

# Interacting with Visualizations

# Introduction

We perceive objects in terms of the possibilities for action. (Affordance. Gibson, 1979.)

All man-made objects offer the possibility for interaction.

A static painting

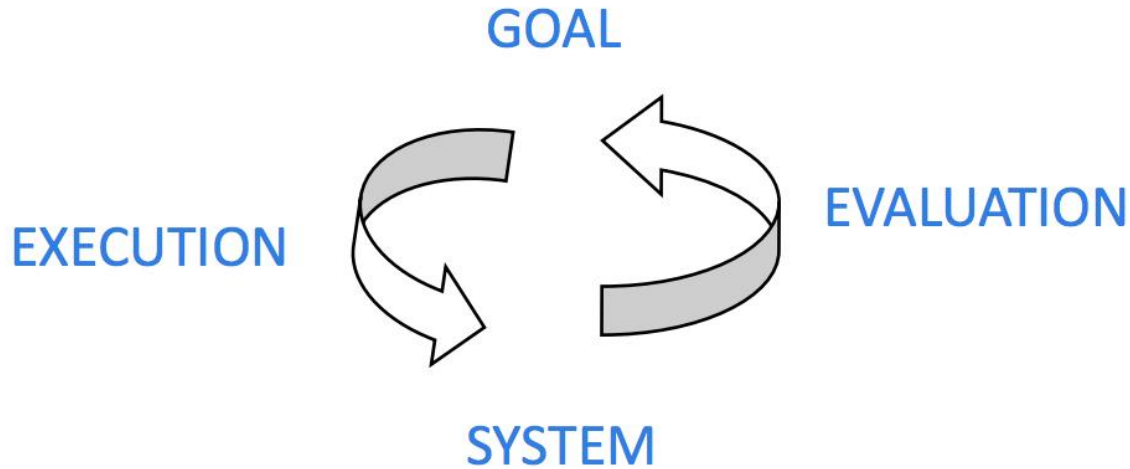
Looking closer/further

Taking a photo



# Interaction in Data Visualization -- Definition

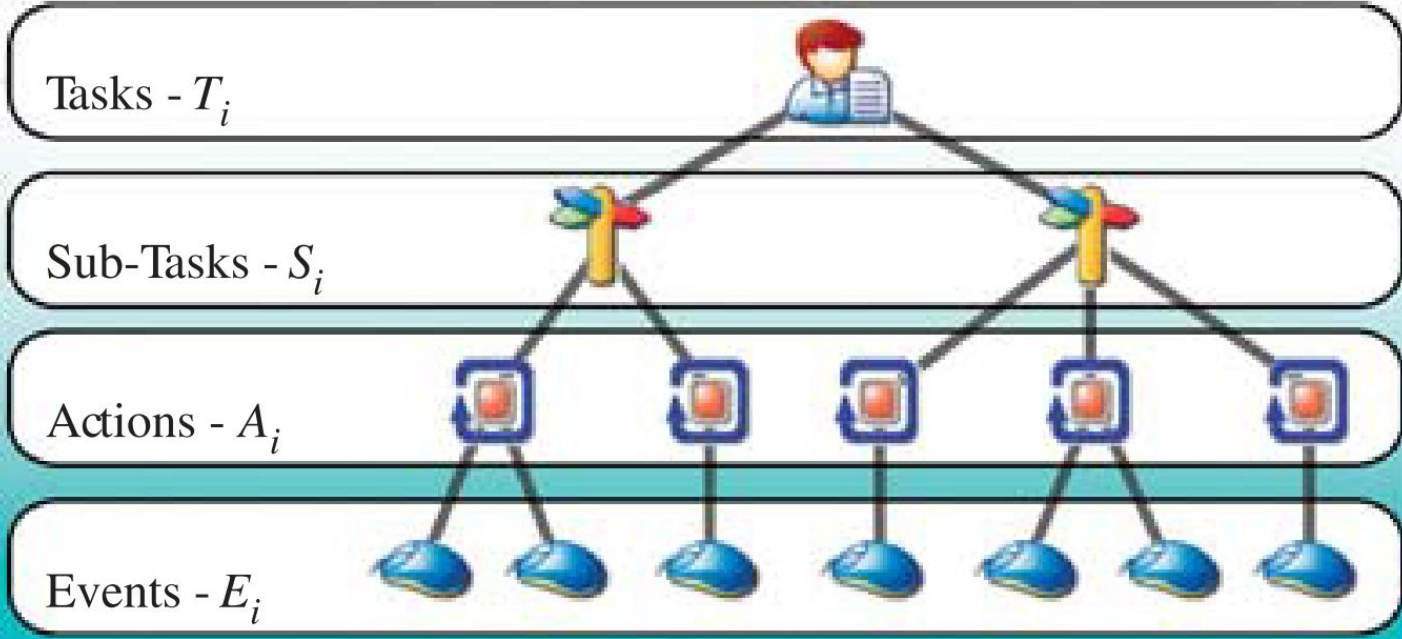
The dialog between the user and the system as the user explores the dataset to uncover insights. [Yi et al., 2007]



Norman's interaction model NORMAN, D.A., 1988. The design of everyday things.

# Execution: Levels of user activities

**Rich  
Semantics**



**Poor  
Semantics**

# Tasks & sub-tasks -- Semantically rich, but domain specific

Task: Identify key market insights to **generate** investment **recommendations**.

S1: **Characterize** the overall 52-week market **trend** in the technology sector.

S2: **Identify** the best and worst performing financial companies over the last 8 weeks.

# Actions

**Generic** with respect to domains and tools,  
yet **semantically rich** in terms of user intent.

For Sub-task 2,

A1: **Query** for 8 weeks worth of stock market data.

A2: **Split** companies by sector.

A3: **Filter** to show only the financial sector.

A4: **Sort** companies by their changes in stock price.

A5: **Inspect** the company with the greatest change in stock price to ask for more details, such as financial reports.

# Events -- Generic, but semantically poor

E1: **mouse-drag** to select all companies to be sorted.

E2: **mouse-right-click** to open a popup menu.

E3: **menu-select** to choose 'Sort' from a list of menu options.

E4 ...E8: **keyboard-events** to set sorting parameters (for example, choosing 'price change' as the property to sort and then selecting the sorting order).

E9: **mouse-click** to submit the entered sorting parameters.

# Seven categories of actions in data visualization

Select

Explore

Reconfigure

Encode

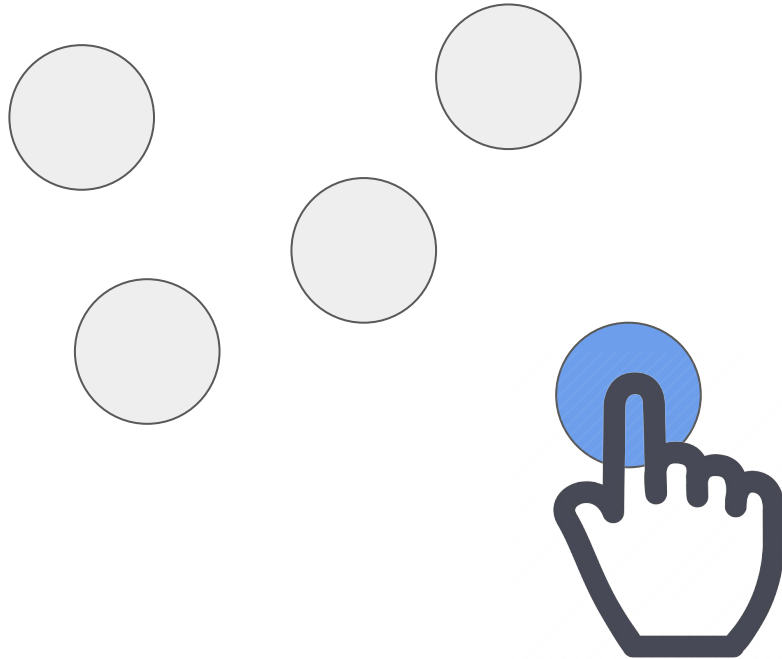
Abstract / elaborate

Filter

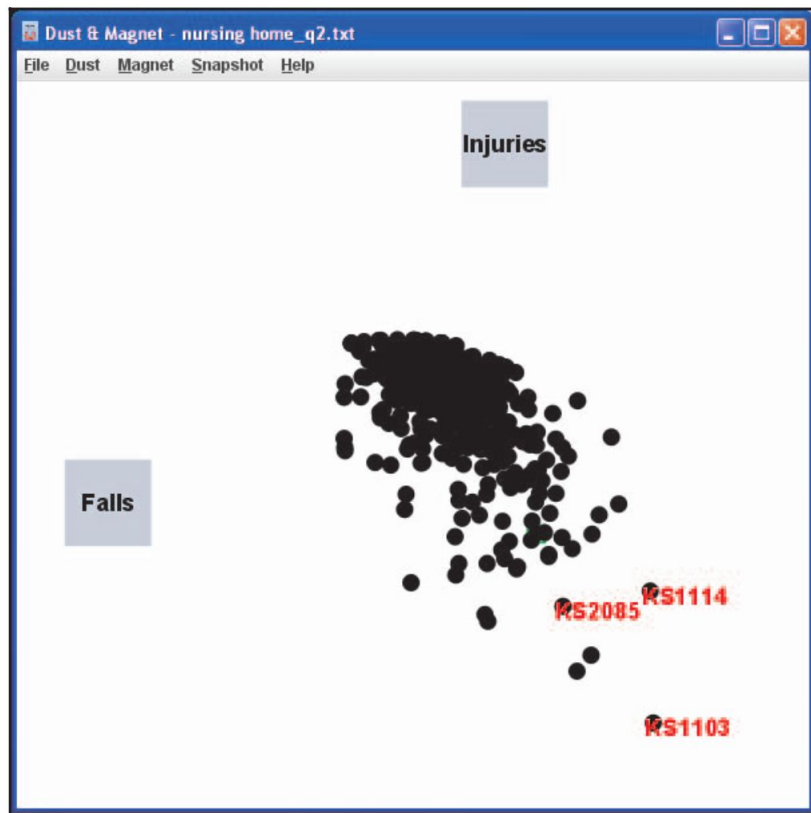
Connect

# Select: mark something as interesting

Select action is coupled with other actions to enrich user exploration and discovery.

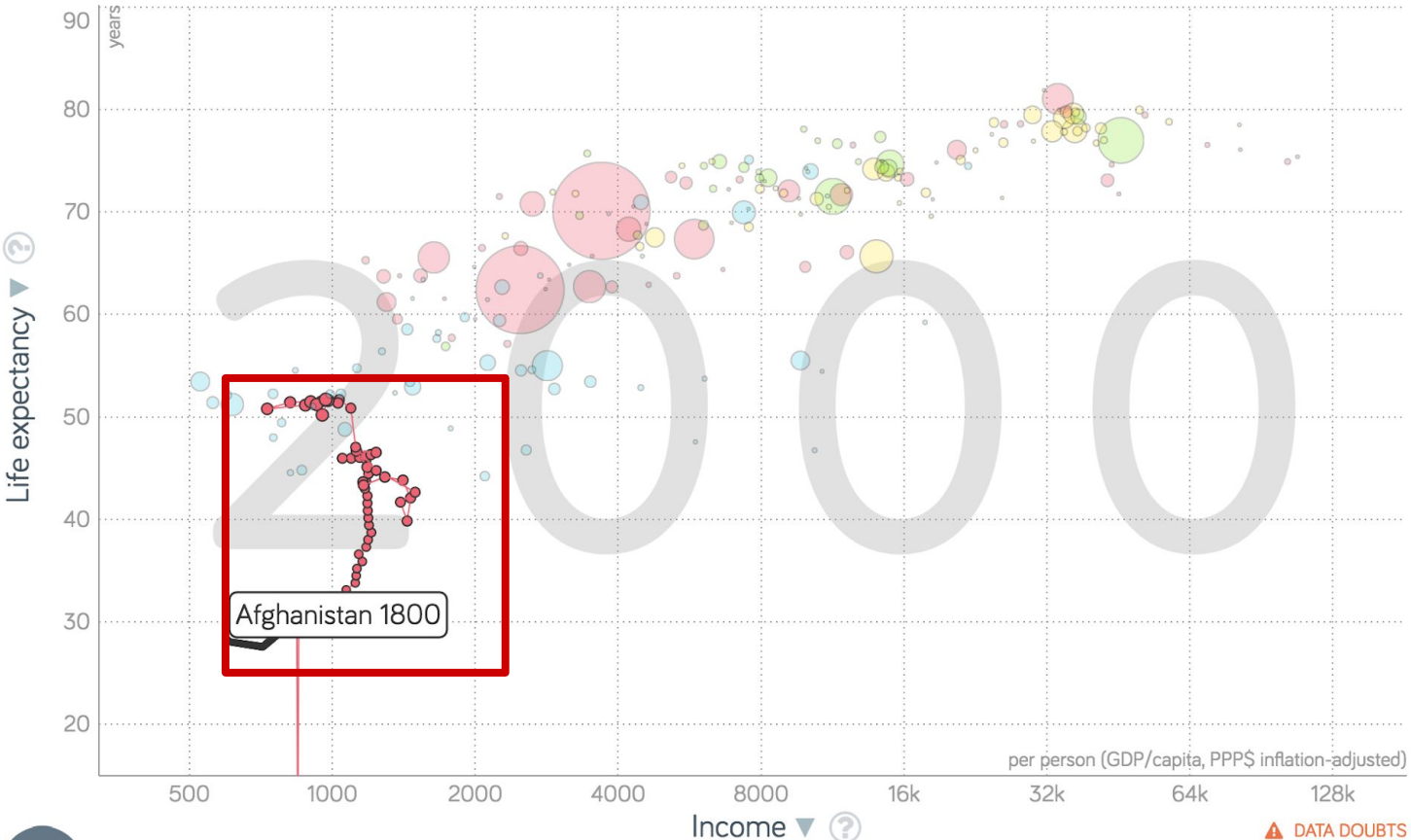


# Select: mark something as interesting



To keep track of items of interest even with changes of layouts.

# Select to inspect the transition of an item over a period.



Color World Regions



Select Search...

Afghanistan

- Albania
- Algeria
- Andorra
- Angola
- Antigua and Barbuda
- Argentina

DESELECT

Size Population, total

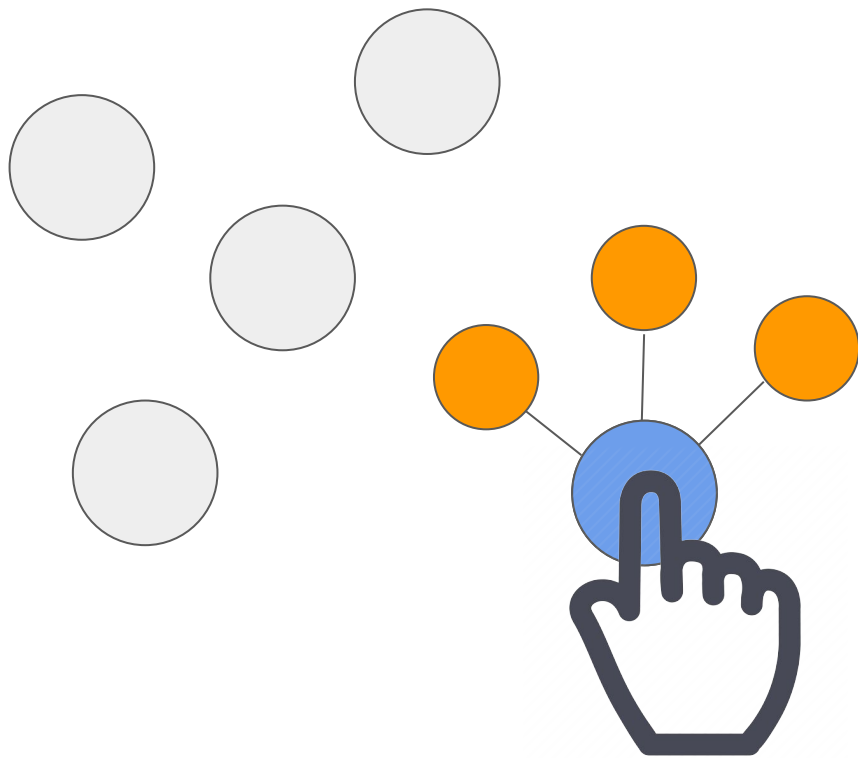
Zoom 100%

- TRAILS
- LOCK
- OPTIONS
- EXPAND
- PRESENT

▶ [Progress bar with play button icon]

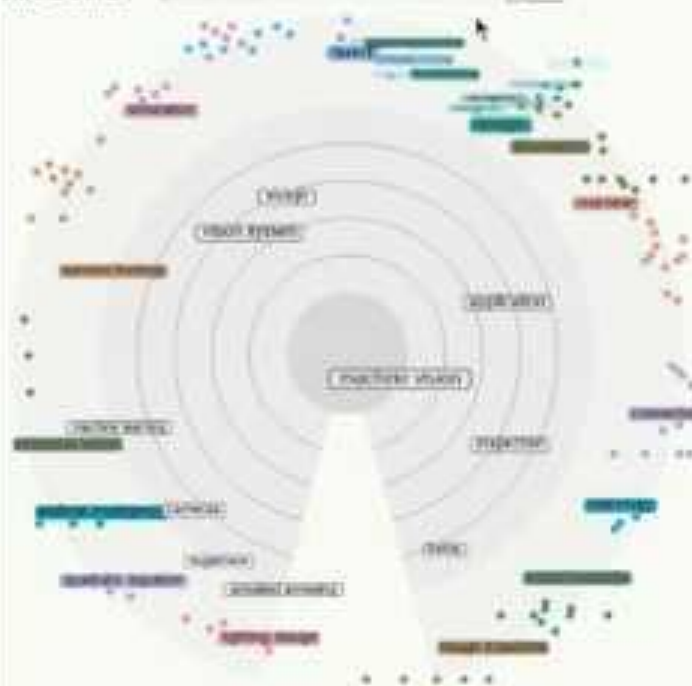
DATA DOUBTS

Explore: show me something else









ALL DONE

Machine vision advances and applications

C Conway (ASSEMBLY AUTOMATION, 2009-01-01)

Image sensors, computer hardware, cameras, automation, applications, machine vision  
 Program - the program of 1014 pages in 1...

Infrared machine vision - A new contender

B Foster (TECHNOLOGICAL, 1990-01-01)

Automation, machine vision, process monitoring, process control, infrared, image processing, vision systems, applications, image, machine vision  
 11-16, resolution of 200, resolution, 00110 11...

Educational experiments in machine vision

D Grever (IEEE TRANSACTIONS ON EDUCATION, 1996-01-01)

Industrial, application, tests, design, high-level, machine, machine vision, thinking  
 We present a set of five educational exp...

MACHINE VISION AND AUTOMATED ASSEMBLY

J L DAVIS, K P GILL (MECHANICS, 1993-01-01)

Automation, application, machine vision  
 An overview of the current state of work...

An introduction to machine vision - A tutorial

D Silver (IEE EVALUATION ENGINEERING, 2001-01-01)

Image, machine vision  
 Develop your knowledge of image analysis...

Machine vision for digital microfluidics

Y J Shi, J B Lee (REVIEW OF SCIENTIFIC INSTRUMENTS, 2010-01-01)

Camera, computer vision, fluid, microfluidics, microfluidics, microfluidics, industrial, automation, inspection, microsystem, application, image, machine vision, vertical, machine vision, measurement  
 Machine vision is widely used in an auto...

# Use sliders to adjust preferences and explore recommendations

Tune weights of the recommender methods: (b)

Most bookmarked papers ?  
0.4

Similar to your favorite articles ?  
0.8

Frequently cited authors in ACM DL ?  
0.4

Update Recommendation List →

\* Hover over circles to explore articles  
\* Click on the diagram to highlight subsets (c)

Articles in top30  
Articles not in top30

Similar to your favorite articles

Most bookmarked papers

**2. Can't see the forest for the trees?  
A citation recommendation system**

2. Can't see the forest for the trees? A citation recommendation system (a)  
by C. Lee Giles, Cornelia Caragea, Adrian Silvescu, Prasenjit Mitra [\[see abstract\]](#)

3. When thumbnails are and are not enough: Factors behind users   
by Dan Albertson [\[see abstract\]](#)

7. Gendered Artifacts and User Agency   
by Andrea R. Marshall, Jennifer A. Rode [\[see abstract\]](#)

8. Two Paths to Motivation through Game Design Elements: Reward-Based Gamification and Meaningful Gamification   
by Scott Nicholson [\[see abstract\]](#)

9. Automatic Identifying Search Tactic in Individual Information Seeking: A Hidden Markov Model Approach   
by Zhen Yue, Shuguang Han, Daqing He [\[see abstract\]](#)

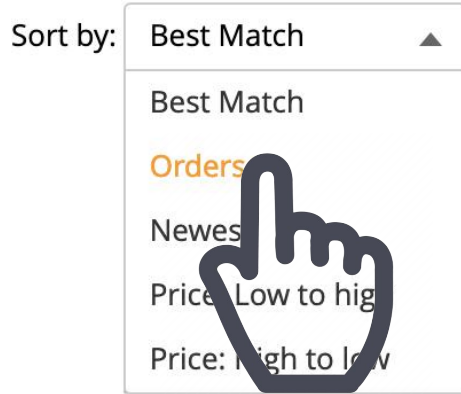
11. Old Maps and Open Data Networks   
by Werner Robitzka, Carl Lagoze, Bernhard Haslhofer, Keith Newman, Amanda Stefanik [\[see abstract\]](#)

14. Effects of User Identity Information On Key Answer Outcomes in Social Q&A   
by Erik Choi, Craig Scott, Chirag Shah [\[see abstract\]](#)

15. Ebooks and cross generational perceived privacy issues   
Jennifer Sue Thiele, Renee Kapusniak [\[see abstract\]](#)

16. Toward a mesoscopic analysis of the temporal evolution of scientific collaboration networks

# Reconfigure: show me a different arrangement



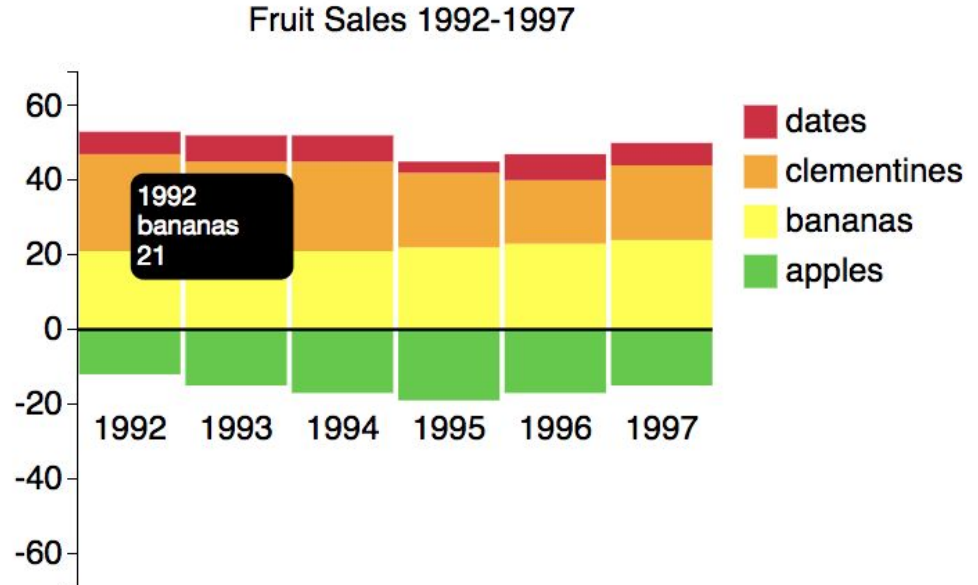
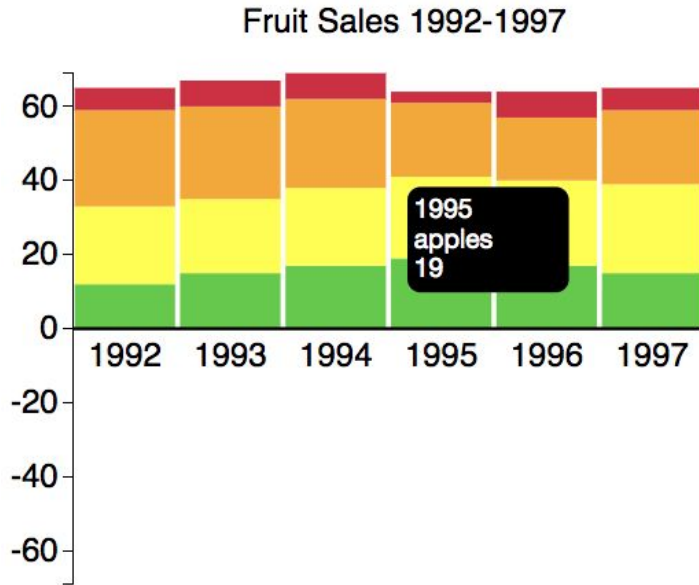
Item 1

Item 2

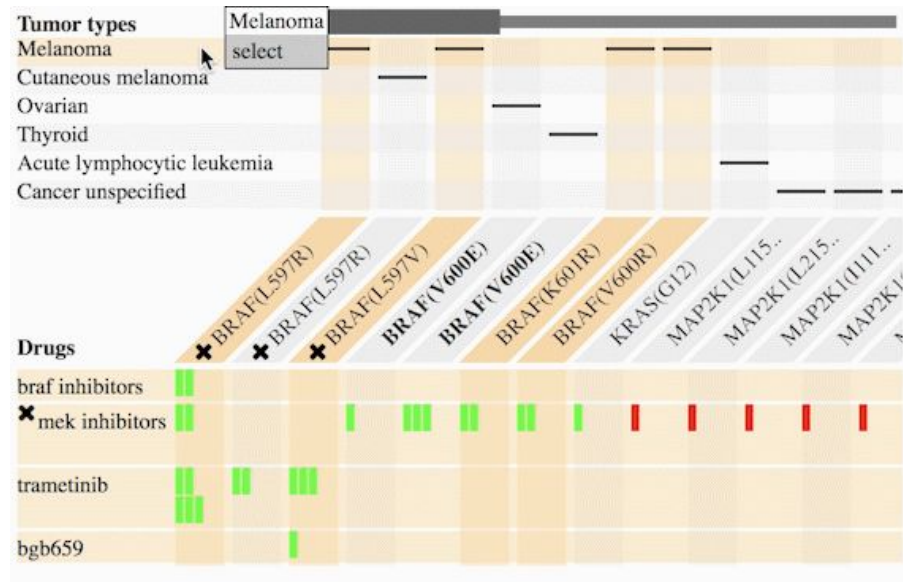
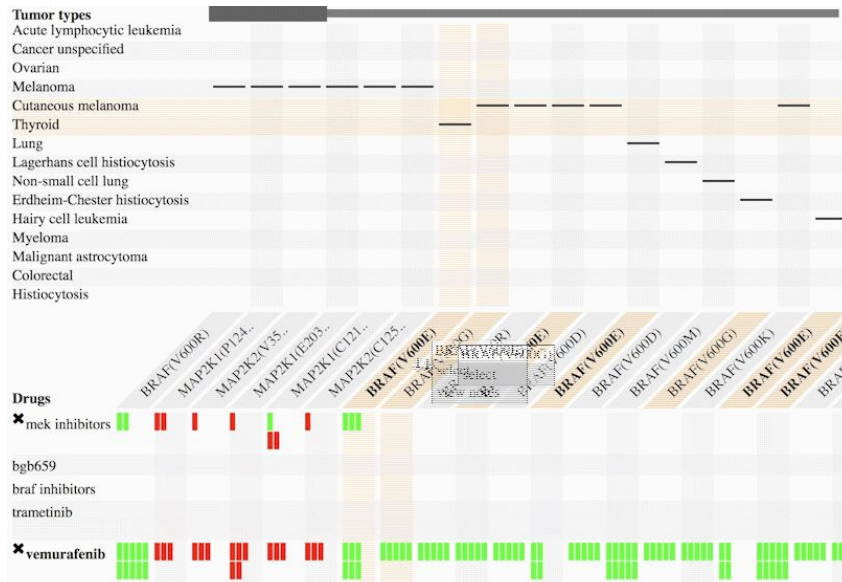
Item 3

# Reconfigure: show me a different arrangement

To facilitate easy comparison of inter-column blocks.

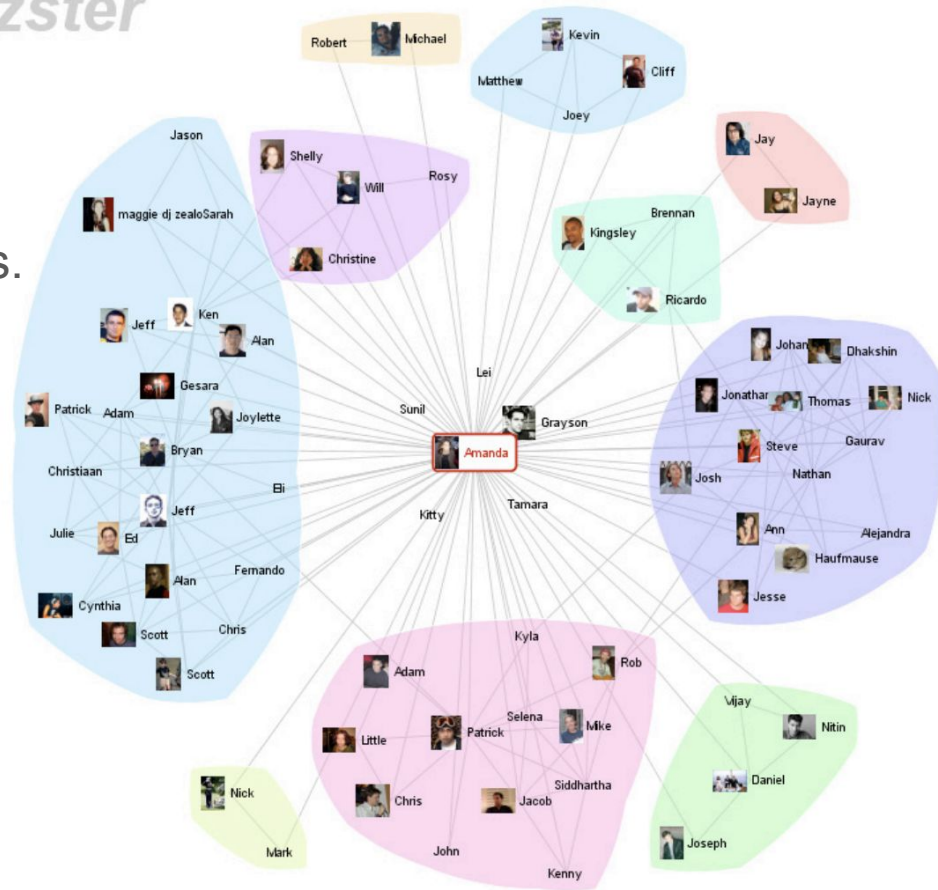


Click an entity header to gather related rows and columns.



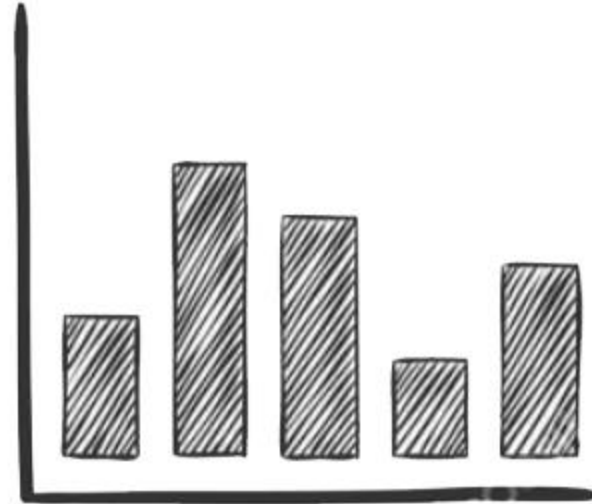
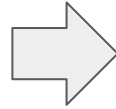
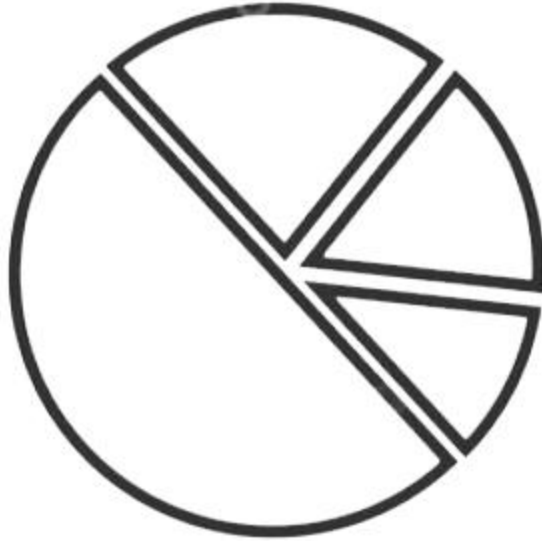
# Reconfigure

A slider to change the number of clusters.



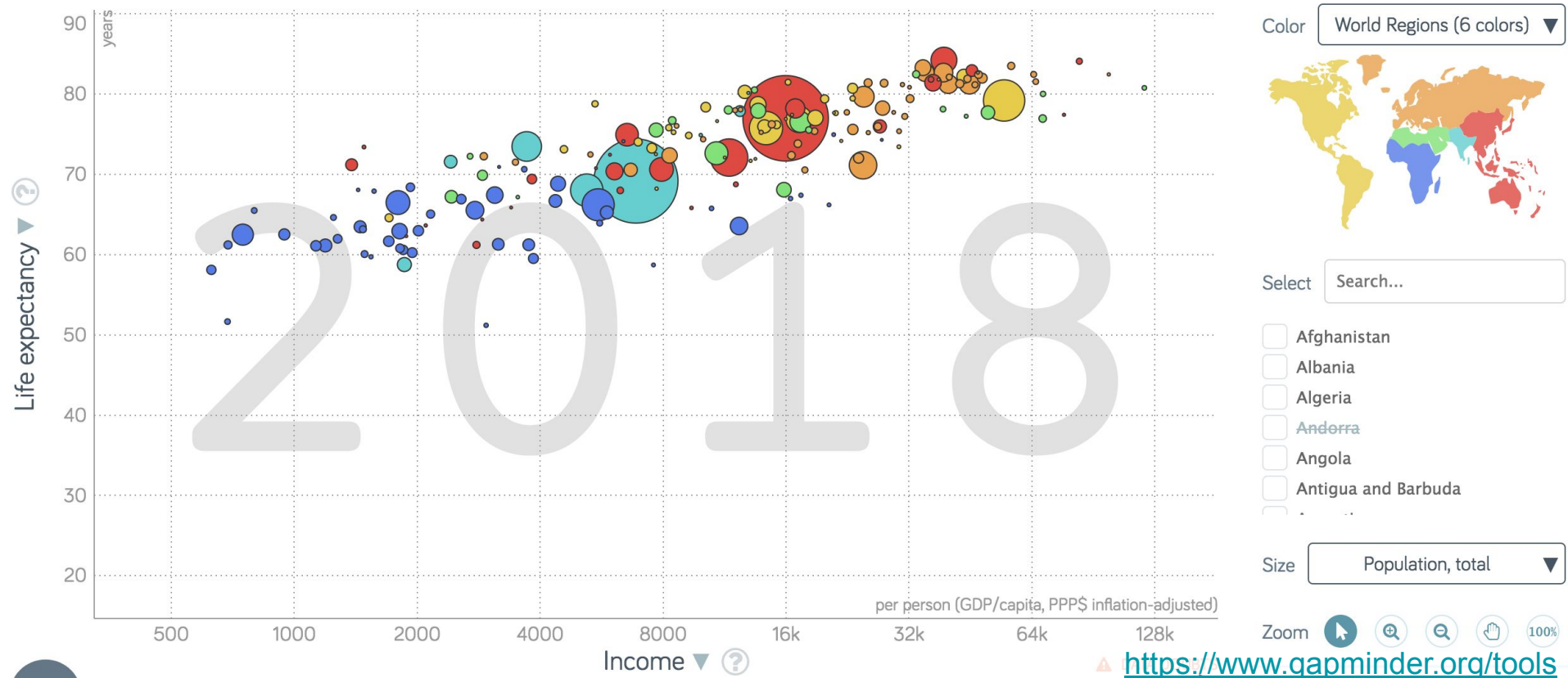
community >>

Encode: show me a different representation

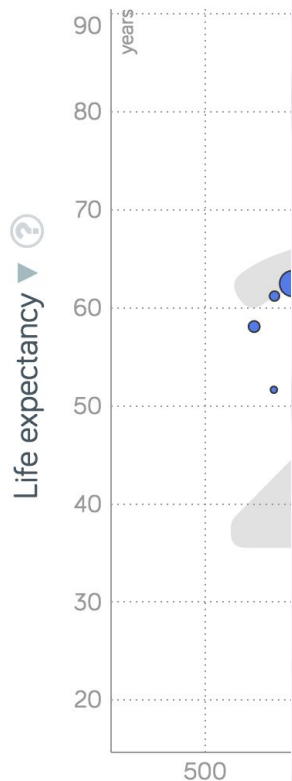




# Change data encodings to uncover new aspects of relationships.



# Change



## Main religion 2008

No description

Country

G77 and OECD countries

Income groups

Landlocked

**Main religion 2008**

World Regions

World Regions (6 colors)

Color

Search...

Time

Babies per woman

CO2 emissions

Child mortality

Income

Life expectancy

Single color

◀ **Categorizations**

◀ Economy

◀ Education

◀ Energy

◀ Environment

# Relationships.

Color World Regions (6 colors) ▼



Select Search...

- Afghanistan
- Albania
- Algeria
- Andorra
- Angola
- Antigua and Barbuda

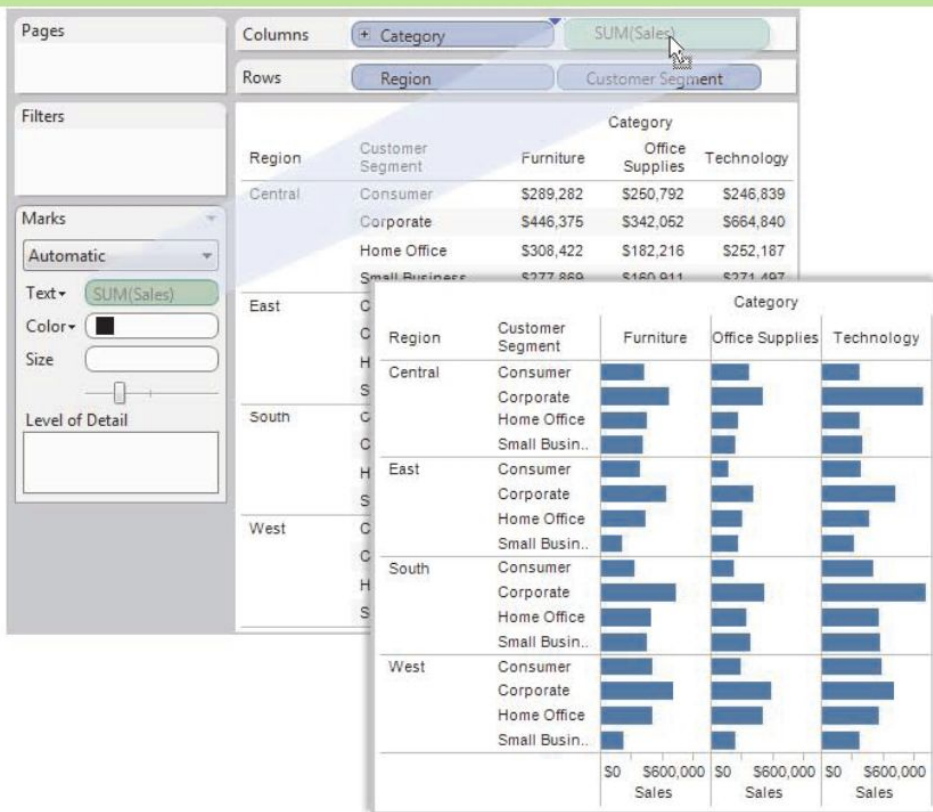
Size Population, total ▼

Zoom

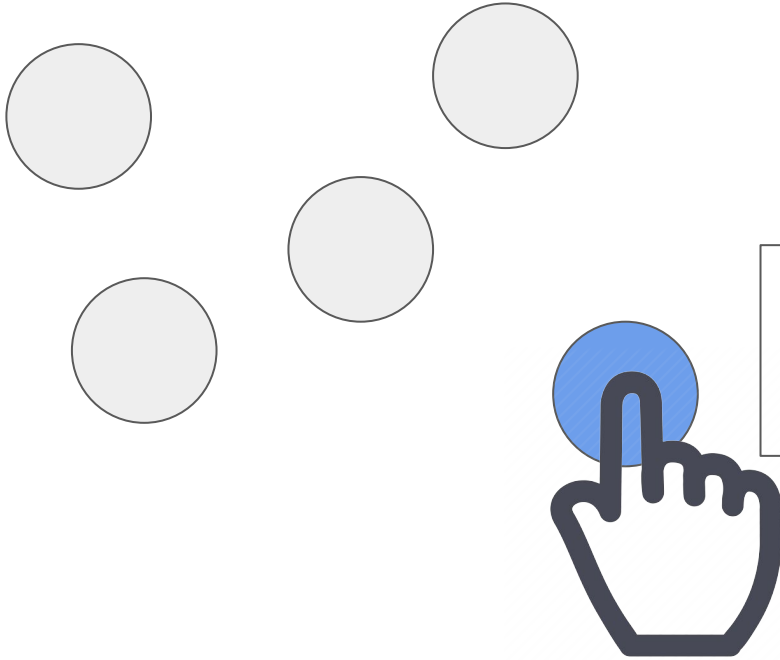
Drag a data parameter, and drop it to a visual variable to encode.

The screenshot shows the Tableau interface with the following configuration:

- Data Pane:** Dimensions include Order Date, Order ID, Order Priority, Products (Category, Sub-Category, Product Name), Profit (bin), Region, Ship Date, Ship Mode, Supplier, Zip Code, and Measure Names. Measures include Discount and Order Quantity.
- Columns Shelf:** Category
- Rows Shelf:** Region
- Marks Card:** Automatic



Abstract / elaborate: show me less / more detail



University of Helsinki  
Faculty of Science  
Department of Computer science

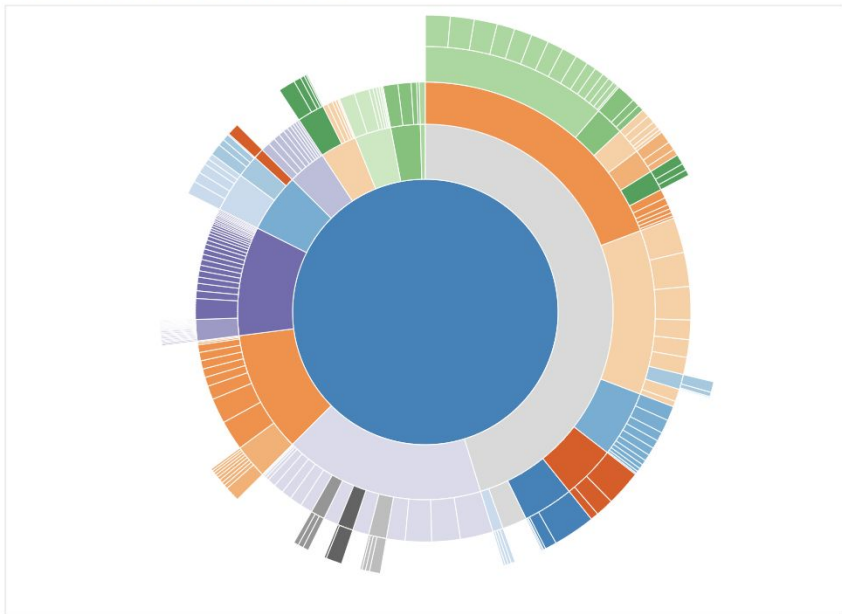




# Semantic zooming to view abstract / elaborate

<https://observablehq.com/@d3/zoomable-sunburst>

## Zoomable Sunburst



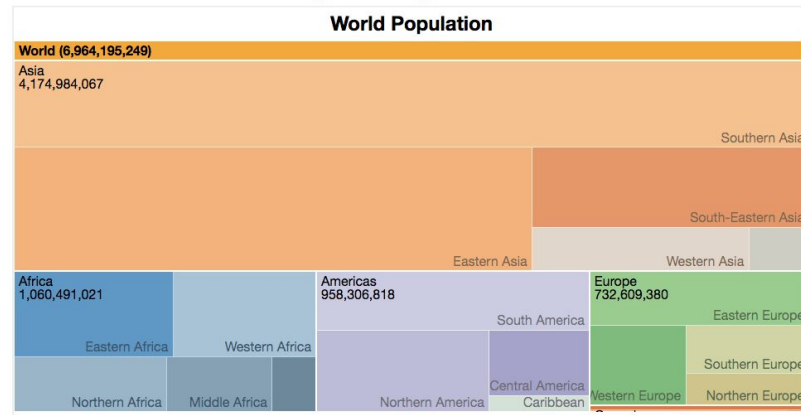
Click on any arc to zoom in. Click on the center circle to zoom out.

[Open](#)

A sunburst is similar to a treemap, except it uses a radial layout. The root node of the tree is at the center, with leaves on the circumference. The area (or angle, depending on implementation) of each arc corresponds to its value. Sunburst design by [John Stasko](#). Data courtesy [Jeff Heer](#).

<https://observablehq.com/@d3/zoomable-treemap>

## Zoomable Treemap Template



[Open](#)

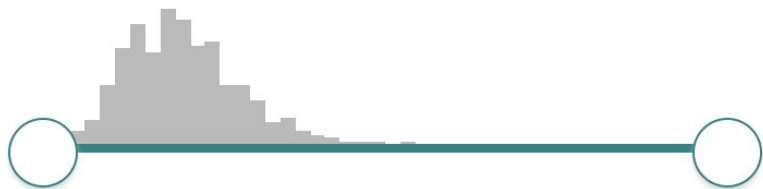
### Zoomable Treemap

Treemaps for visualizing hierarchical data. Click to zoom to the next level. Click on the top orange band to zoom out. Based on Mike Bostock's [Zoomable Treemaps](#)

This template follows [pigshell's](#) convention for "gist templates":

- It is supplied data using `postMessage()`, as a single object of the form `{ opts: {...}, data: [...] }`
- It posts a message to the parent with an object of the form `{ height: <number> }` to enable the framing context to adjust the height of the iframe.
- If the URL does not contain a hash fragment, it displays sample data from the containing gist.

# Filter: show me something conditionally



Entire place

Have a place to yourself

Private room

Have your own room and share some common spaces

Shared room

Stay in a shared space, like a common room

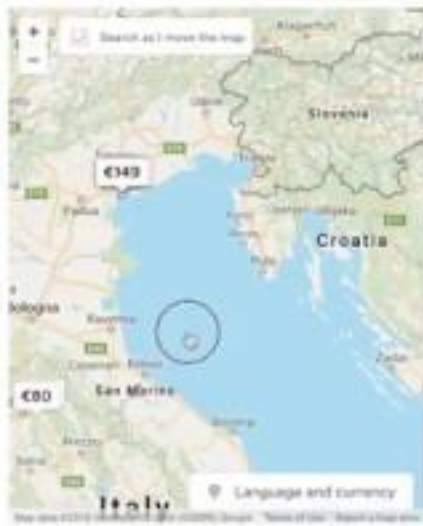
← April 2018							May 2018 →						
Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7			1	2	3	4	5
8	9	10	11	12	13	14	6	7	8	9	10	11	12
15	16	17	18	19	20	21	13	14	15	16	17	18	19
22	23	24	25	26	27	28	20	21	22	23	24	25	26
29	30						27	28	29	30	31		



ENTIRE APARTMENT - BIGNANO SULL'ARNO  
**Holiday in Tuscany in the Strettoio**  
From €69 per night - Free cancellation  
★★★★★ Superhost

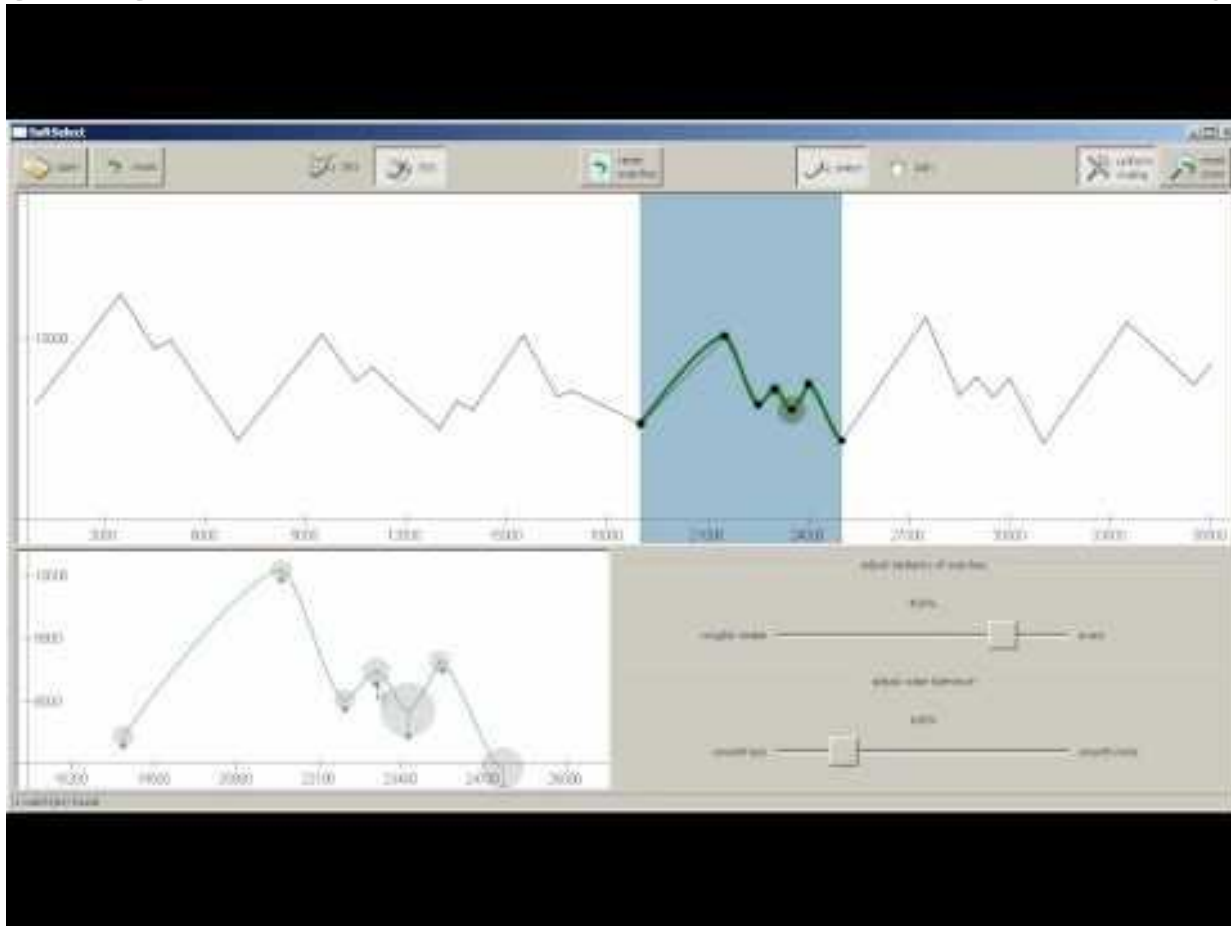


ENTIRE LOFT - VENEZIA  
**Venetian loft with canal view!!**  
From €100 per night - Free cancellation  
★★★★★

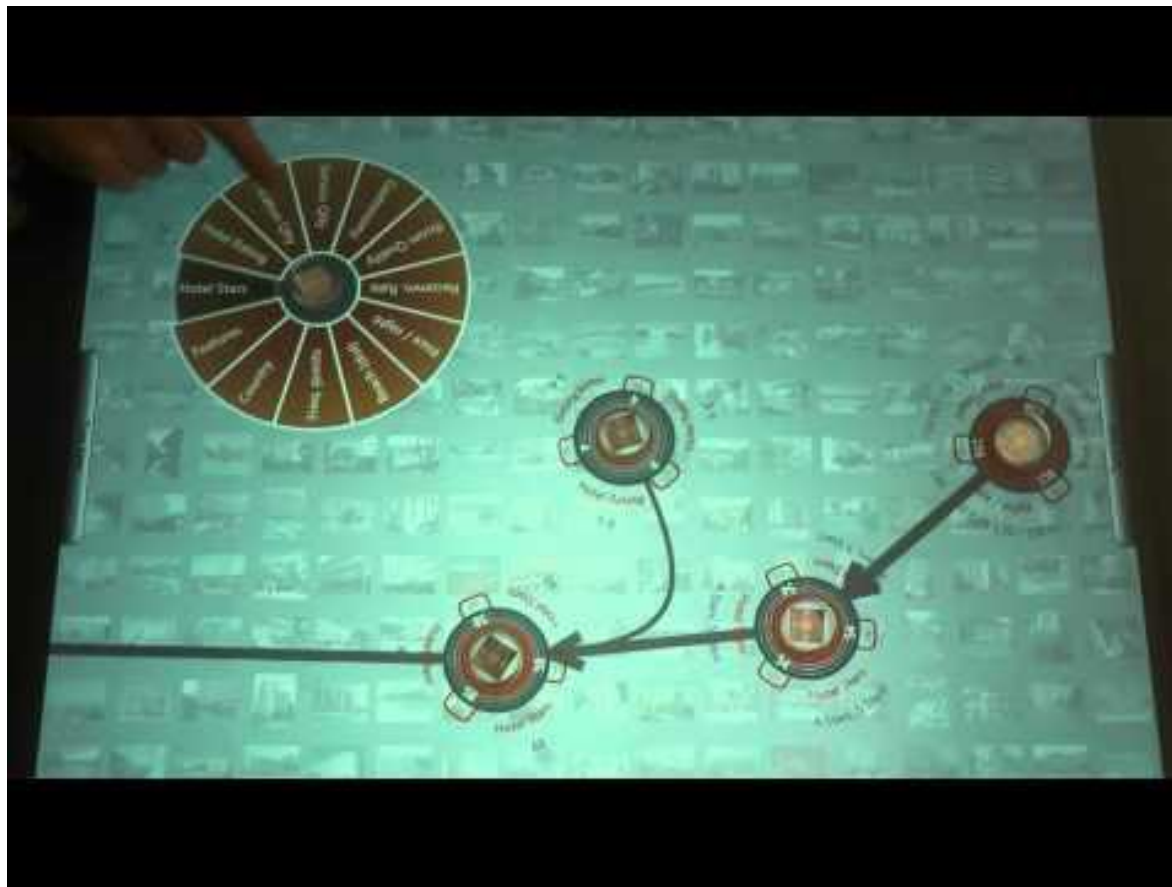


Zoom and pan to filter  
<https://www.airbnb.com>

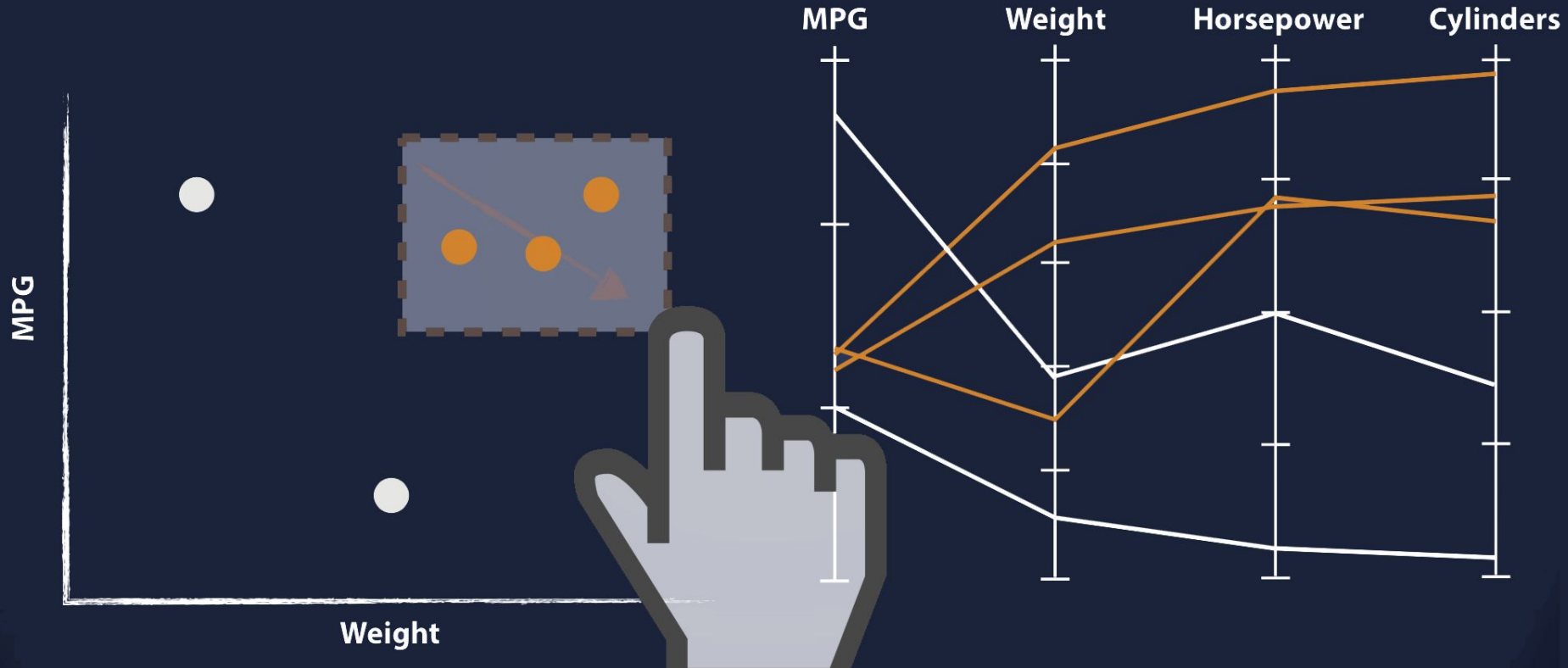
# A single gesture interaction to filter data by patterns



## Use physical object to support collaborative filtering.

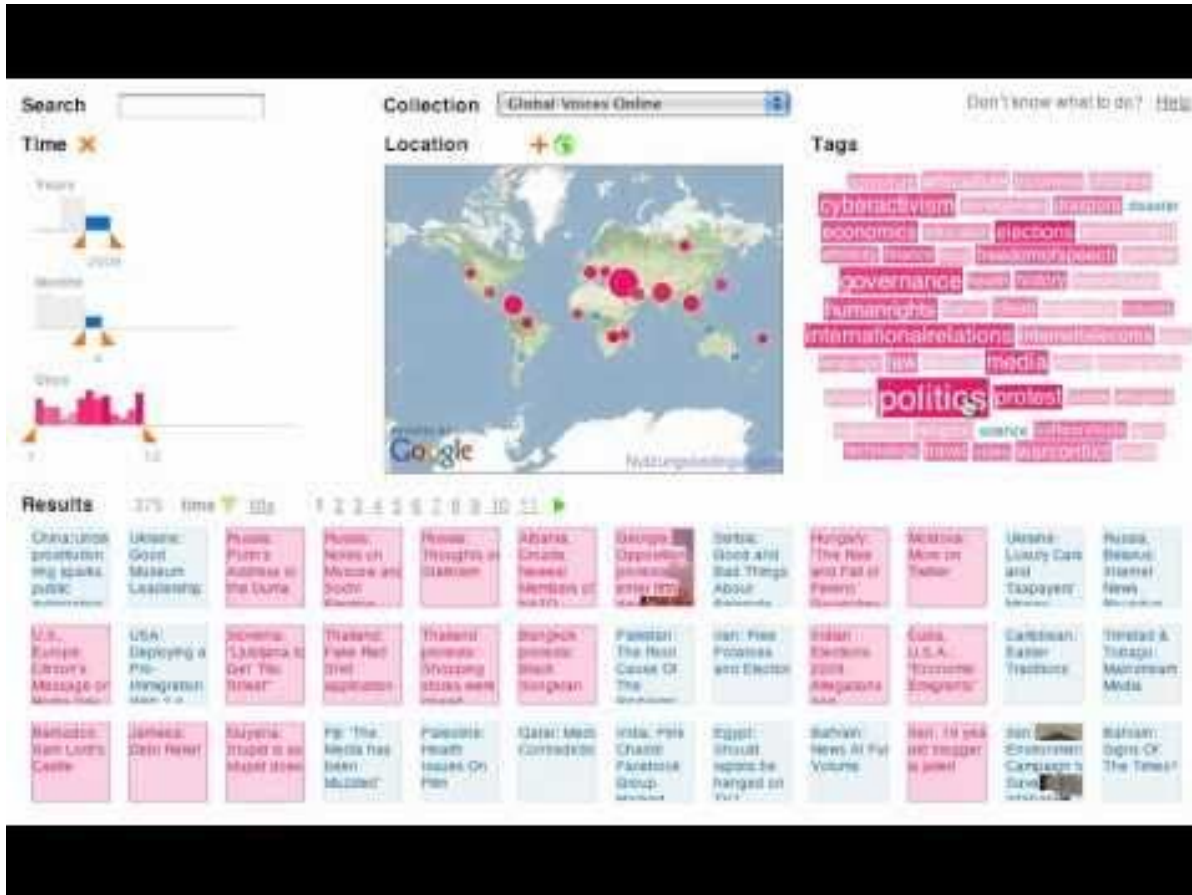


# Connect: show me related items

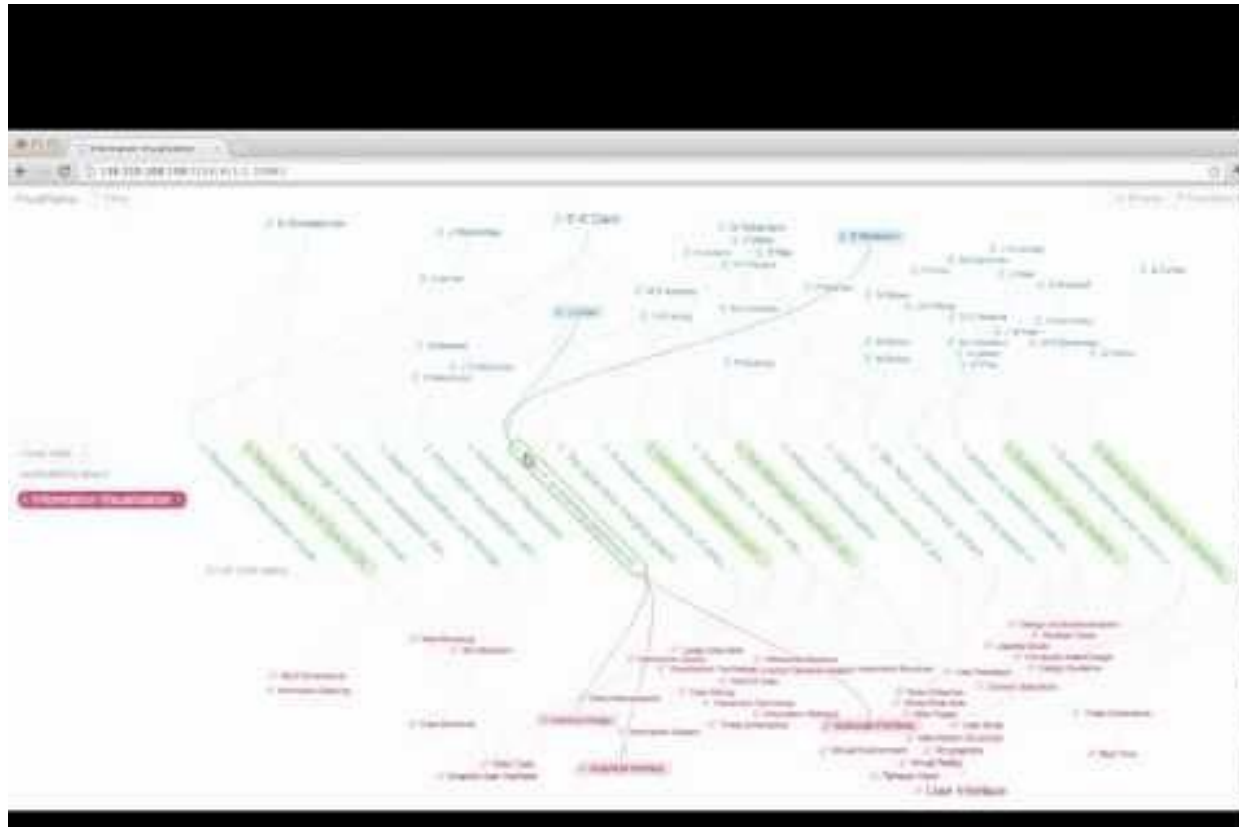


# Connect: show me related items

Linking & brushing to highlight the same items in other views.

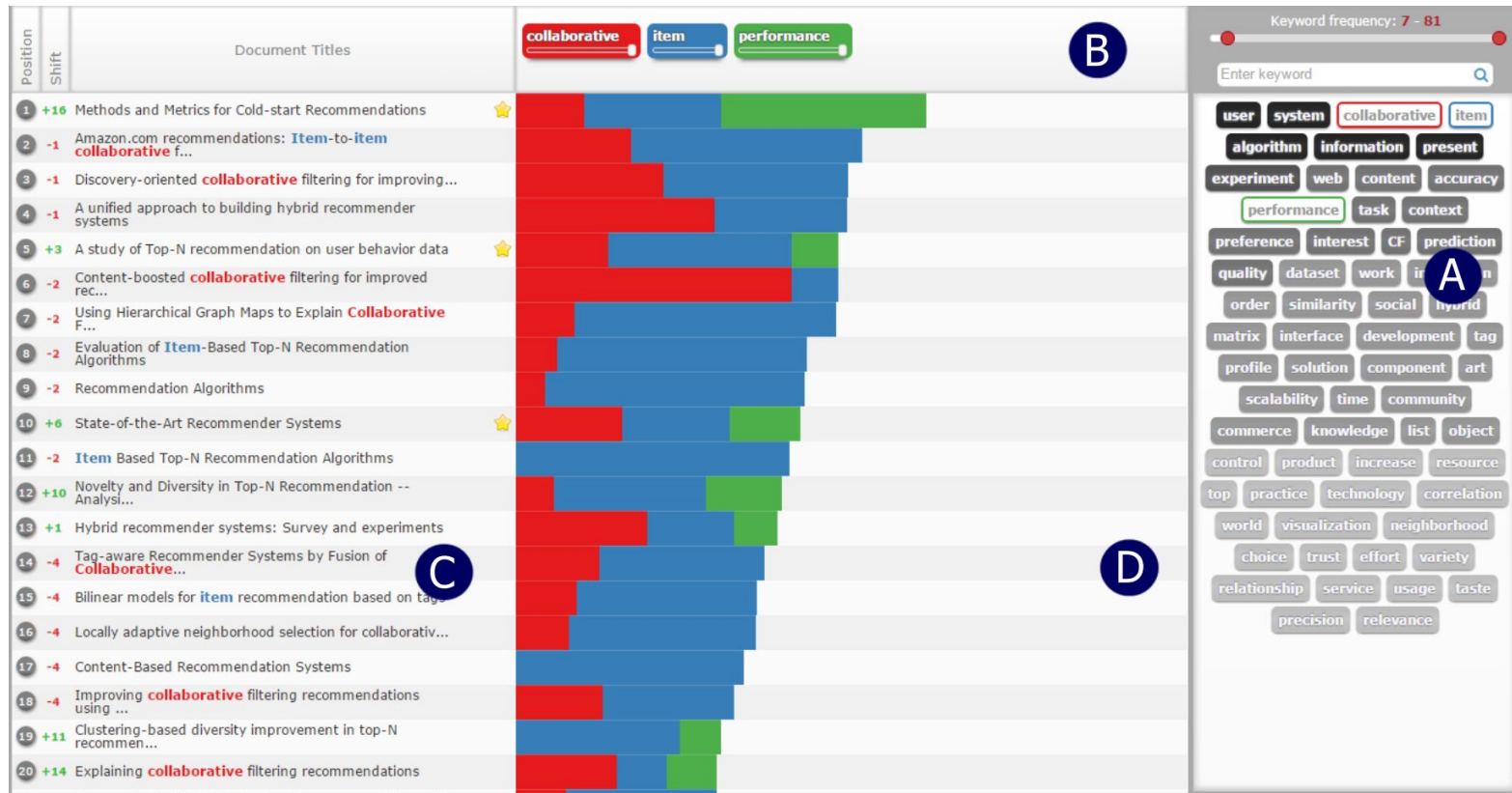


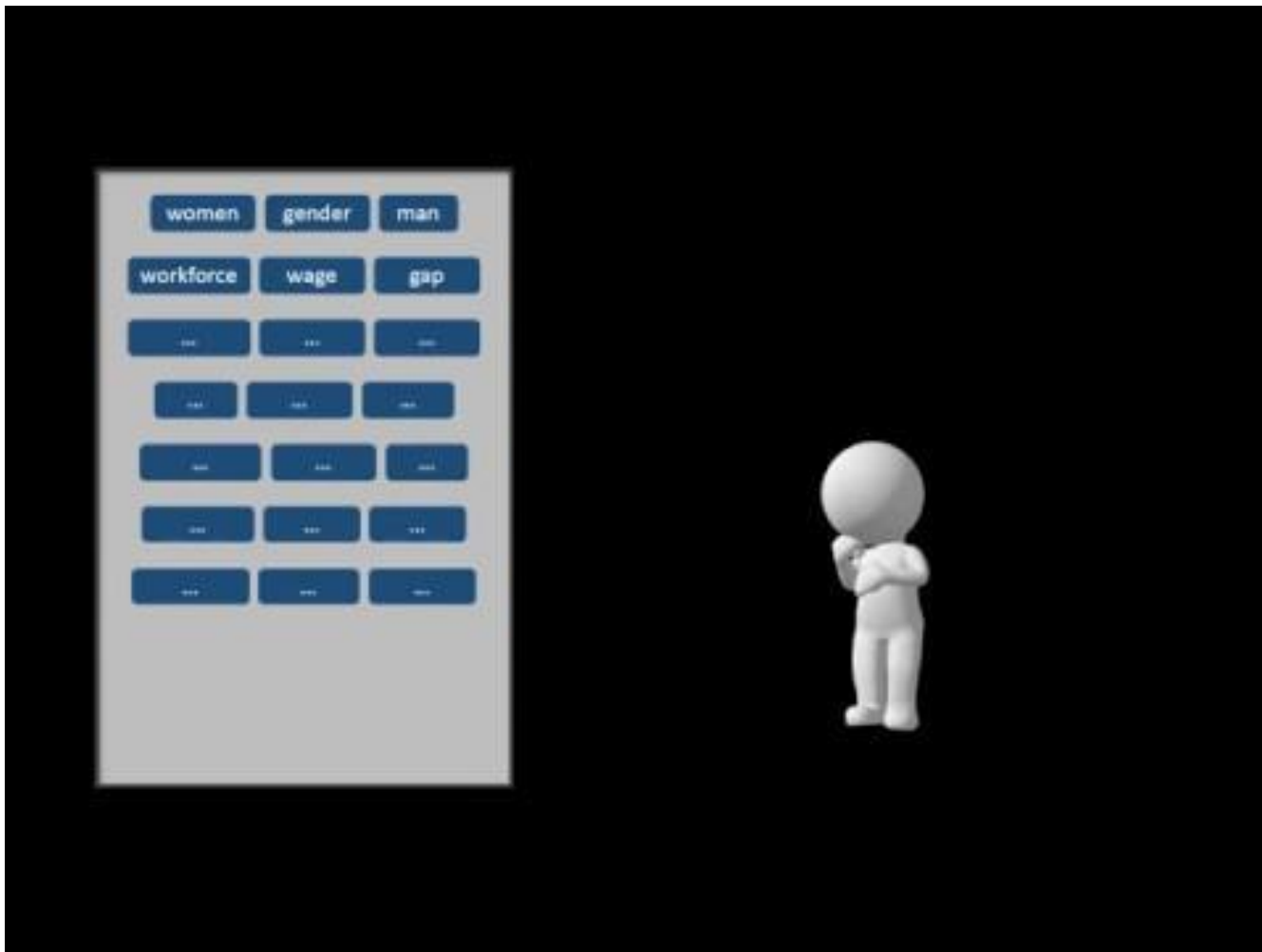
Mouseover to **highlight** directly connected nodes.



# Multiple categories of an action

Drag and drop to **reconfigure** documents and **connect** keywords to documents.





# Multiple categories of an action

A lens metaphor for **encoding** and **elaborating**.



# Seven categories of actions

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 less / more detail**

Filter: **show me something conditionally**

Connect: **show me related items**

# Information seeking mantra

Overview first, zoom and filter, details on demand

Overview first, zoom and filter, details on demand

Overview first, zoom and filter, details on demand

Overview first, zoom and filter, details on demand

Overview first, zoom and filter, details on demand

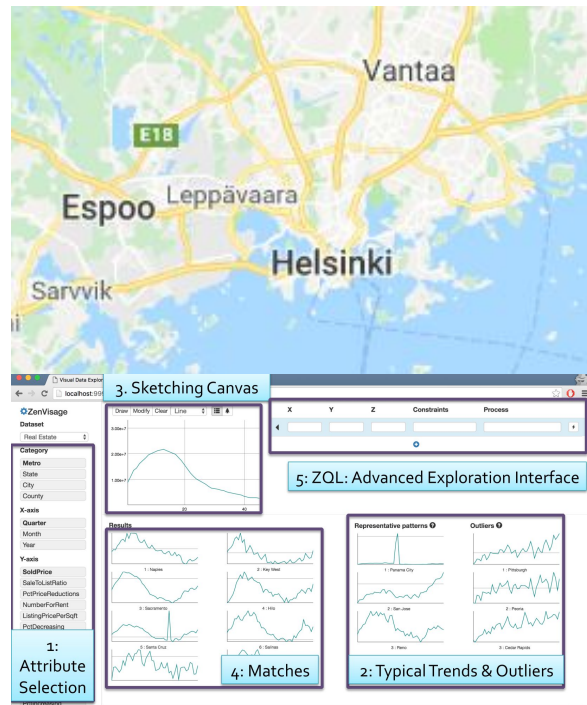
Overview first, zoom and filter, details on demand

Overview first, zoom and filter, details on demand

# Overview first, zoom and filter, details on demand Though there can be exceptions...

E.g. when the system knows your context

E.g. when the system jumps right into insights.



# Navigation between focused and contextual views

Overview+detail

Zooming

Focus+context

Cue-based technique

# Overview+detail: spatial separation

```
history.js
129
130 if(eva){
131   his.parent = hisVar.curView
132   hisVar.curViewHis.children.
133   postUpdateEffects(hisVar.cu
134 }
135 else if(!$.isEmptyObject(hisVar
136 allNoteEva());
137 his.parent = hisVar.curNote
138 hisVar.curNoteAction.childr
139 postUpdateEffects(hisVar.cu
140 }
141 else if(hisVar.curSelectionActi
142 hisVar.curSelectionAction.c
143 his.parent = hisVar.curSele
144 }
145 if(getParent) hisVar.firstSele
146
147 if(interactionHistory.length >
148 interactionHistory.push(his)
149 hisVar.curSelectionAction = his
150 hisVar.possibleAddParent = his;
151
152 }
153
154 //branch at select, deselect, notes
155 //if(add is not related to detail o
156 function addAction(entity){
157   var iAction = hisVar.possibleAD
158   var his = {
159     action: "add",
160     _id: getFormattedTime(),
161     entity: entity.entity,
162     type: entity.type,
163     //selectedEntities: visObj.
164     parent: hisVar.curSelection
165     children: [],
166     //combine: false,
167     dataset: Object.assign({},
168   }
169
170   hisVar.selectionOnGoing = false
```

Intro ☆

File Edit View Insert Format Slide Arrange Tools Add-ons Help Last edit was 7 days ago

PRESENT SHARE

4 Use perception to amplify cognition

5 Purposes of visualization

- Make a decision
- See a change
- Discover
- Present knowledge

6 Purposes of visualization – Decision making

7 Purposes of visualization – Decision making

8 Purposes of visualization – Decision making

<https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/data-visualization-for-human-perception>

## Use perception to amplify cognition

CI

2009 Sales (thousands of U.S. \$)

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Domestic	1,983	2,343	2,593	2,283	2,574	2,838	2,382	2,634	2,938	2,739	2,983	3,493	31,783
International	574	636	673	593	644	679	593	139	599	583	602	690	7,005
Total	2,557	2,979	3,266	2,876	3,218	3,517	2,975	2,773	3,537	3,322	3,585	4,183	38,788

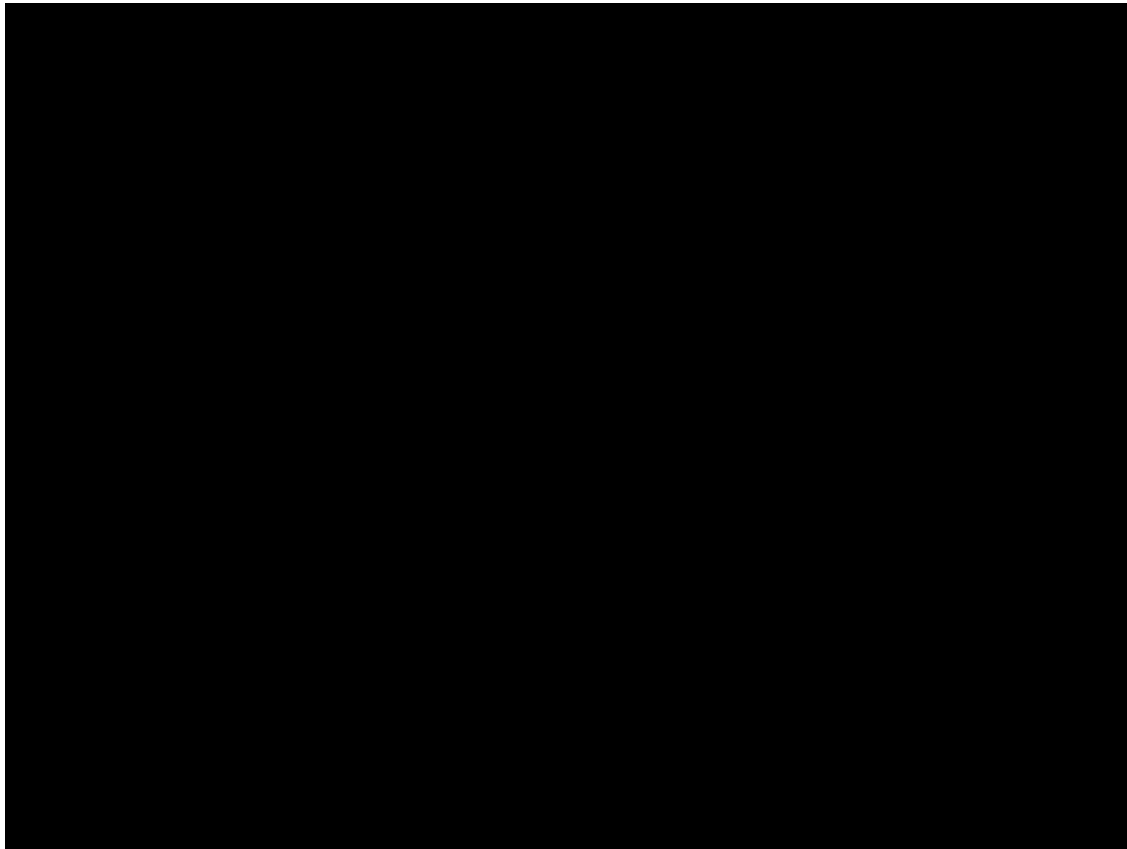
U.S. Dollars (thousands)

2009 Sales

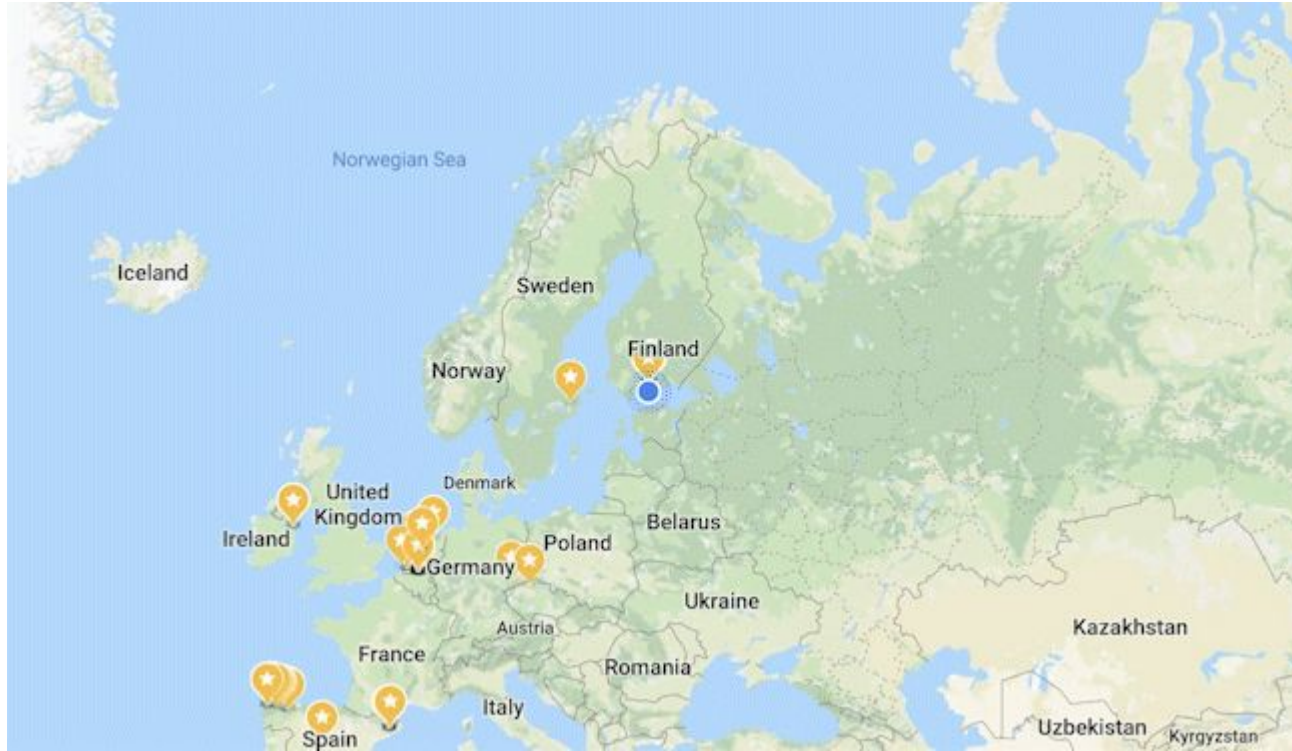
Domestic

International

# Spatial separation on z-coordinate



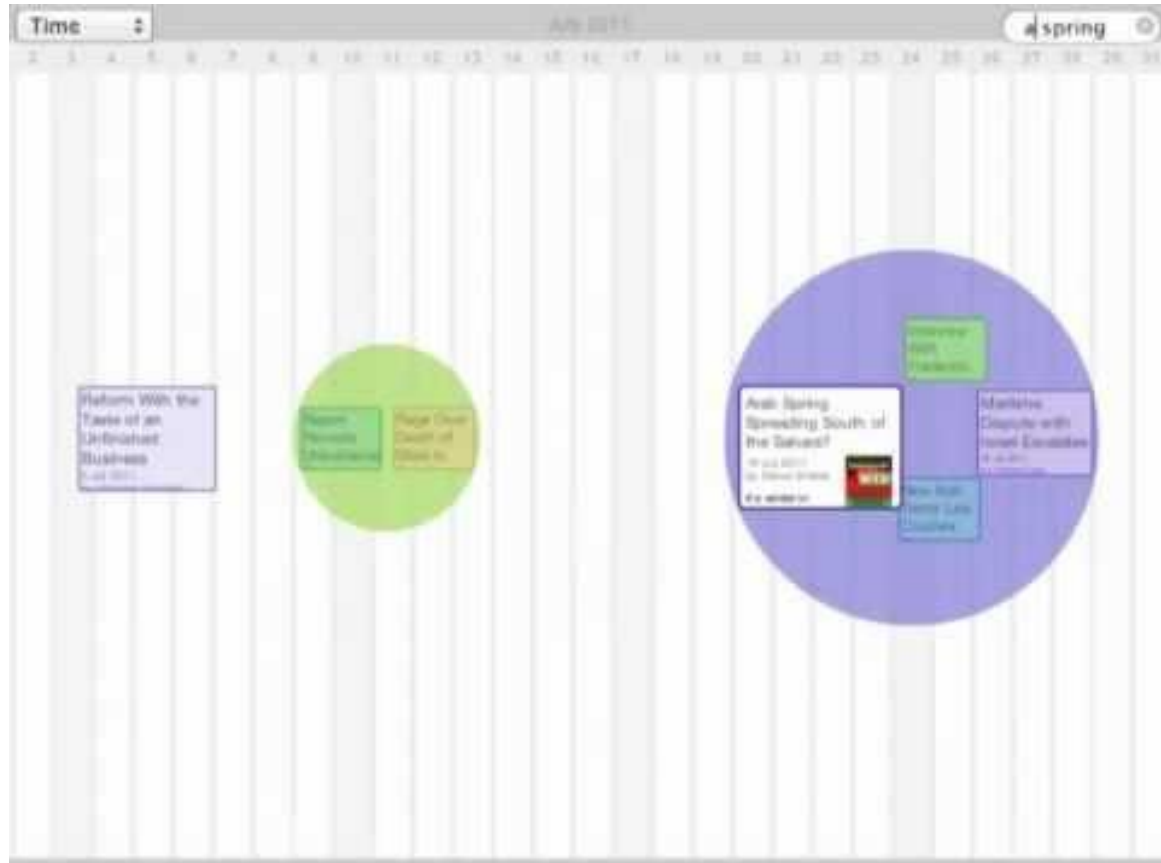
# Zooming: temporal separation



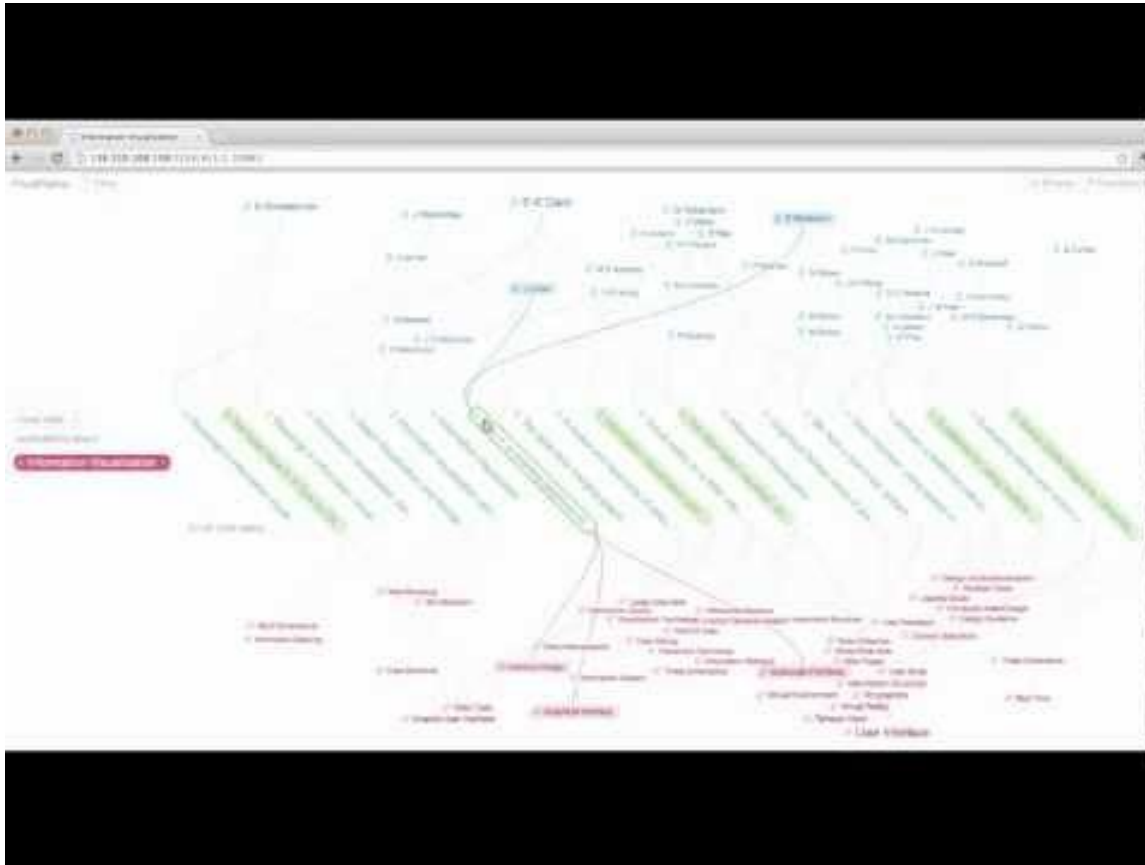
# Zooming: temporal separation

Base layer + item layer;

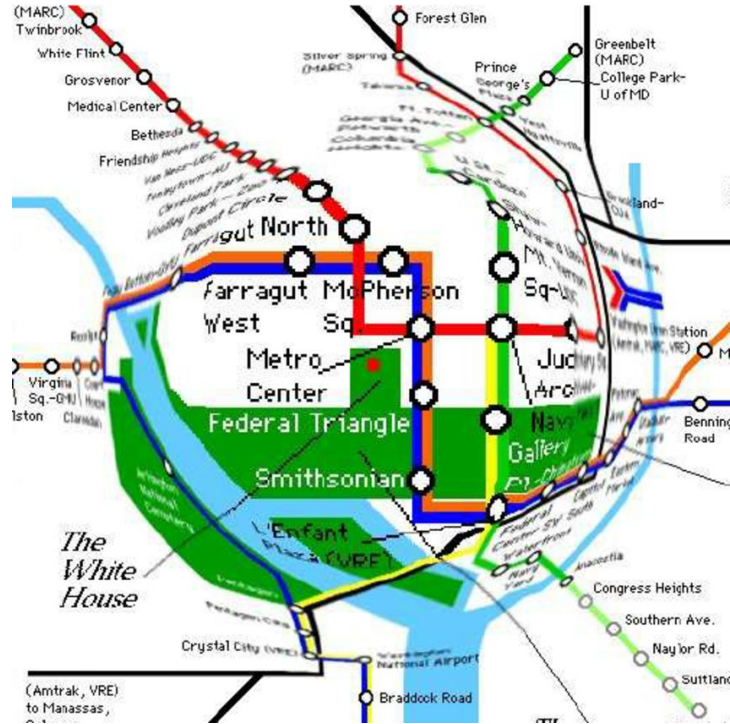
Note: good use of the information seeking mantra.



Visual transitions between views help maintain context.



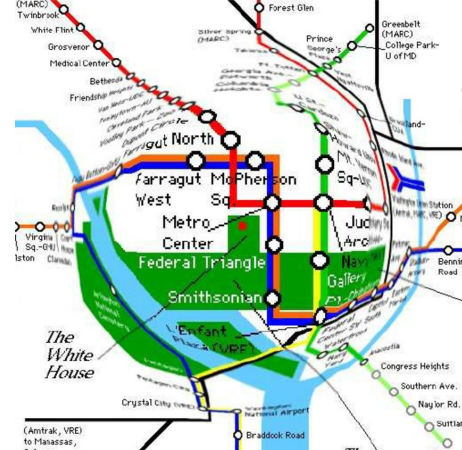
# Focus+context: displaying the focus within the context in a single continuous view



# Fisheye limitations

Distortion of the view can cause

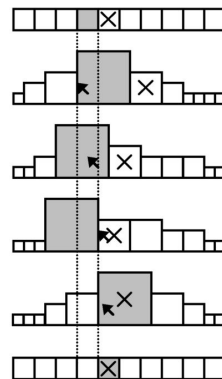
- Misinterpretation of the underlying data;
- Challenges in target acquisition.



Lines distort around the center, leading to ambiguity regarding location and direction interpretation.

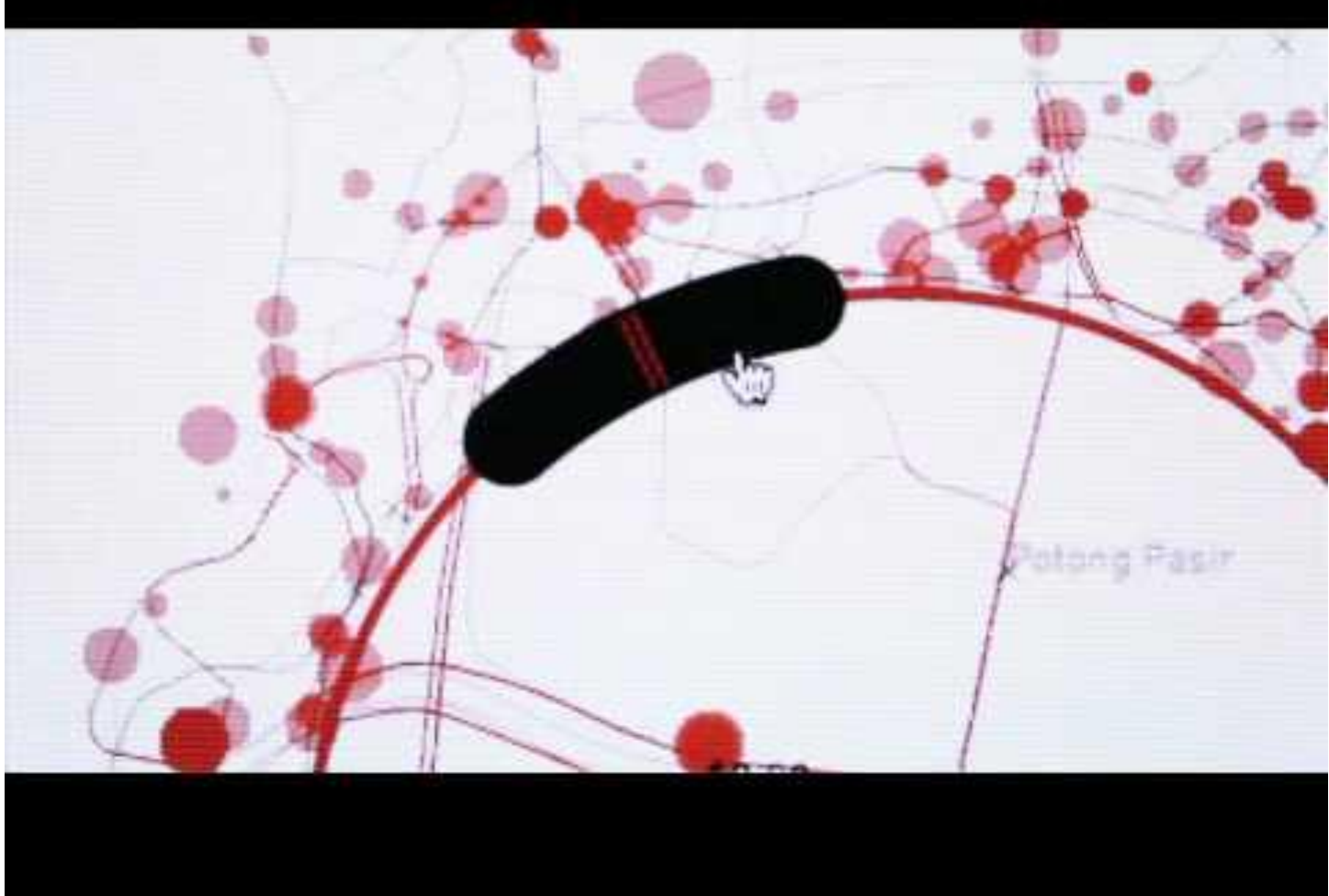


(a) the Mac OS X Dock icon-panel



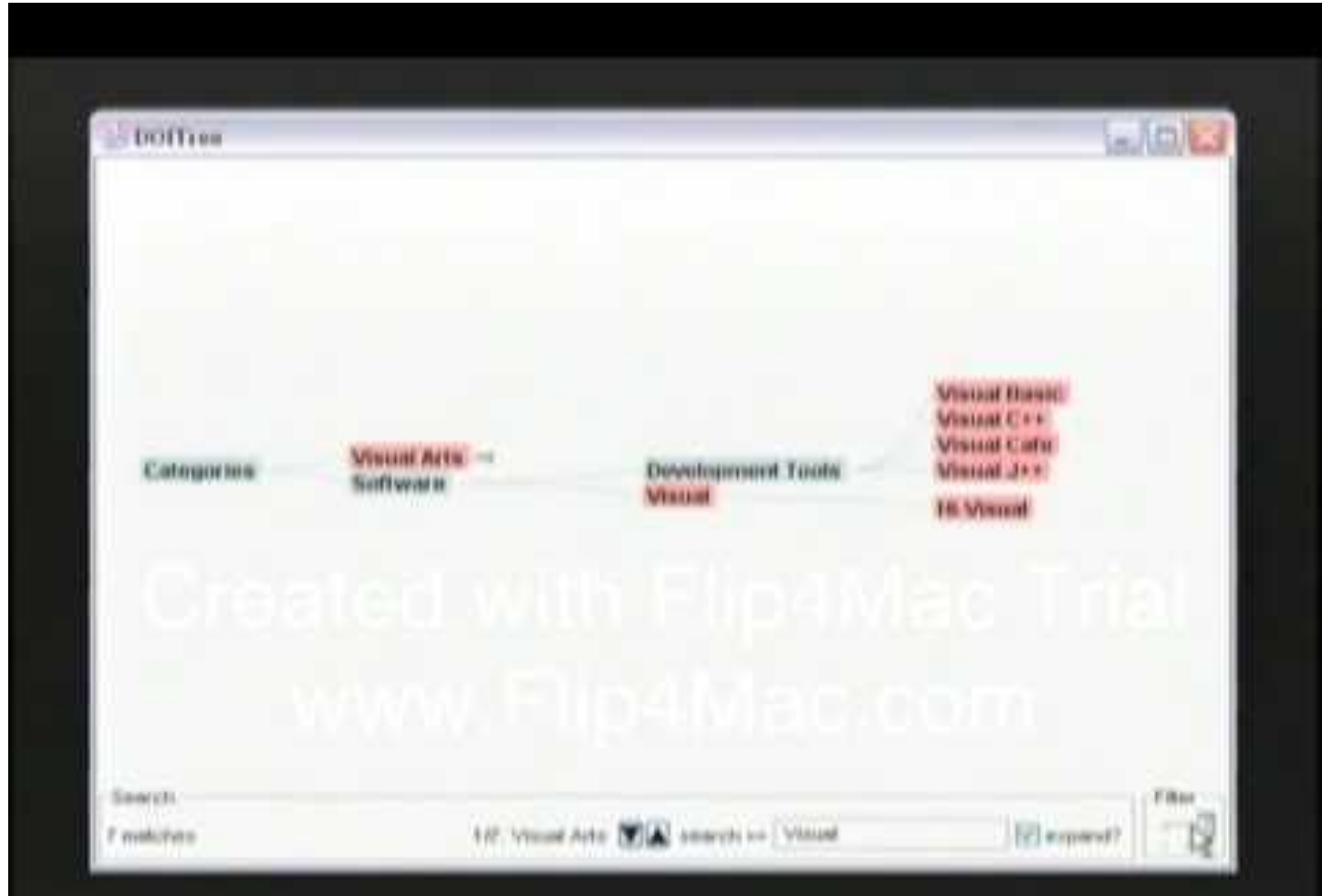
(b) target movement caused by distortion. Items can be displayed at different locations (middle rows) from the actual locations needed to select them (top and bottom rows)

The lens displaces items away from the actual screen location used to activate them.

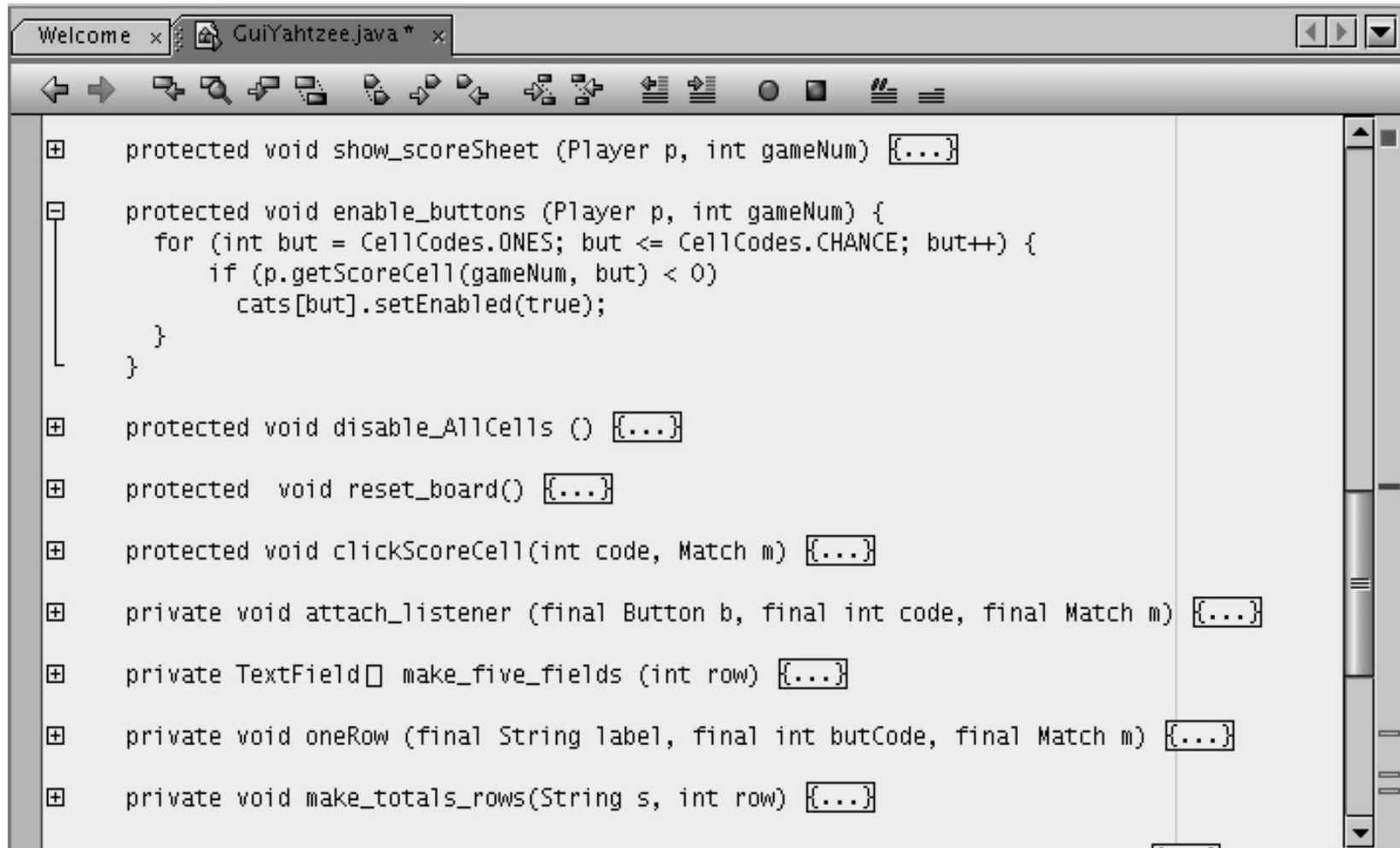




# Focus+context for tree visualization



# Focus+context



The image shows a screenshot of an IDE window titled "Welcome x" and "GuiYahtzee.java \* x". The window contains Java code for a Yahtzee game interface. A focus+context overlay is visible, showing a vertical bar on the right side of the code editor. The code is as follows:

```
protected void show_scoreSheet (Player p, int gameNum) {...}

protected void enable_buttons (Player p, int gameNum) {
    for (int but = CellCodes.ONES; but <= CellCodes.CHANCE; but++) {
        if (p.getScoreCell(gameNum, but) < 0)
            cats[but].setEnabled(true);
    }
}

protected void disable_AllCells () {...}

protected void reset_board() {...}

protected void clickScoreCell(int code, Match m) {...}

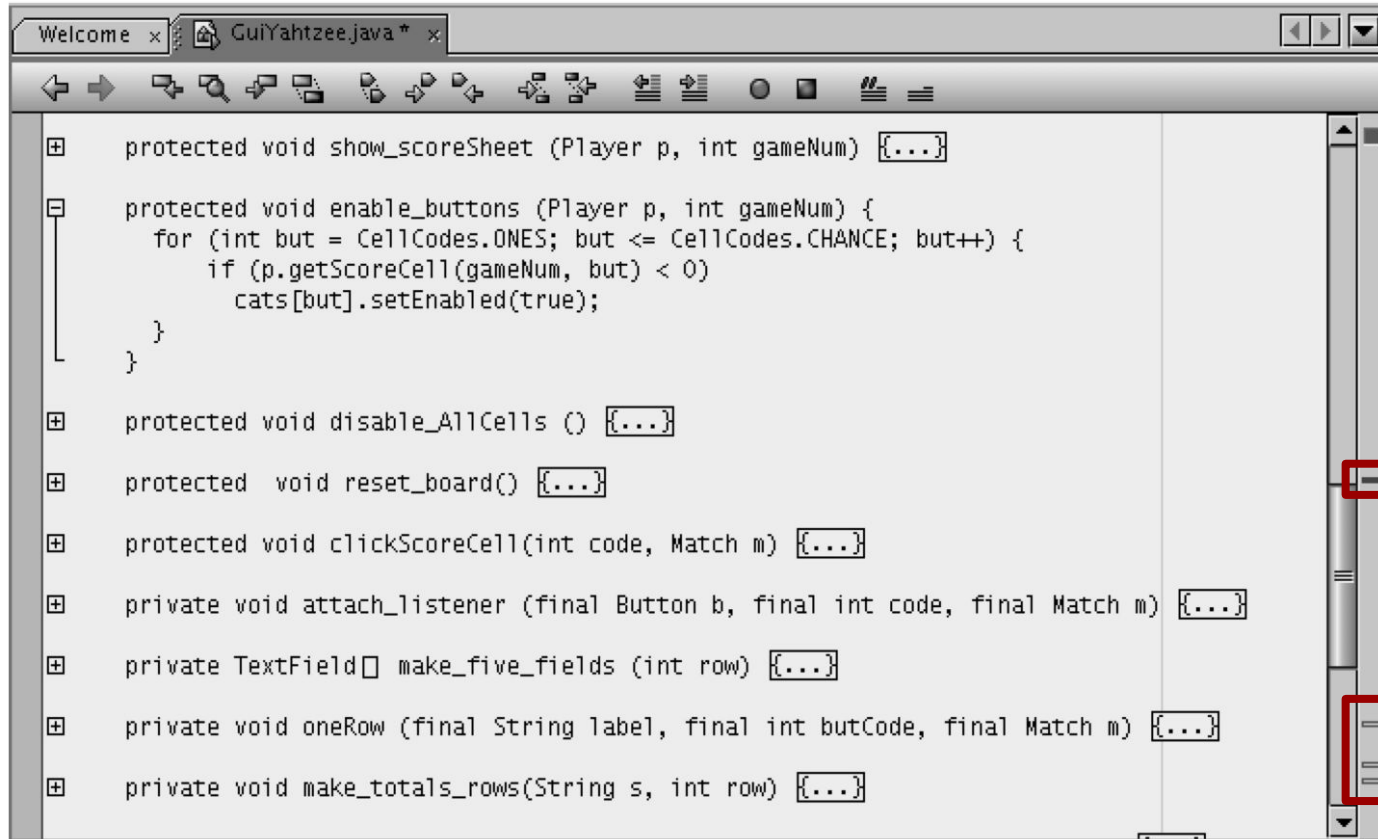
private void attach_listener (final Button b, final int code, final Match m) {...}

private TextField[] make_five_fields (int row) {...}

private void oneRow (final String label, final int butCode, final Match m) {...}

private void make_totals_rows(String s, int row) {...}
```

# Cue-based techniques: use visual cues to imply focuses within context



The screenshot shows an IDE window titled 'Welcome x' and 'GuiYahtzee.java \* x'. The code is as follows:

```
protected void show_scoreSheet (Player p, int gameNum) {...}

protected void enable_buttons (Player p, int gameNum) {
    for (int but = CellCodes.ONES; but <= CellCodes.CHANCE; but++) {
        if (p.getScoreCell(gameNum, but) < 0)
            cats[but].setEnabled(true);
    }
}

protected void disable_AllCells () {...}

protected void reset_board() {...}

protected void clickScoreCell(int code, Match m) {...}

private void attach_listener (final Button b, final int code, final Match m) {...}

private TextField[] make_five_fields (int row) {...}

private void oneRow (final String label, final int butCode, final Match m) {...}

private void make_totals_rows(String s, int row) {...}
```

Red boxes highlight the recent edit markers (horizontal lines) on the right side of the code editor, specifically on the lines for `reset_board()` and `make_totals_rows()`.

Mark recent edits within the code.

# Cue-based techniques

Where offscreen objects are located?

Stefano Burigat, Luca Chittaro, and Silvia Gabrielli. 2006. Visualizing locations of off-screen objects on mobile devices: a comparative evaluation of three approaches. MobileHCI '06



a

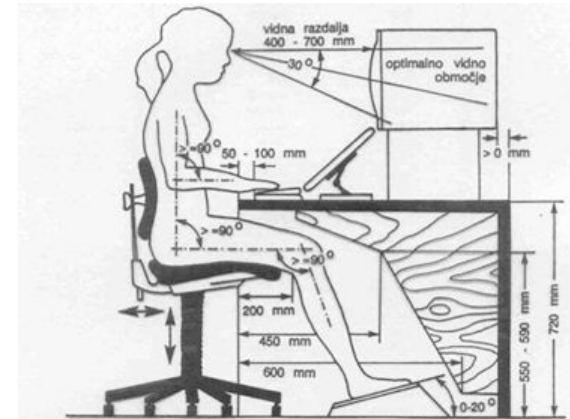


b

# Alternative modalities

Most interaction techniques assume traditional work setting:

- 15-22" screen
- High positional accuracy and a single pointer (a mouse or touchpad cursor)
- Single user



Priloge: Priporočljive velikosti delovnega mesta z računalniškim zaslonom za optimalni telesni položaj pri delu.

# Alternative modalities

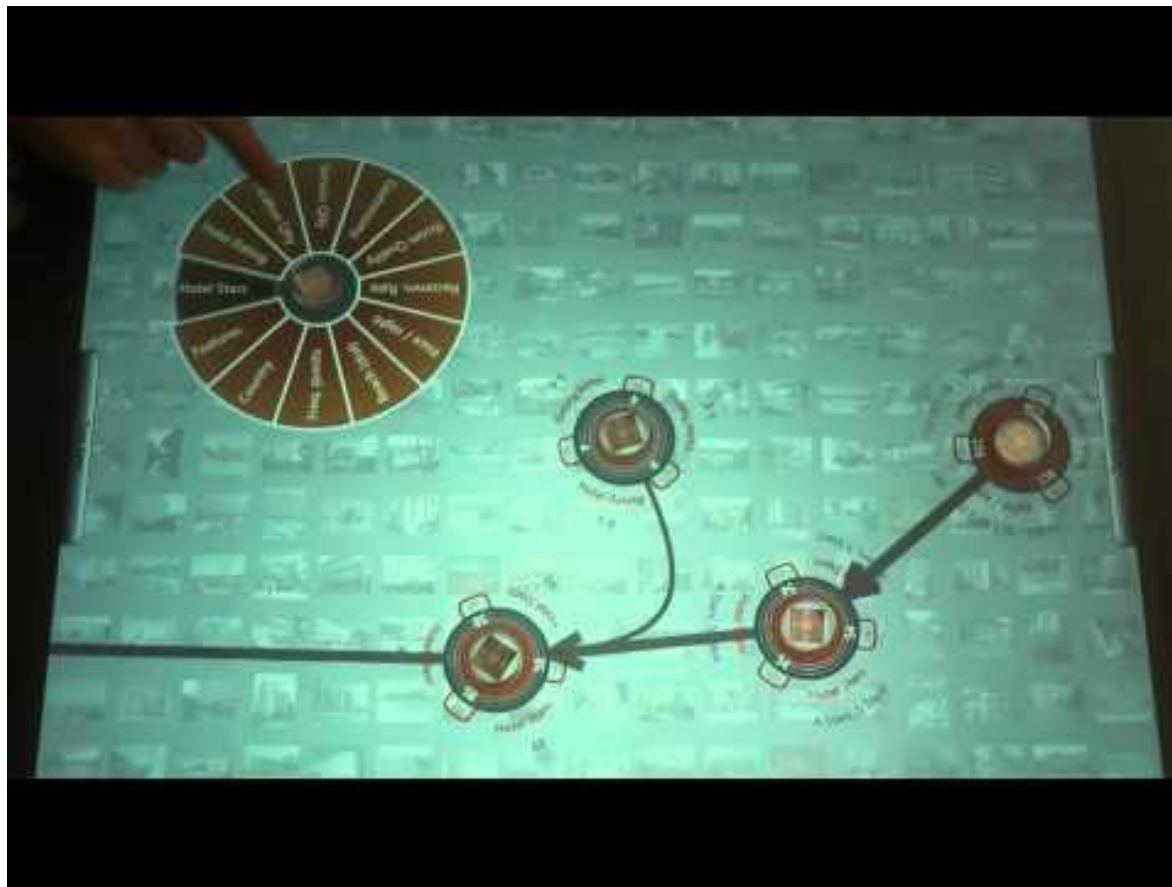
Most interaction techniques assume traditional work setting:

- 15-22" screen
- High positional accuracy and a single pointer (a mouse or touchpad cursor)
- Single user

**Alternative settings pose new challenges and opportunities:**

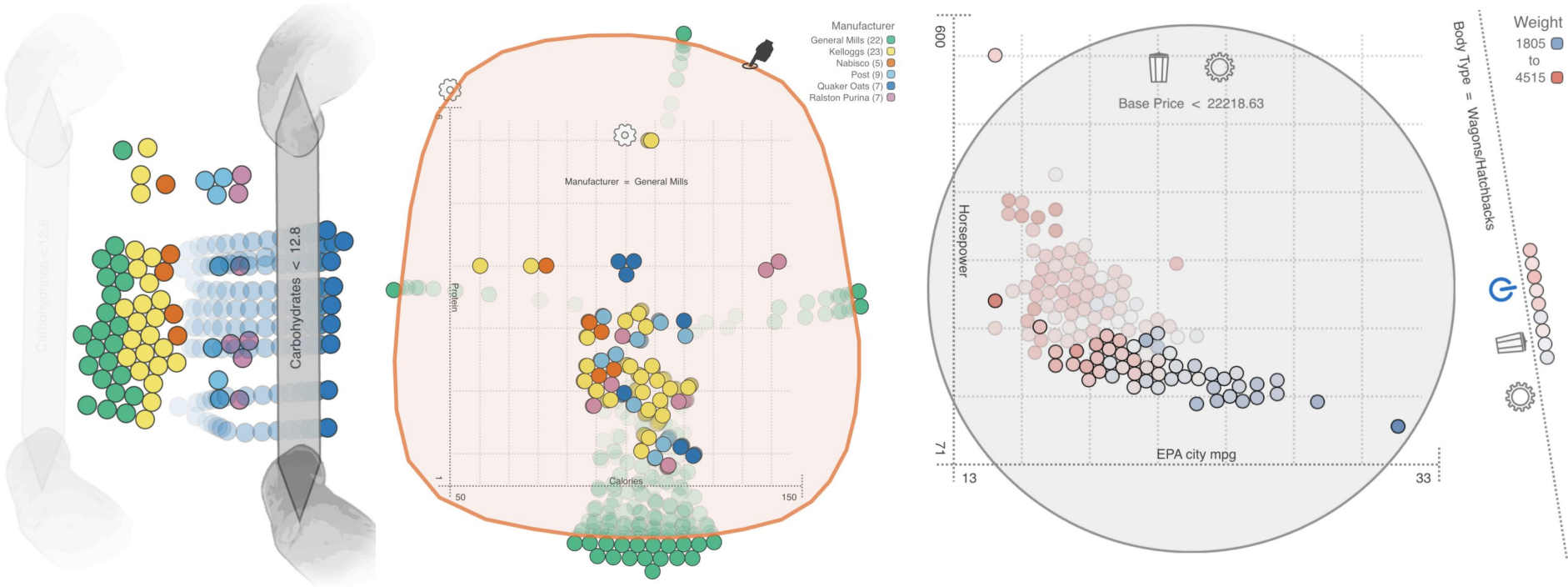
- Mobile and touch devices (smaller screen, fat finger, multi-touch)
- Alternative inputs (gaze, speech)
- Multi-user

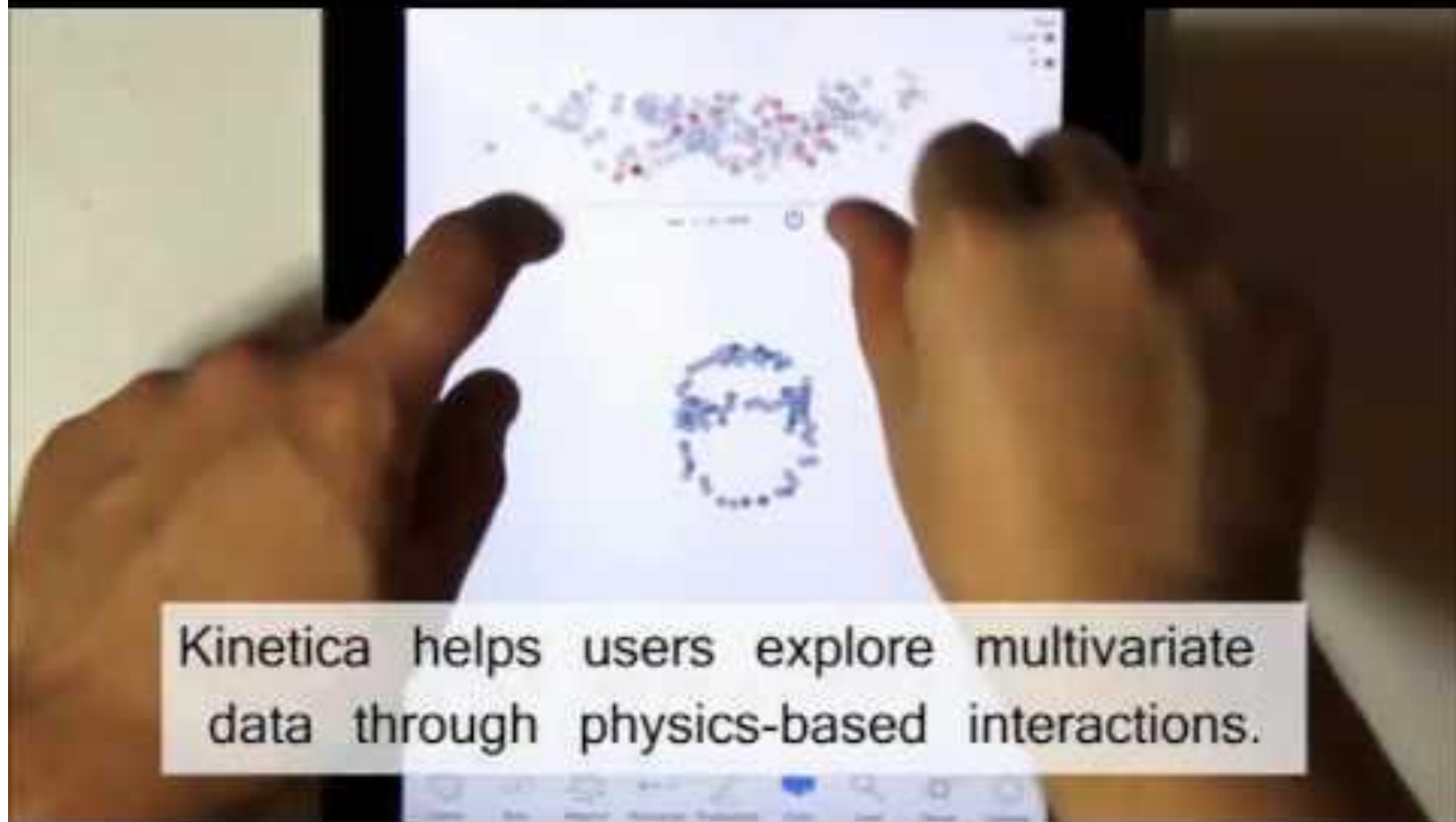
## Physical objects and touch to support collaborative filtering.



# Multi-touch gestures for different actions

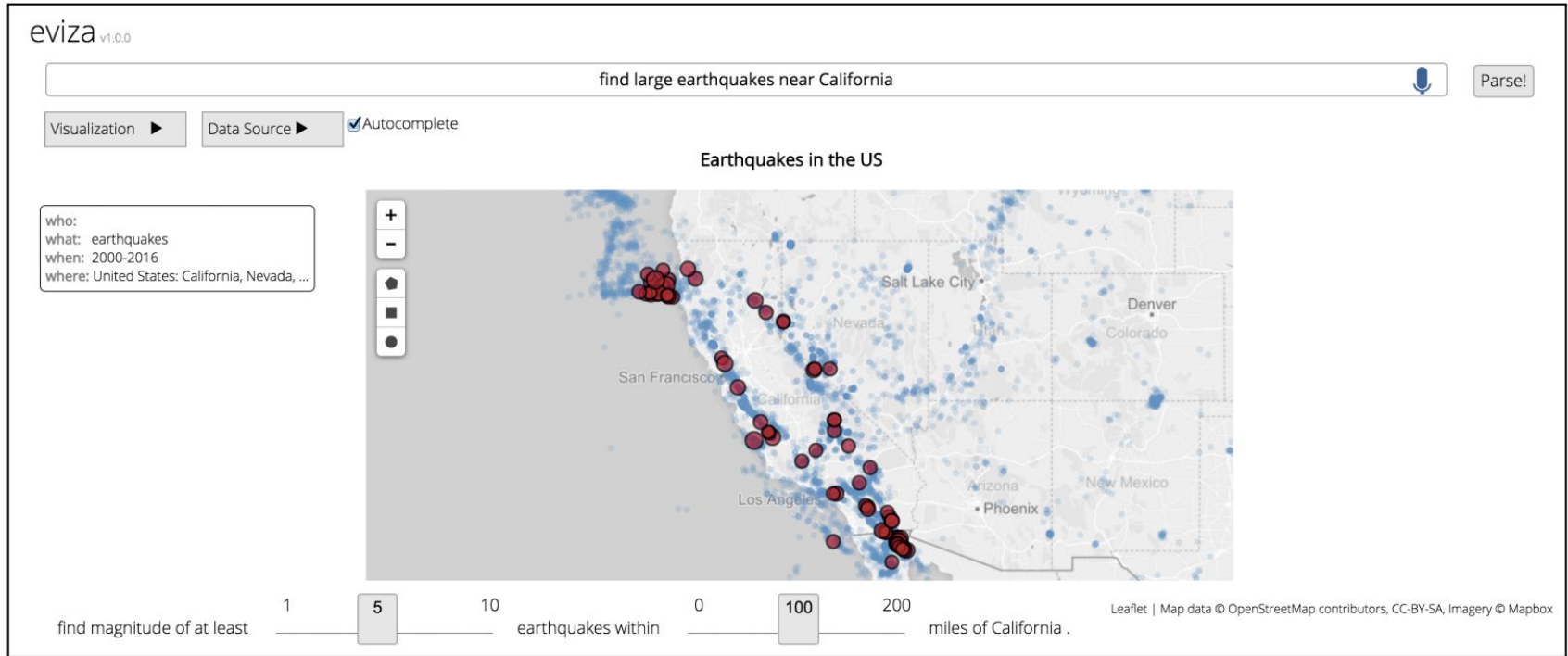
E.g., filter.





Kinetica helps users explore multivariate data through physics-based interactions.

# Natural Language-Based Query Interface



Vidya Setlur, Sarah E. Battersby, Melanie Tory, Rich Gossweiler, and Angel X. Chang. 2016. Eviza: A Natural Language Interface for Visual Analysis. UIST '16.

eviza

type or say "find large earthquakes near California"

Visualize

### Earthquakes in the US

What:  
what: earthquakes  
when: 2000-2014  
where: United States, California, Nevada



Source: Map data © OpenStreetMap contributors, CC-BY, Imagery © Mapbox

# Sensemaking Process

## Bottom-up processes

2: collect documents/information into the showbox

5: extract evidence to draw inferences, support or disconfirm a theory

8: organize raw evidence

11: build a case by gathering evidence to support or disconfirm a hypothesis

14: present the case to the audience

## Top-down processes

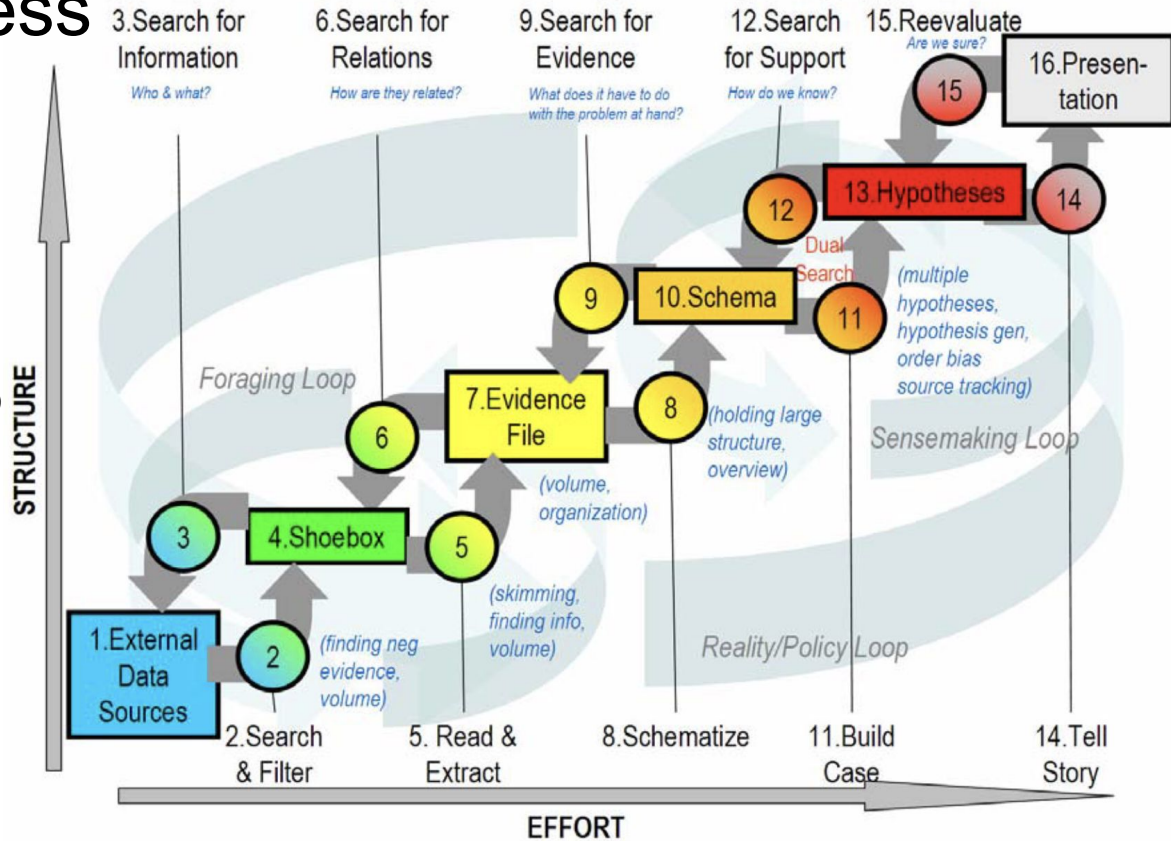
15: feedback from audience may require re-evaluate the theory

12: re-examine the organization of facts

9: re-examine, search for more evidence

6: search for new patterns

3: dig deeper into raw data



# Recap

Seven categories of actions in data visualization

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 less / more detail**

Filter: **show me something conditionally**

Connect: **show me related items**

Information seeking mantra

**Overview first, zoom and filter, details on demand**

# Recap

An overhead, top-down view of a meeting space. Several round, light-colored tables are arranged on a dark tiled floor. People are seated around the tables, some using laptops. The scene is dimly lit, with the text overlaid on the left side.

Focused and contextual views

Overview+detail: **spatial separation**

Zooming: **temporal separation**

Focus+context: **displaying the focused within the context in a single continuous view**

Cue-based techniques: **use visual cues to imply focuses within context**

Alternative interaction modalities

**Touch, speech...**

The sensemaking process