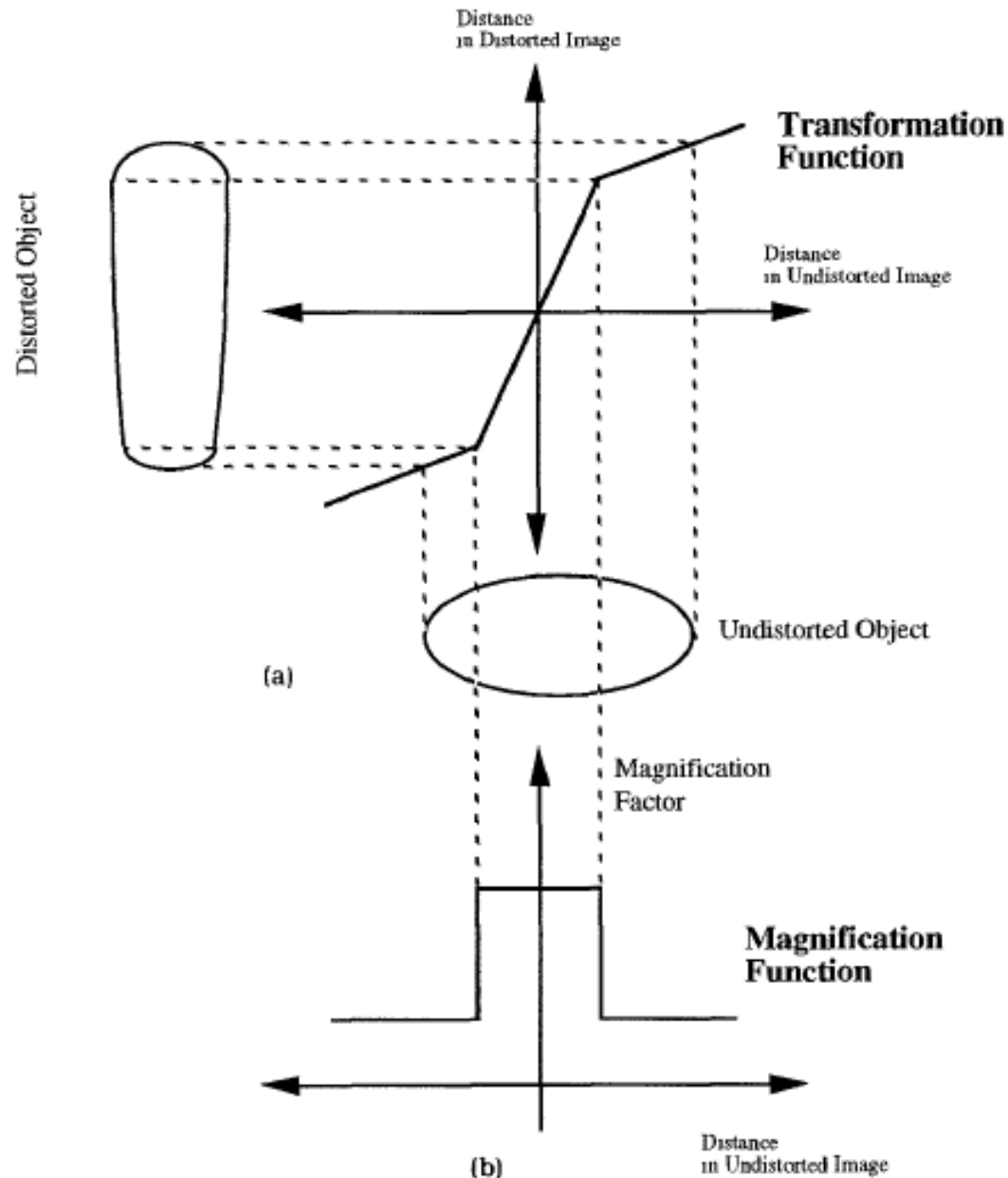
to the Abstract Data

Apply a ***Magnification Function***

to the Transformed Data

# Distortion :: Methods

[Leung & Apperly, 1994]



T. Alan Keahey  
[holisticsofa](http://holisticsofa.com)

Fig. 3. (a) The transformation of an elliptic object by applying the transformation function of a Bifocal Display in one dimension; (b) the corresponding magnification function of the Bifocal Display.



# Distortion :: History

1982 Bifocal Display (Spence & Apperley)

1986 Fisheye Views (Furnas)

1991 Perspective Wall

(MacKinlay, Robertson, Card)

1992 Fisheye Views for Graphs

(Sarkar & Brown)

1993 Stretching rubber sheet:

(Sarkar, Snibbe, Reiss)

Document Lens +

3D Interactive Animation

(Robertson, MacKinlay)

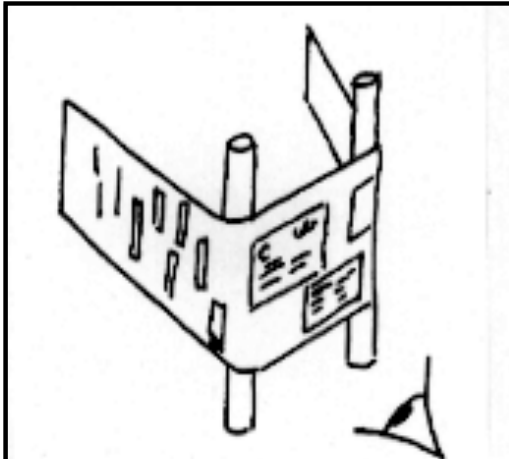
21DF-browser

(Huang and Quan)

Icon Panel Fisheye Distortion

# Distortion :: History

## 1982 Bifocal Display (Spence & Apperley)



Fisheye Views (Furnas)

1991 Perspective Wall

(MacKinlay, Robertson, Card)

1992 Fisheye Views for Graphs

(Sarkar & Brown)

1993 Stretching rubber sheet:

(Sarkar, Snibbe, Reiss)

Document Lens +

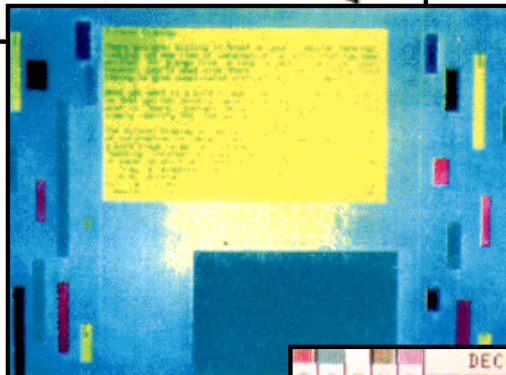
3D Interactive Animation

(Robertson, MacKinlay)

21DF-browser

(Huang and Quan)

Icon Panel Fisheye Distortion

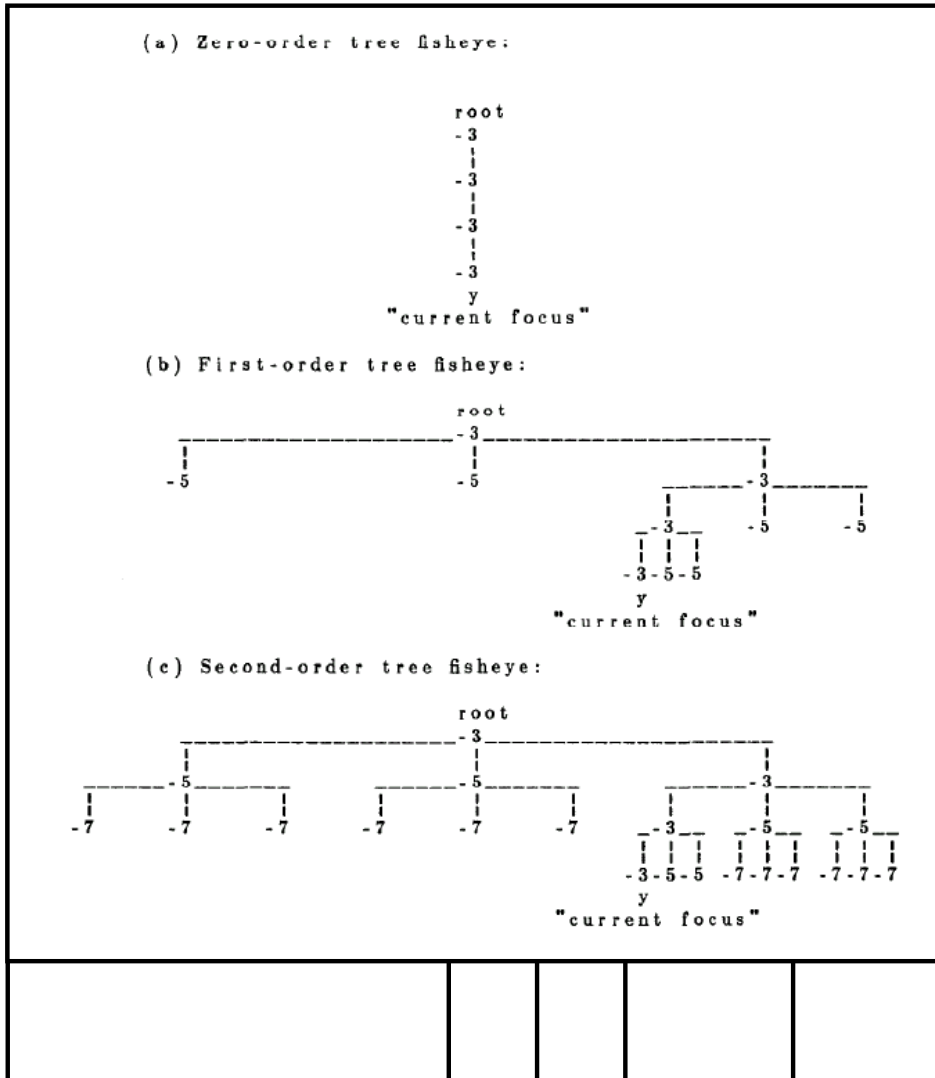


DECEMBER 1980											
A	S	D	N	D	N	I	E	E	E	E	E
U	E	C	D	E	07	I	E	E	E	E	E
G	P	T	V	C	TU						
					08						
					U	09	S	E	T	U	P
					TH		R	E	C	O	R
					10						
					F	11	L	E	C	T	U
					SA						
					12						
					SU						
					13						

# Distortion :: History

## 1982 Bifocal Display (Spence & Apperley)

## 1986 Fisheye Views (Furnas)



ertson, Card)

## Rules for Graphs

**Brown)**

## hg rubber sheet:

ar, Snibbe, Reiss)

## Pinpoint Lens +

# Interactive Animation

rtson, MacKinlay)

## browser

(Huang and Quan)

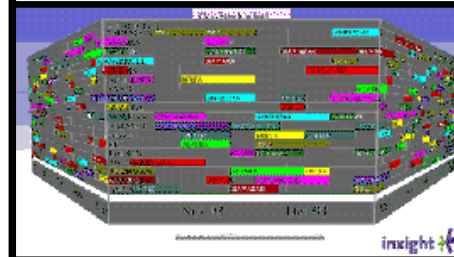
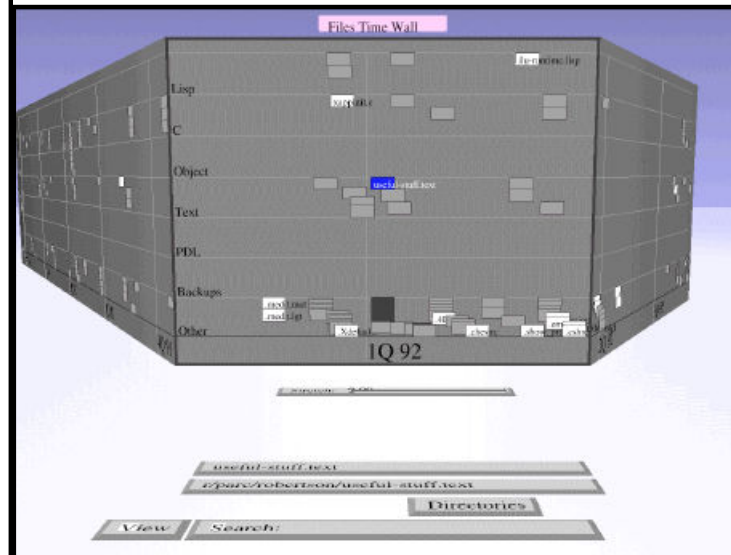
## Icon Panel Fisheye Distortion

# Distortion :: History

1982 Bifocal Display (Spence & Apperley)

1986 Fisheye Views (Furnas)

1991 Perspective Wall  
(MacKinlay, Robertson, Card)



F-browser  
(Huang and Quan)

Icon Panel Fisheye Distortion

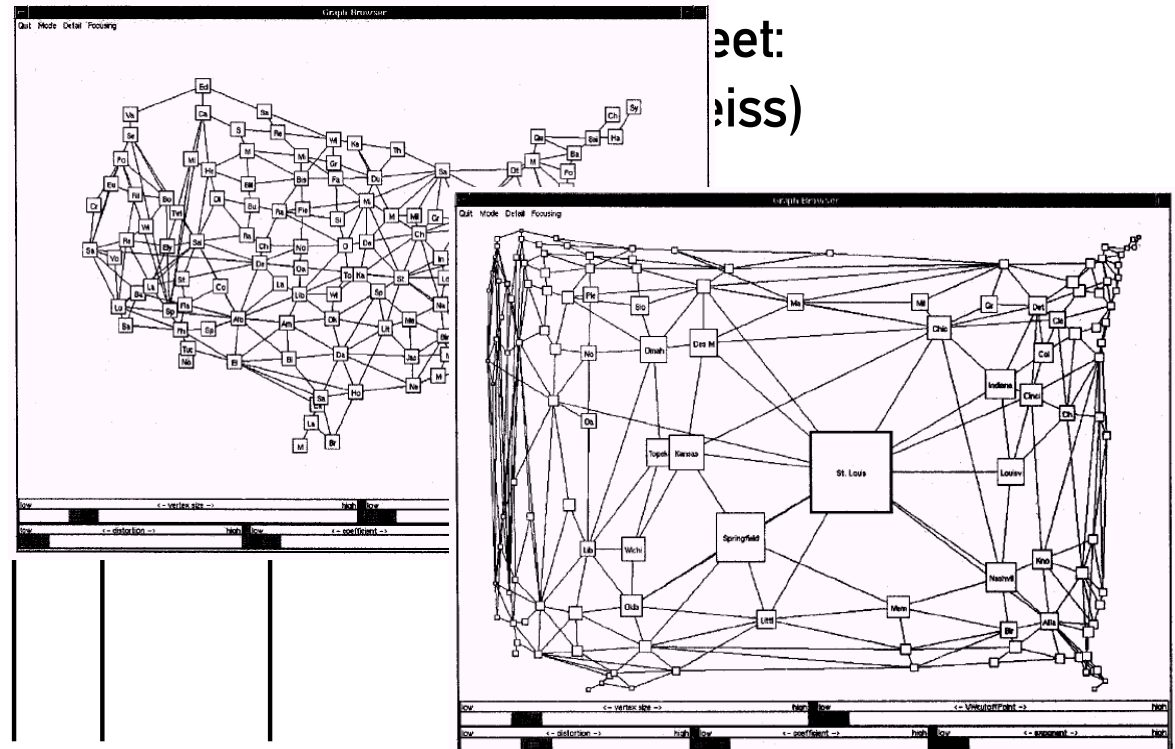
# Distortion :: History

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1991 Perspective Wall  
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1992 Fisheye Views for Graphs  
(Sarkar & Brown)

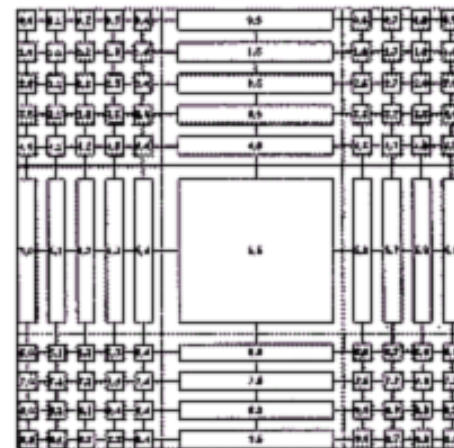
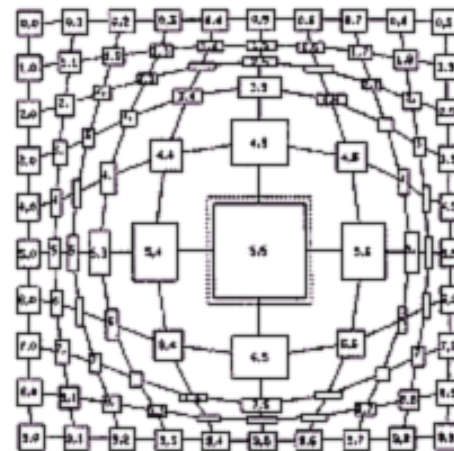
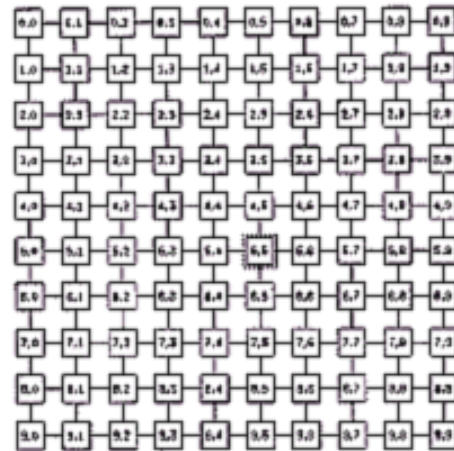


et:  
miss)

# Distortion History

1982 Bifocal Display

1986



as)

erspective Wall

MacKinlay, Robertson, Card)

92 Fisheye Views for Graphs  
(Sarkar & Brown)

1993 Stretching rubber sheet:  
(Sarkar, Snibbe, Reiss)

Document Lens +  
3D Interactive Animation  
(Robertson, MacKinlay)

21DF-browser  
(Huang and Quan)

Icon Panel Fisheye Distortion

# Distortion :: History

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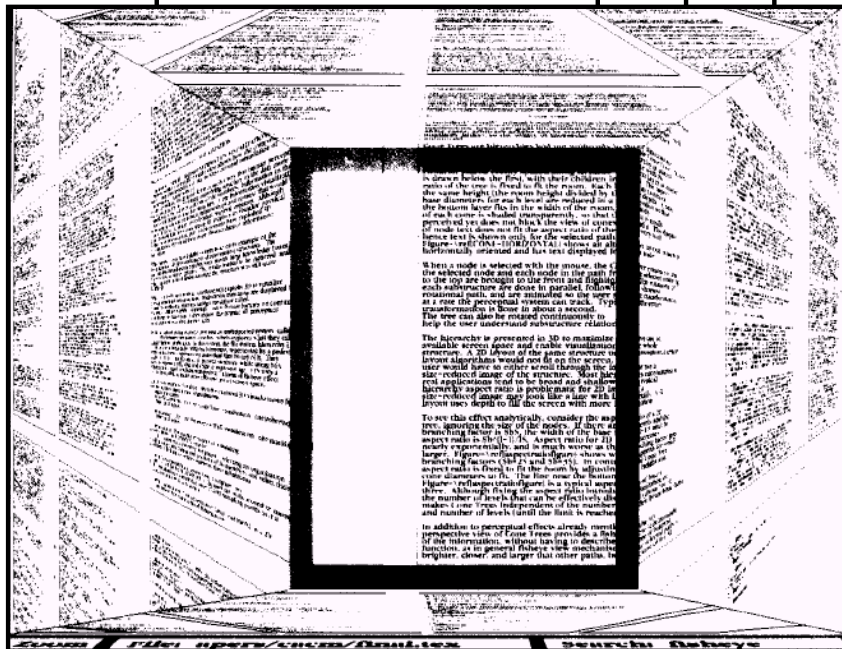
1992 Fisheye Views for Graphs  
(Sarkar & Brown)

1993 Stretching rubber sheet:  
(Sarkar, Snibbe, Reiss)

Document Lens +  
3D Interactive Animation  
(Robertson, MacKinlay)

21DF-browser  
(Huang and Quan)

Conformal Magnifier





# Distortion :: History

1982 Bifocal Display (Spence & Apperley)

1986 Fisheye Views (Furnas)

1991 Perspective Wall  
(MacKinlay, Robertson, Card)

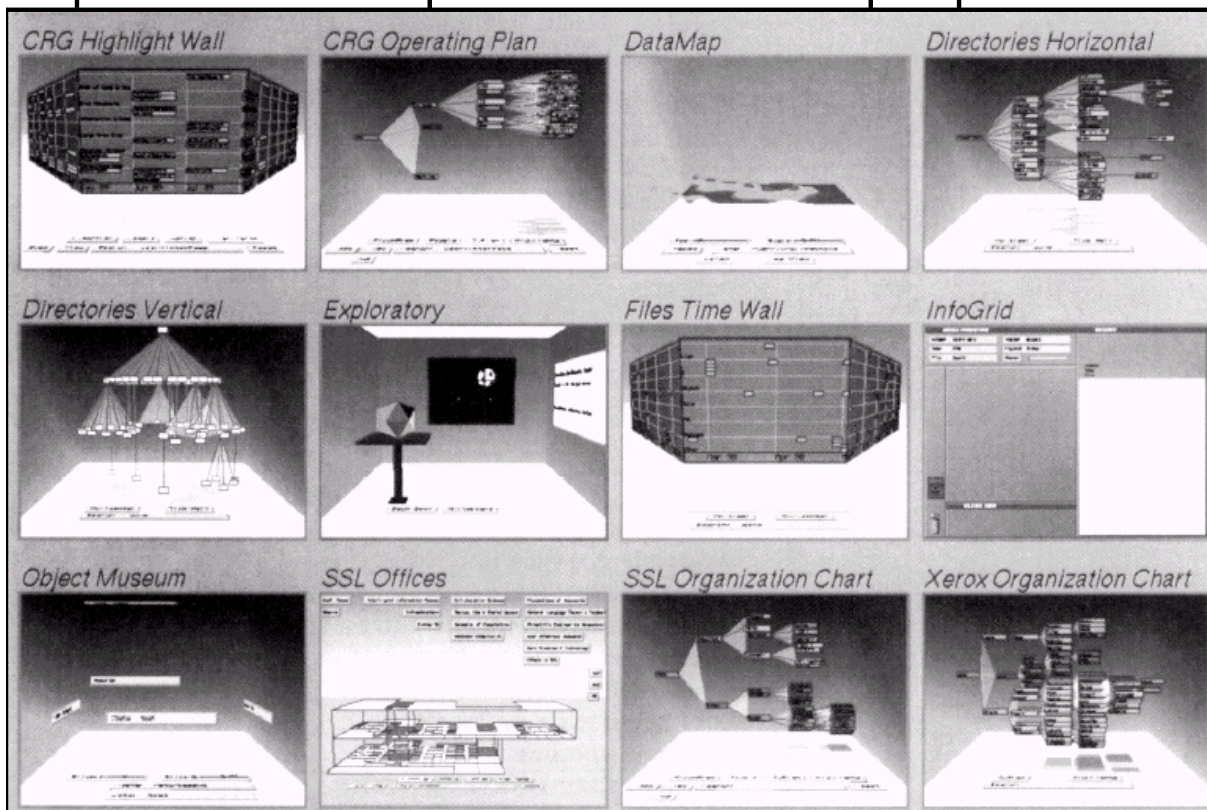
1992 Fisheye Views for Graphs  
(Sarkar & Brown)

1993 Stretching rubber sheet:  
(Sarkar, Snibbe, Reiss)

Document Lens +  
3D Interactive Animation  
(Robertson, MacKinlay)

21DF-browser  
(Huang and Quan)

Conformal Magnifier

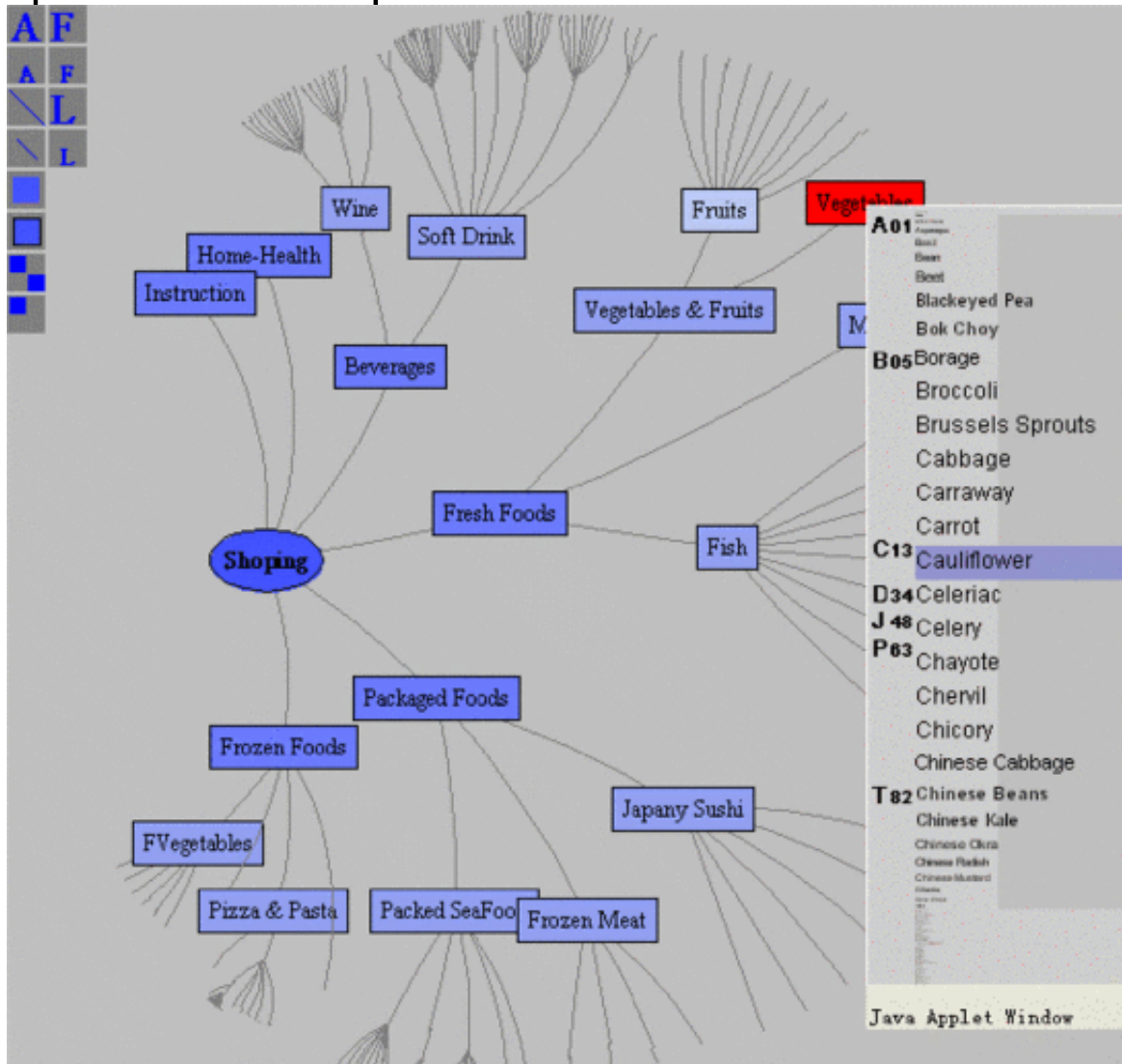




# Distortion :: History

1982 Bifocal Display (Spence & Apperley)

1986 Fisheye Views (Furnas)



ve Wall

y, Robertson, Card)

eye Views for Graphs  
(Sarkar & Brown)

retching rubber sheet:  
(Sarkar, Snibbe, Reiss)

Document Lens +  
3D Interactive Animation  
(Robertson, MacKinlay)

21DF-browser  
(Huang and Quan)

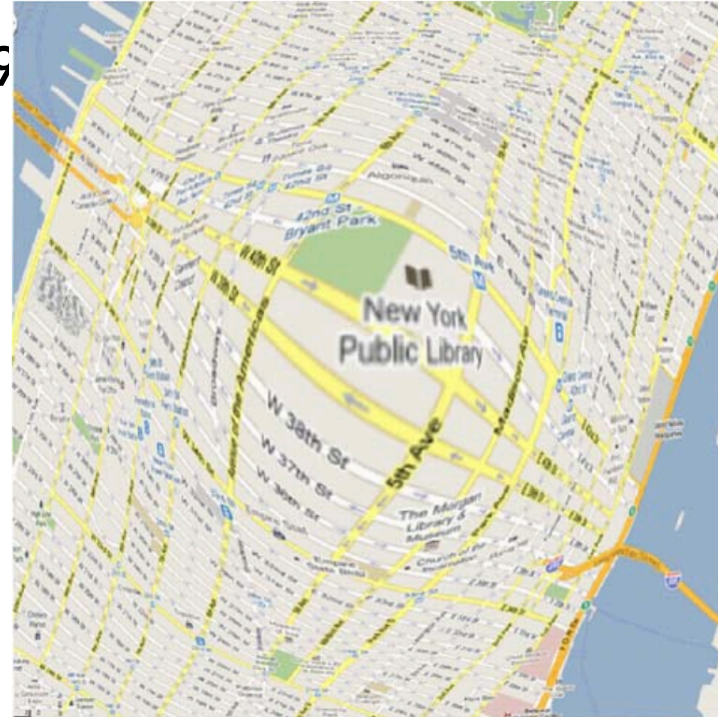
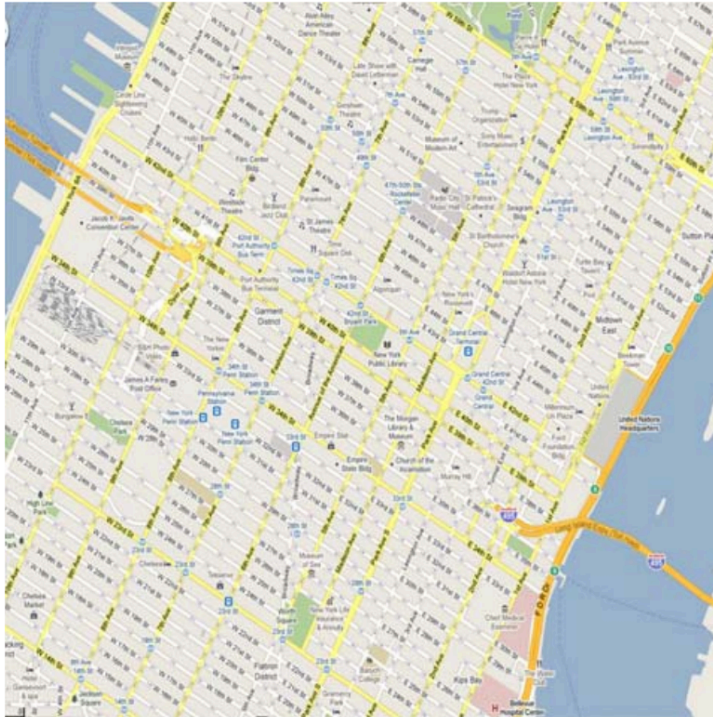
Conformal Magnifier

# Distortion :: History

1982 Bifocal Display (Spence & Apperley)

1986 Fisheye Views (Furnas)

1991 Perspective Wall  
(MacKinlay, Robertson, Card)



(Huang and Quan)

Conformal Magnifier  
(Zhao et al.)

## Conformal Magnifier

More usage in Scientific Visualization (SciVis)

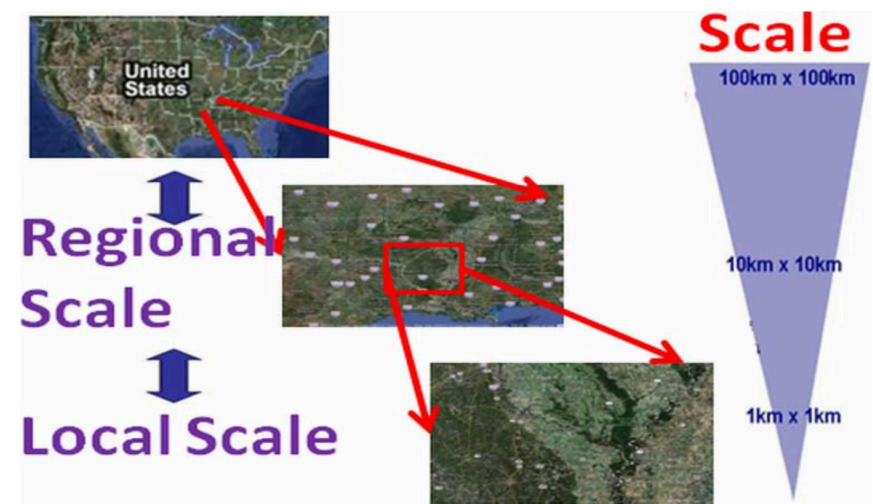
Region-of-interest (ROI) function

(a) Multiscale satellite images of the United States. The ROI contains more details/pixels as the scale decreases

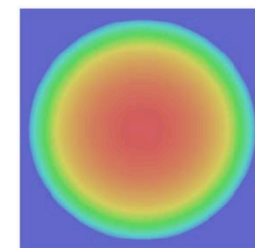
(b) The top view and

(c) the side view of the continuous magnification ratios of conformal magnifier mapping

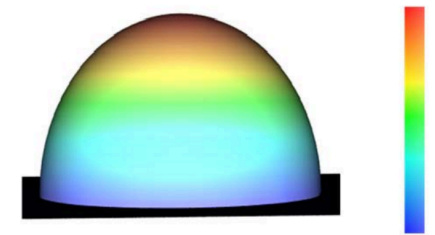
The colorbar shows the scale of the magnification ratio: from large (red) to small (purple).



(a)



(b)



(c)

# Focus+Context :: Eliding + Distortion

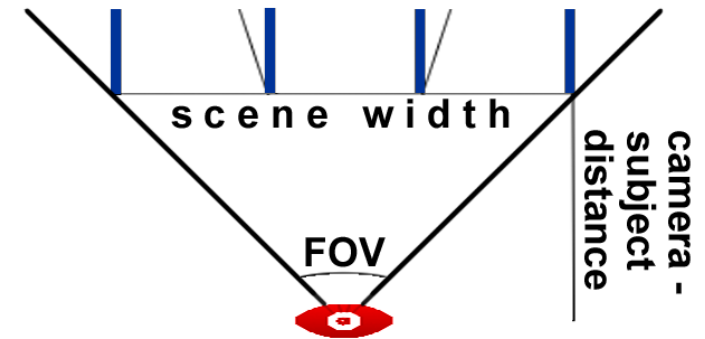
[Federico et al., 2012]

## Vertigo Zoom

2.5D visualization

interactively change and adapt  
field of view based on task

Exploration of changes in dynamic networks



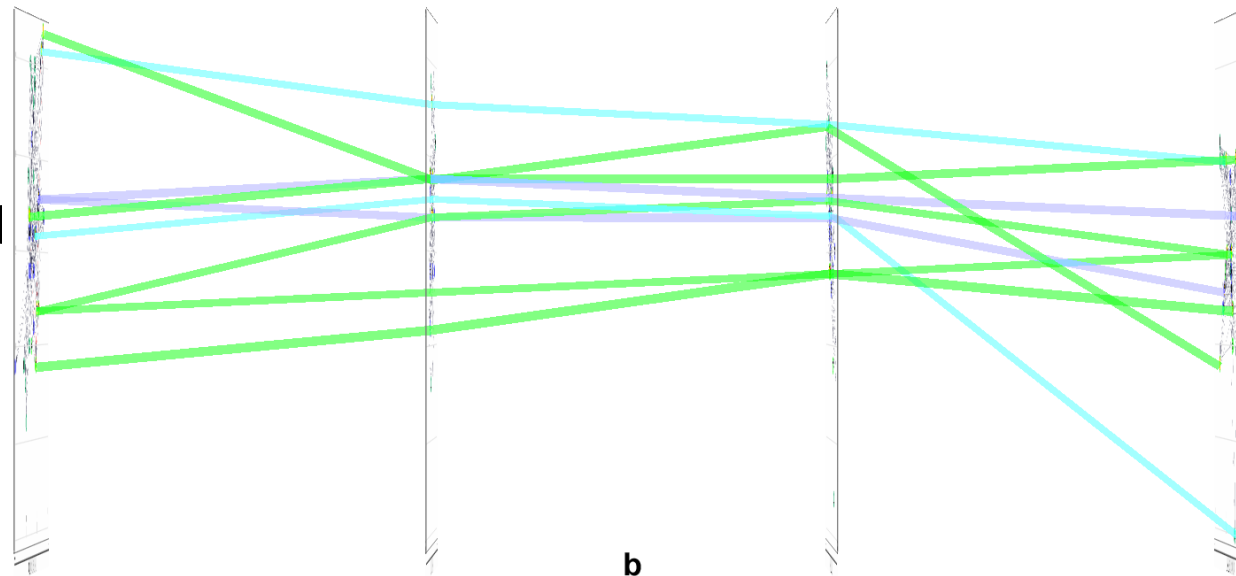
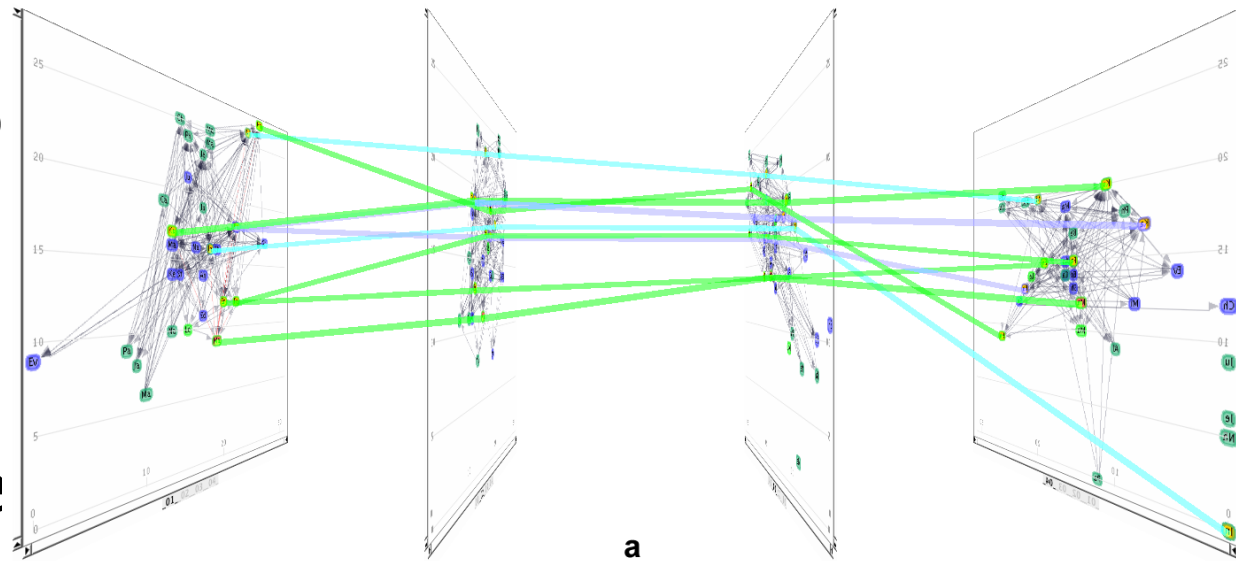
# Focus+Context :: Eliding + Distortion

[Federico et al., 2012]

Vertigo Zo

2.5D visual  
interactive  
field of view

Exploration





# F+C: Strengths

Flexible toolset for different data and tasks

Good Navigation Tool for Interactively Exploring Data

Probe Regions of Interest Before Committing to Navigating to Them (Easily Reversible)

Can be combined with other Viewing Paradigms such as Pan+Zoom, etc.

# F+C: Disadvantages & Limitations

## No unified toolkit

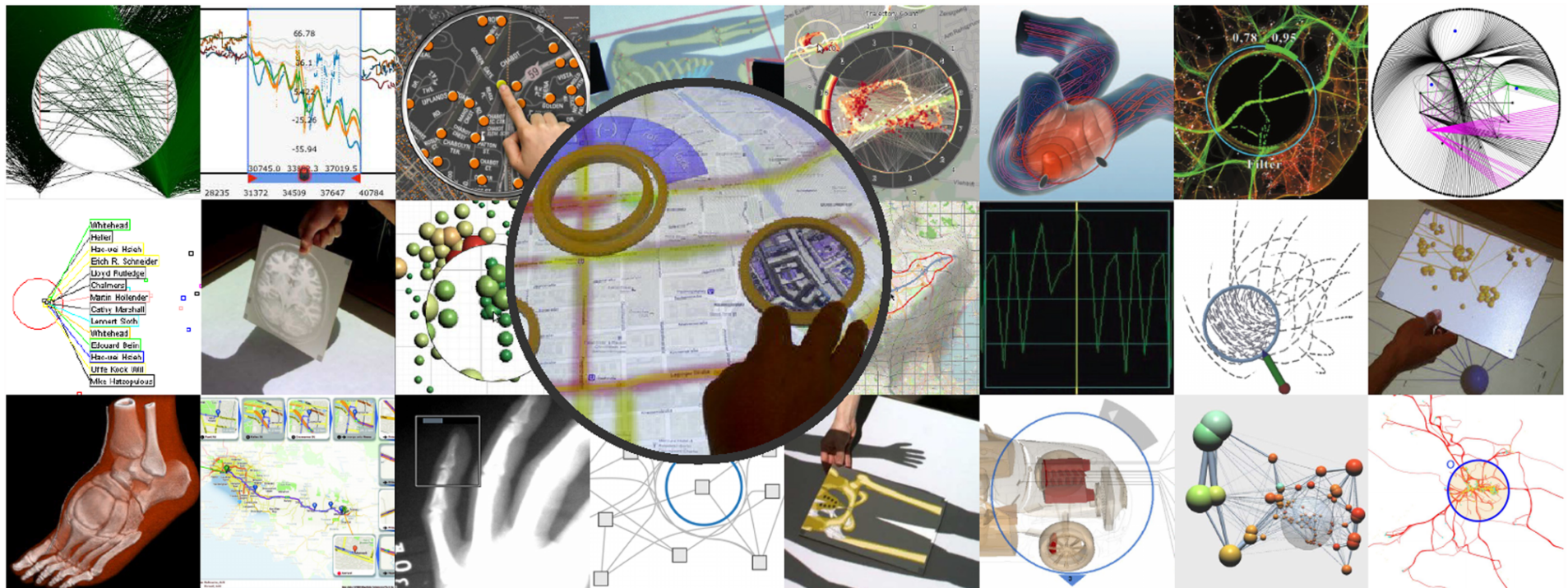
- Distortion can be distracting

- Can be very difficult to implement

- Any change in focal point potentially requires re-calculation of DOI/ROI for all objects

# Focus+Context :: Interactive Lenses Survey

C. Tominski, S. Gladisch, U. Kister, R. Dachzelt, and H. Schumann,  
“Interactive Lenses for Visualization: An Extended Survey,” Comput.  
Graph. Forum, vol. 36, no. 6, pp. 173–200, Sep. 2017.

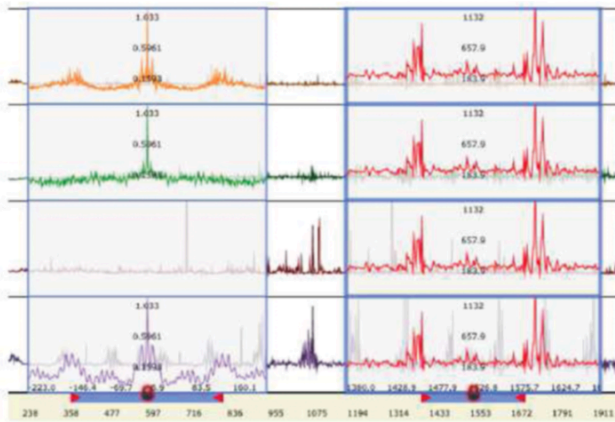




# Focus+Context :: Interactive Lenses

[Tominski et al., 2017]

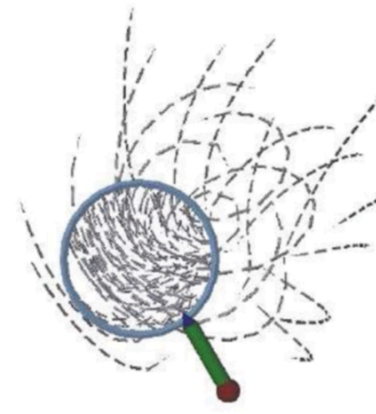
## Lenses for different types of data



(a) Temporal data



(b) Geospatial data



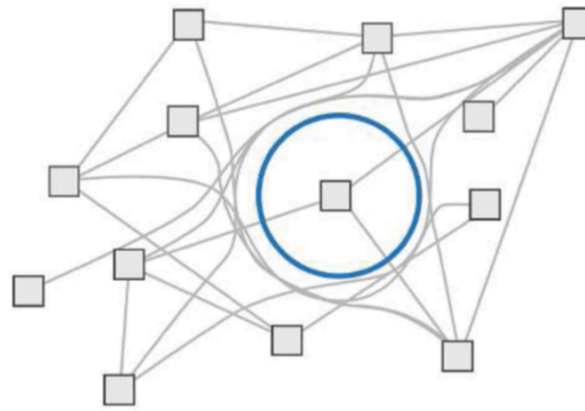
(c) Flow data



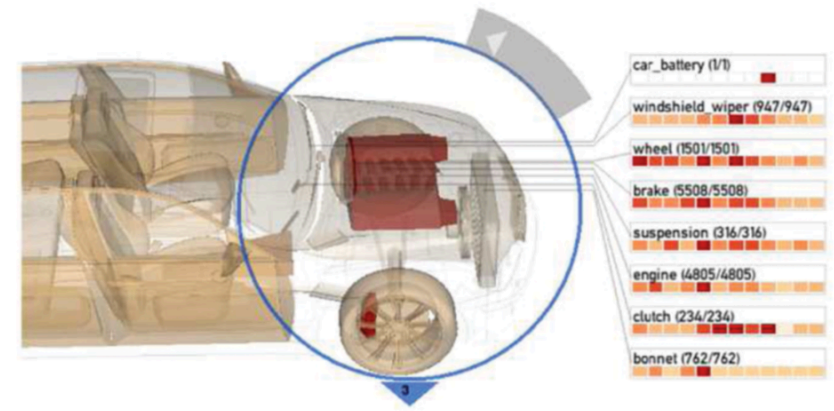
(d) Volume data



(e) Multivariate data



(f) Graph data

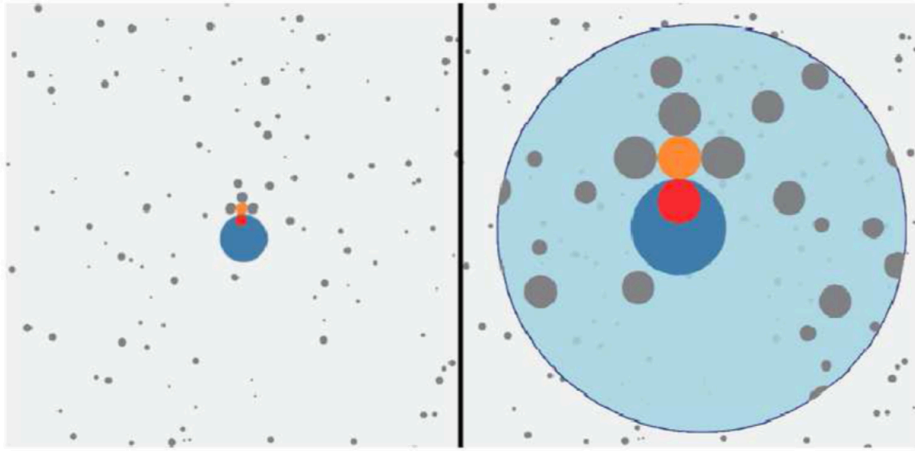


(g) Text and document data

# Focus+Context :: Interactive Lenses

[Tominski et al., 2017]

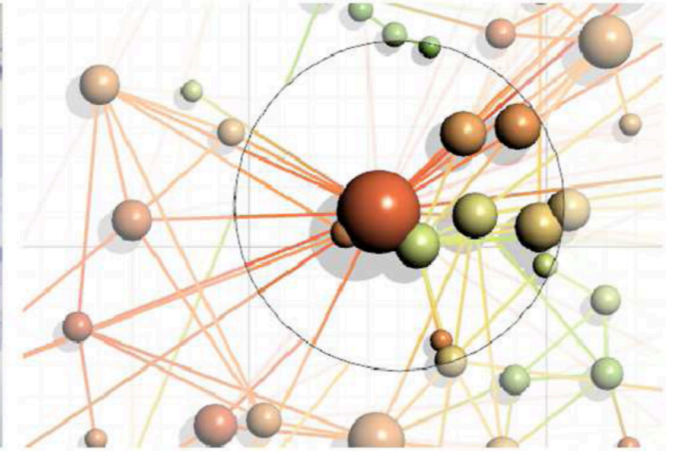
## Lenses for specific tasks



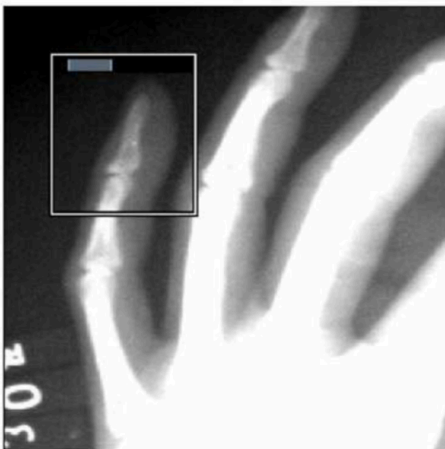
(a) Select



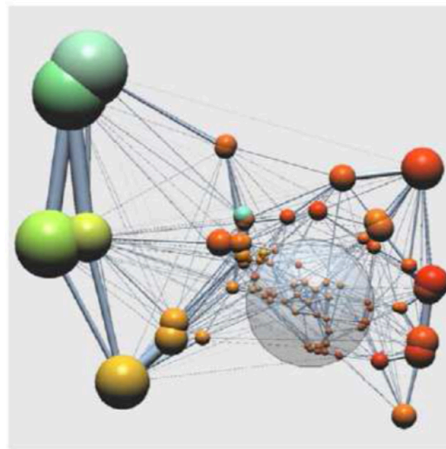
(b) Explore



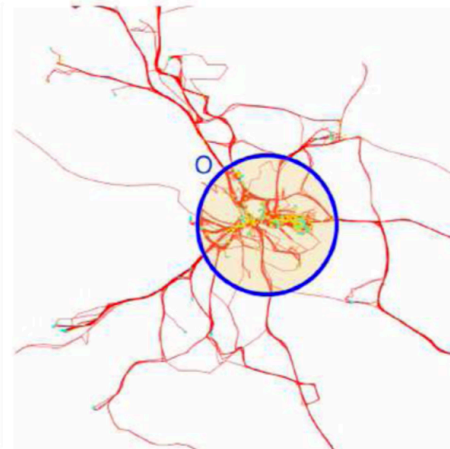
(c) Reconfigure



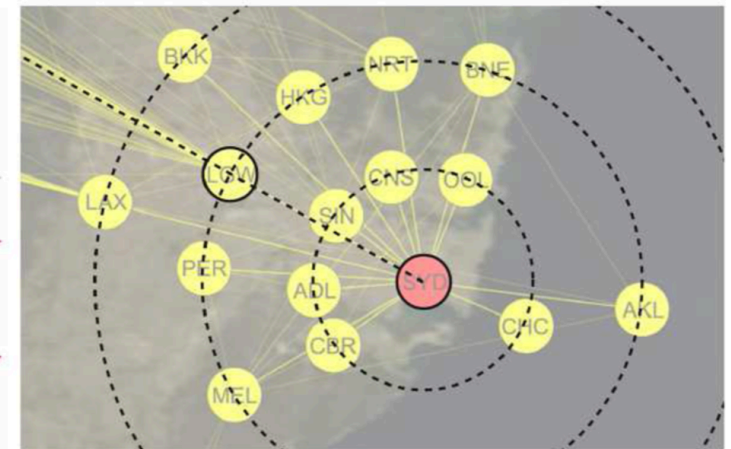
(d) Encode



(e) Abstract/Elaborate



(f) Filter



(g) Connect

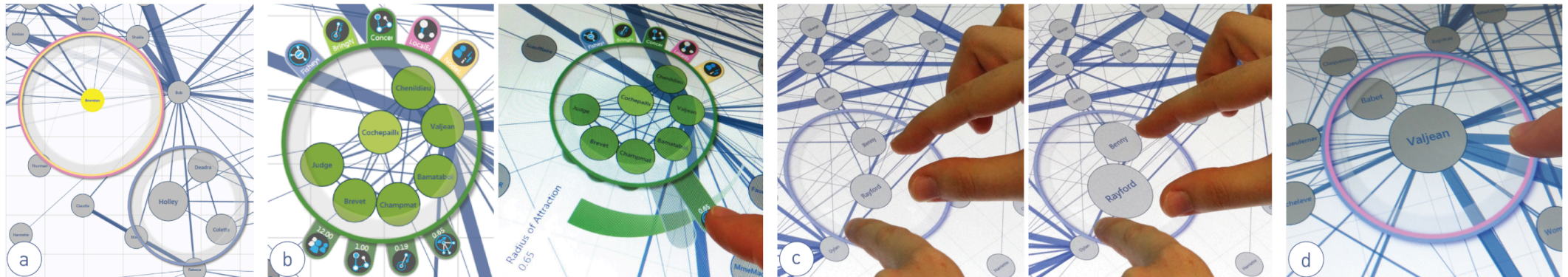


# Focus+Context :: Interactive Lenses

[Kister et al, 2016]

Less used in conventional InfoVis context

lenses in combination with large interactive surfaces or displays can become powerful tools for collaboration



Novel ways of interaction

(Multi-)Touch, Tangible, Gaze-based interaction, ...

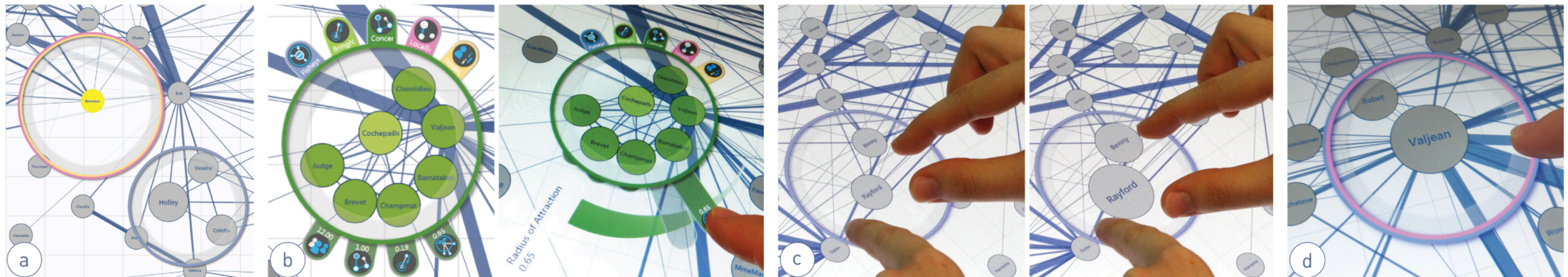
# Focus+Context :: Interactive Lenses

[Kister et al, 2016]

## Interaction

### Generalizability

„the fundamental problem is how you provide the user a quick and easy way to: Position the lens, work through the lens, and (possibly) parameterize the lens“



# DISTORTION TECHNIQUES

## CONCLUSION

# Conclusion

Spatial separation demands indication of relationship between the concurrent displays

overview+detail and zooming interfaces – became standard components in GUIs

overview+detail & fisheye interfaces – performance advantages for certain tasks

Effectiveness of different techniques depends on many factors, particularly the users' tasks

# Overview + Detail

- + Preferred over other techniques.
- + Most effective solution for particular tasks, e.g. document comprehension
- Additional use of screen real estate
- sub-optimal for dynamic activities due to more time being spent

Provide immediate feedback in detail view to maintain responsiveness of the environment

# Interactive Zooming

- + Temporal Dependency between pre- and post-zoom state
- + Improves user performance
- Inflates cognitive load when done badly

Implement concurrent, well-established controls for panning and zooming to decrease users' cognitive load



- + Favorable for gaining a rapid overview of the data-space quickly
- + Favorable for following graph structures with clear categories.
- Likely to impair users' ability to make relative spatial judgements
- Can cause target acquisition problems

Take advantage of high resolution displays for focused visual attention and peripheral vision

# LESSONS LEARNED

# Conclusion - Lessons learned

Adapted [Stasko, 2011, Heer 2011, Lecture Slides]

## **“Science of Interaction”**

User-centered versus system-centered characterizations

Facilitate and utilize dialog between user and visualization

Good visualizations are task dependent

## **Fundamental interaction techniques**

Selection / Annotation, Sorting, Navigation, Brushing & Linking, Dynamic Querying, Multiple Views

## **Advanced interaction techniques**

F+C, Interactive Lenses

# ADDITIONAL SLIDES

# Direct Manipulation

[Shneiderman, 1983, Shneiderman and Plaisant, 2005]

Visual representation (metaphor) of the "world of action"

Objects and actions are shown

Analogical reasoning is tapped

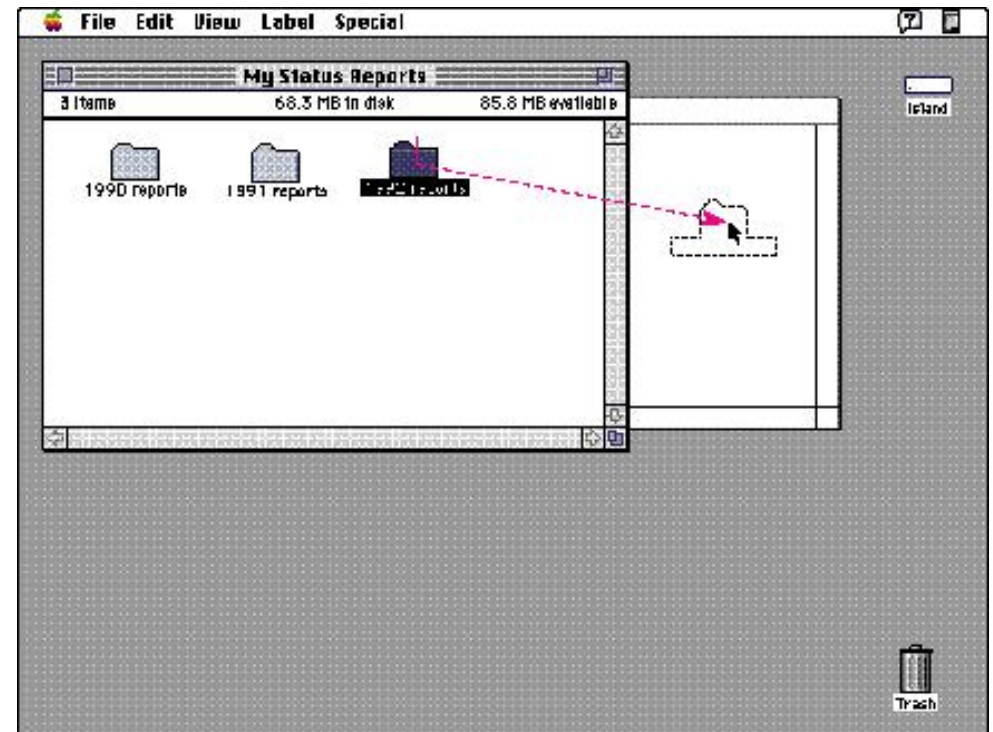
Rapid, incremental, and reversible actions

Replacement of typing with pointing and selecting

Immediate visibility of results of actions

GOAL:

Allow the user to **directly interact with the object**

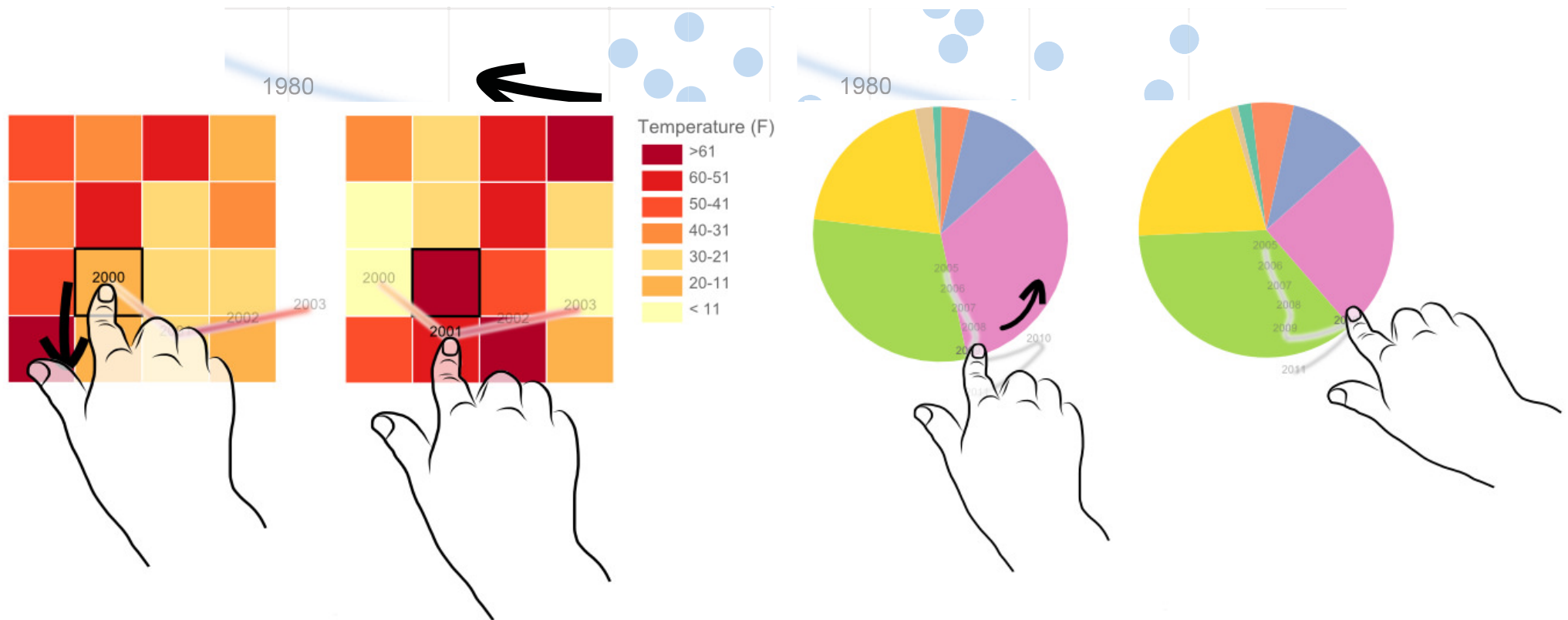


[Apple Computer]

# Direct Manipulation: DimpVis

Kondo & Collins, 2014

## Exploring Time-varying Information Visualizations by Direct Manipulation



<https://vega.github.io/vega/examples/global-development/>

# Direct Manipulation Pros/Cons

[Shneiderman and Plaisant, 2005]

## Benefits over commands

- Visibility of the objects of interest
- Control/display compatibility
- Less syntax reduces error rates
- Errors are more preventable
- Faster learning and higher retention
- Reversibility of all actions
- Encourages exploration
- Replacement of complex command languages with actions to manipulate directly the visible objects
- Immediate visibility of results of actions

## Concerns

- Increased system resources, possibly
- Some actions might be cumbersome; typing commands with the keyboard might be faster
- Macro techniques are often weak
- History and other tracing may be difficult
- Visually impaired users may have more difficulty
- Users must learn the graphical representations

# Thanks to ...

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John Stasko, Georgia Institute of Technology

... for making nice slides of previous classes available.