# Interactivity + Accessibility

## Data Visualization

dig.cmu.edu

**Frank Elavsky**
**based on materials by Dominik Moritz, Jeff Heer, Arvind Satyanarayan**

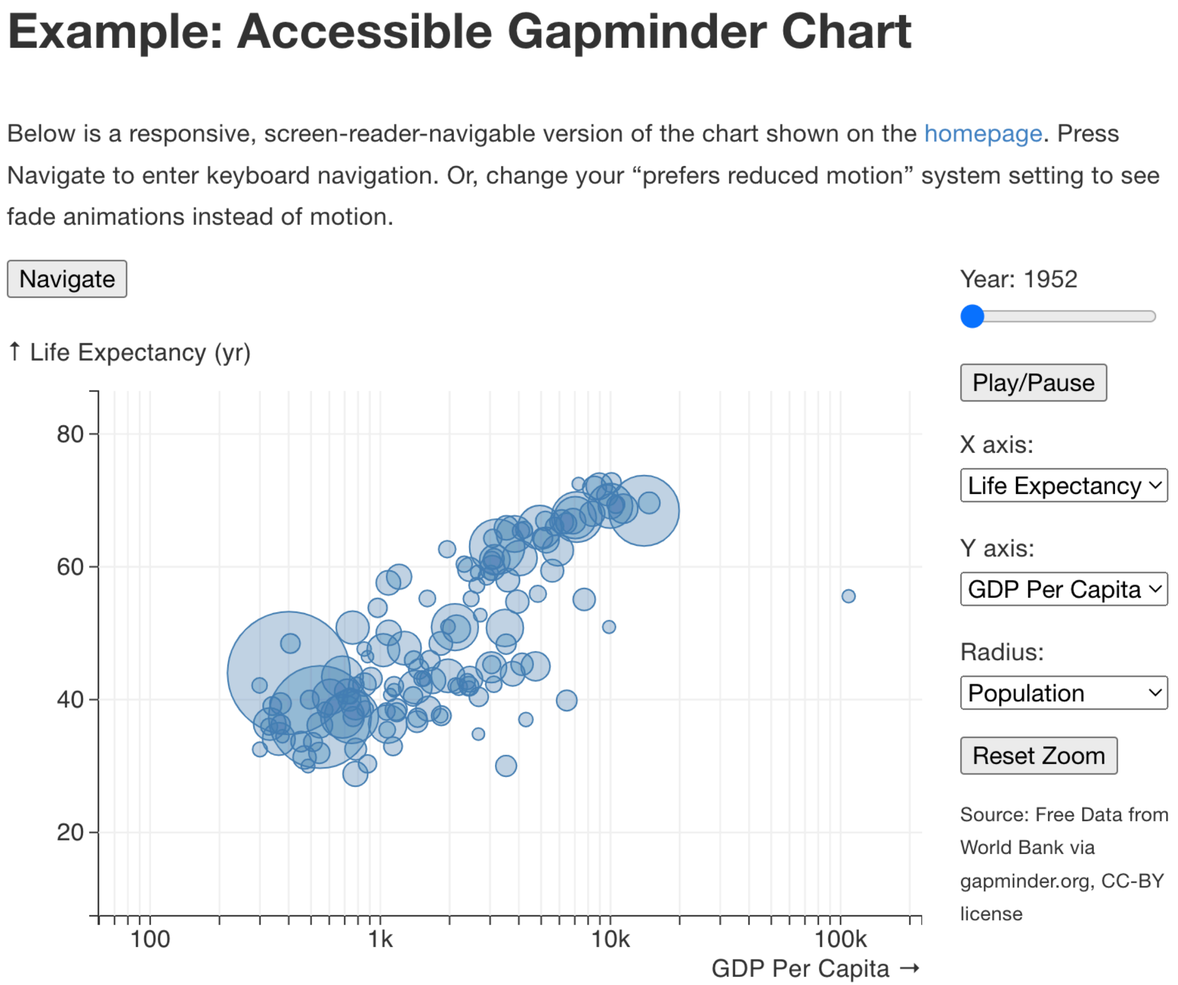
# What you will learn today

The value of interactivity

Principles of interaction design

Principles of accessible interaction design

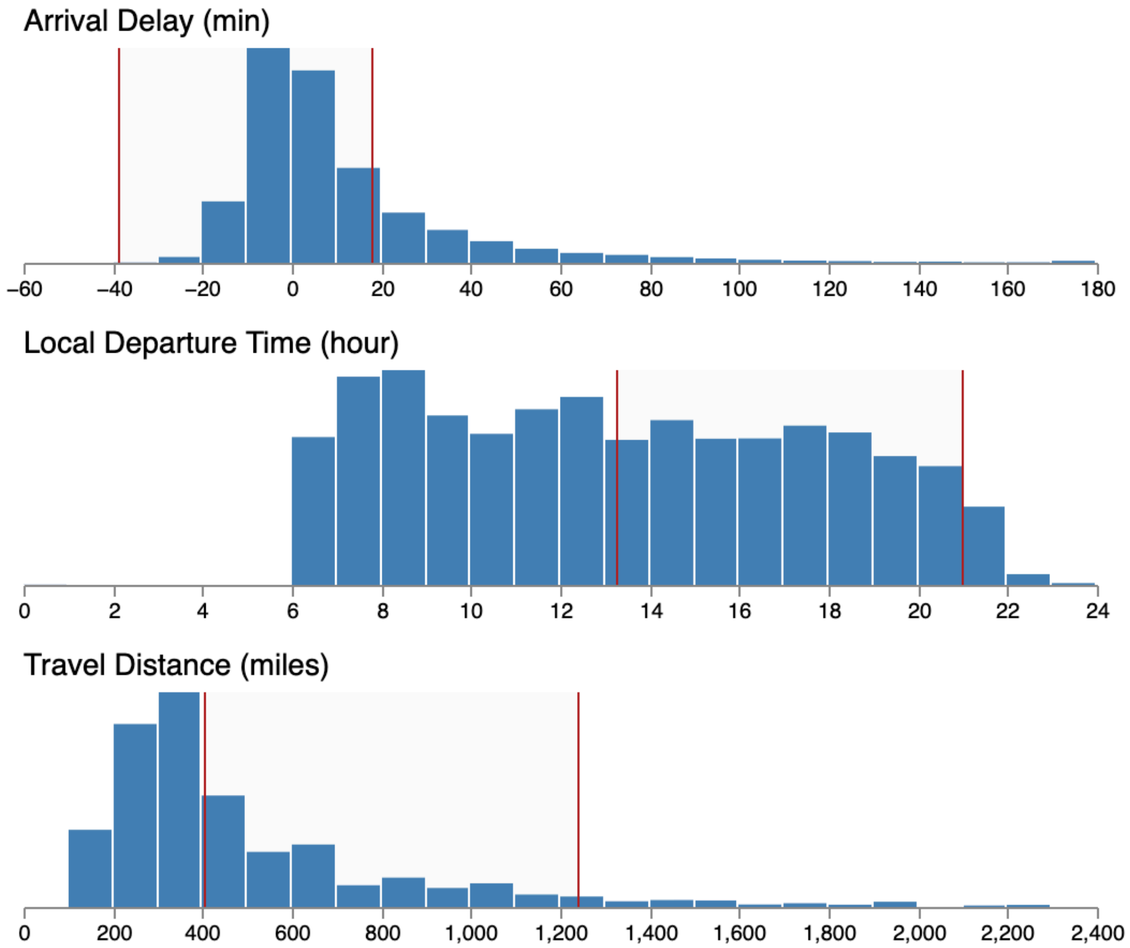
# The Value of Interactivity




https://dig.cmu.edu/counterpoint/2024/04/30/gapminder-accessible.html

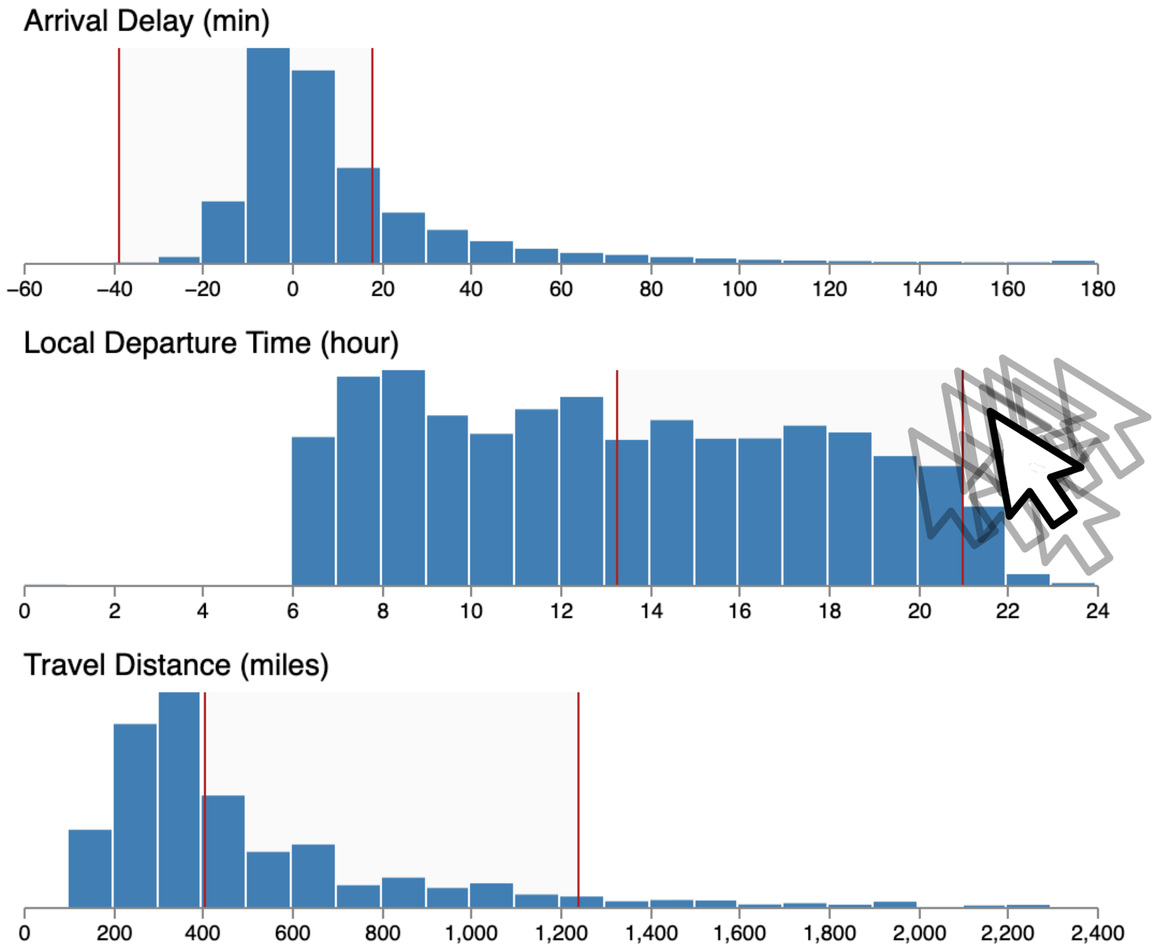

Dragicevic, P., Ramos, G., Bibliowitcz, J., Nowrouzezahrai, D., Balakrishnan, R., and Singh, K. (2008). **Video Browsing by Direct Manipulation.** CHI '08.

# The Value of Interactivity




https://vega.github.io/editor/#/examples/vega/crossfilter-flights

# The Value of Interactivity




**Note: Expecting users to hover on something tiny is an accessibility design failure**

https://vega.github.io/editor/#/examples/vega/crossfilter-flights

# The Value of *Accessible* (multi-modal) Interactivity

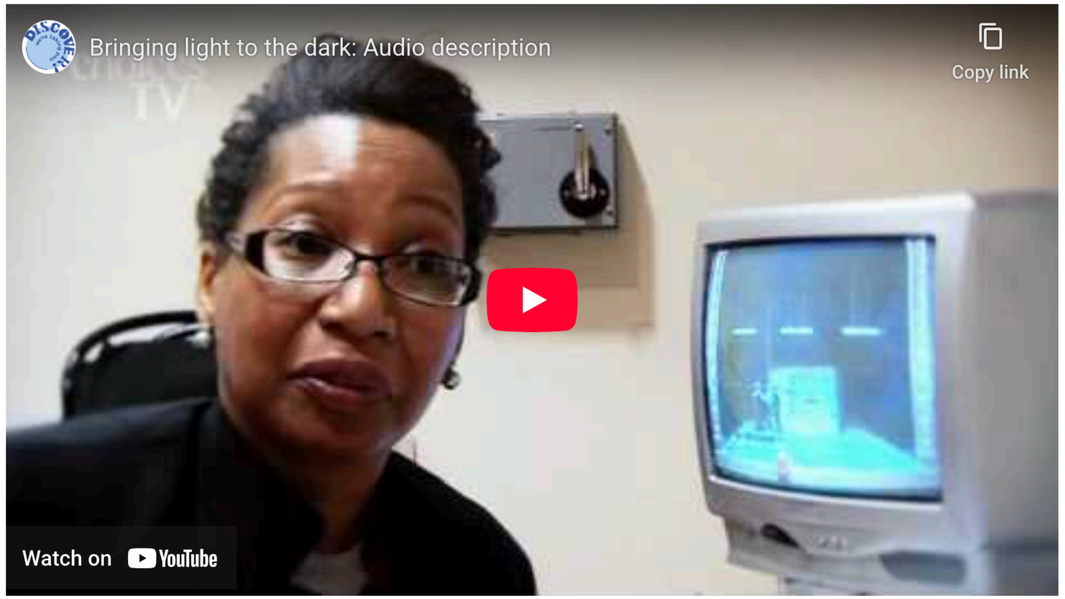
## A video with sliders

Video loaded. You may now connect.

Connect Feelter

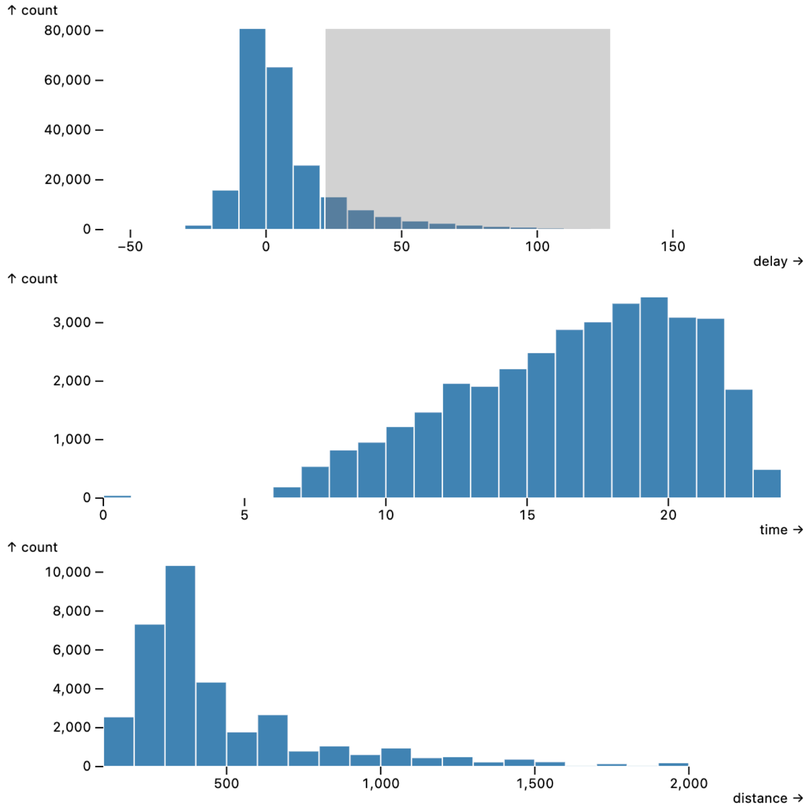
The top slider controls the volume, the bottom controls the video's progress. Moving the bottom slider will move you rapidly forward or backward through the video.

Tapping or touching the top slider will also pause or unpause the video. Note that adjusting the volume may pause or unpause the video. Simply tap the top slider again if it paused or unpaused when you didn't want it to.




Go back to main page

https://dig.cmu.edu/cross-feelter/video.html




https://dig.cmu.edu/cross-feelter/slider.html

# Accessibility principle: “Operability”

Can someone operate this in multiple ways? Is each way easy?

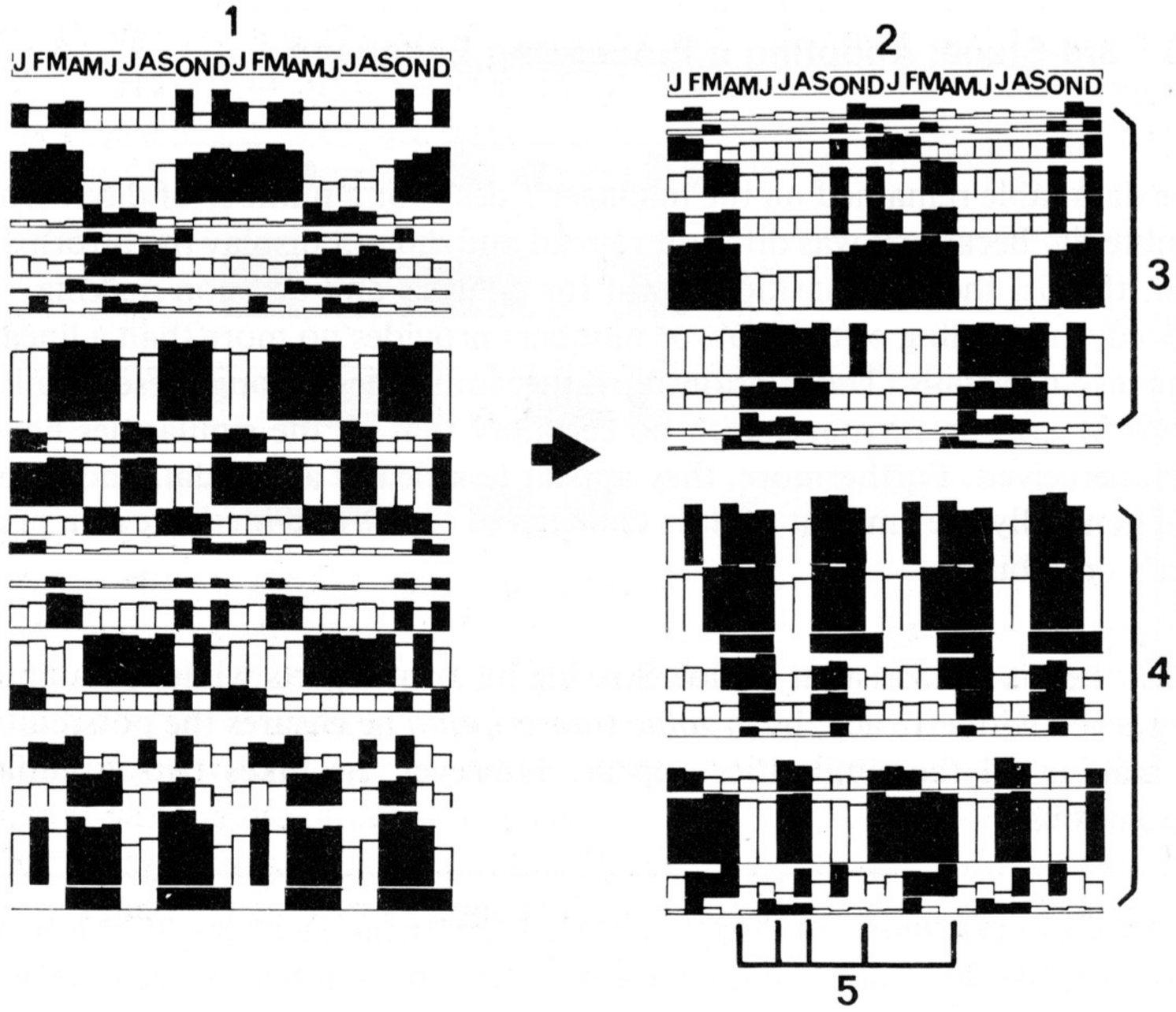
A graphic is not “drawn” once and for all; it is “constructed” and reconstructed until it reveals all the relationships constituted by the interplay of the data. The best graphic operations are those carried out by the decision-maker [themselves].

Jacques Bertin (1918 – 2010)

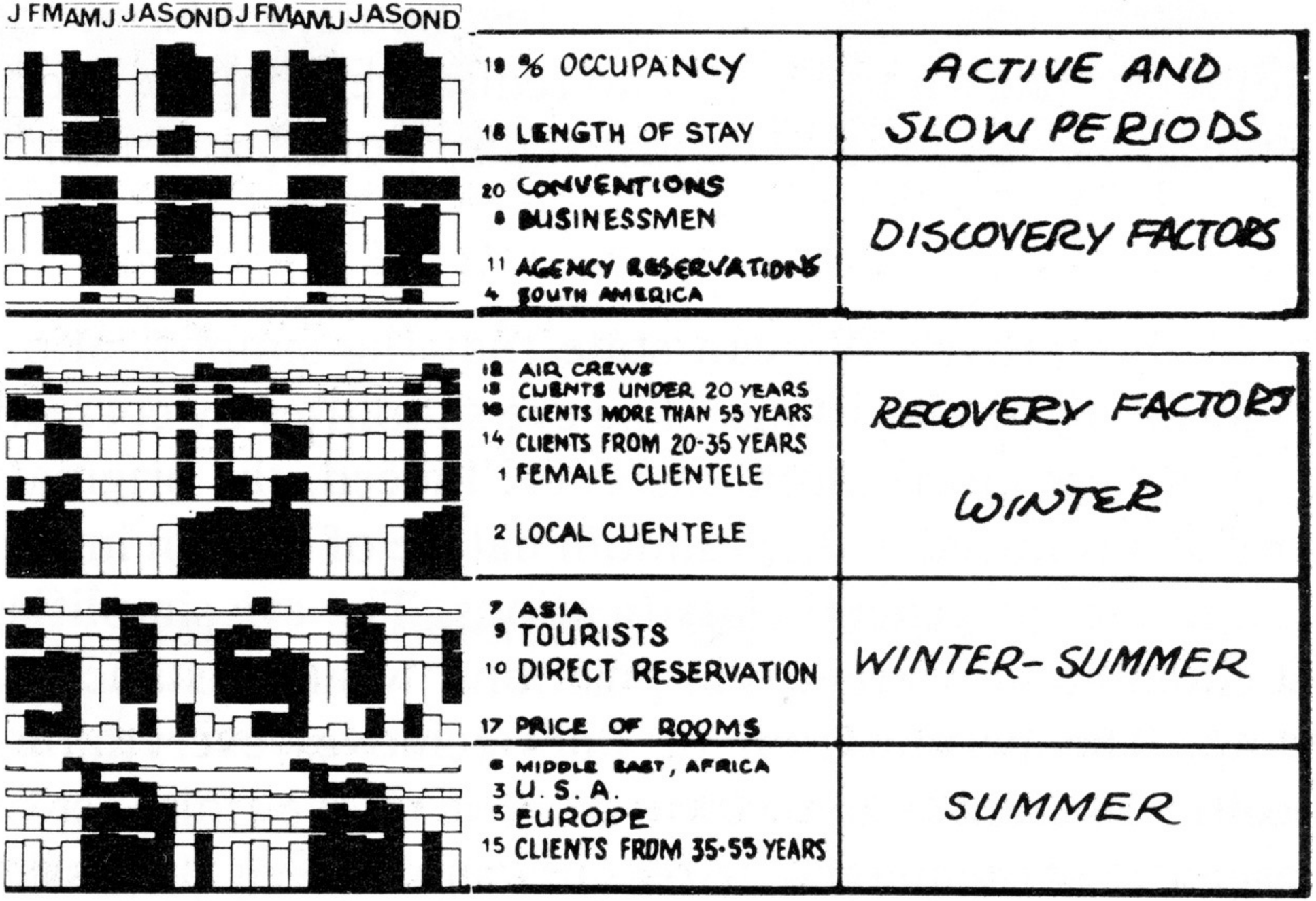
[Bertin. Graphics and Graphic Information Processing. 1981]

| J | F | M | A | M | J | J | A | S | O | N | D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 21 | 26 | 28 | 20 | 20 | 20 | 20 | 20 | 40 | 15 | 40 | 1 | % CLIENTELE FEMALE |
| 69 | 70 | 77 | 71 | 37 | 36 | 39 | 39 | 55 | 60 | 68 | 72 | 2 | % —〃— LOCAL |
| 7 | 6 | 3 | 6 | 23 | 14 | 19 | 14 | 9 | 6 | 8 | 8 | 3 | % —〃— U.S.A. |
| 0 | 0 | 0 | 0 | 8 | 6 | 6 | 4 | 2 | 12 | 0 | 0 | 4 | % —〃— SOUTH AMERICA |
| 20 | 15 | 14 | 15 | 23 | 27 | 22 | 30 | 27 | 19 | 19 | 17 | 5 | % —〃— EUROPE |
| 1 | 0 | 0 | 8 | 6 | 4 | 6 | 4 | 2 | 1 | 0 | 1 | 6 | % —〃— M.EAST, AFRICA |
| 3 | 10 | 6 | 0 | 3 | 13 | 8 | 9 | 5 | 2 | 5 | 2 | 7 | % —〃— ASIA |
| 78 | 80 | 85 | 86 | 85 | 87 | 70 | 76 | 87 | 85 | 87 | 80 | 8 | % BUSINESSMEN |
| 22 | 20 | 15 | 14 | 15 | 13 | 30 | 24 | 13 | 15 | 13 | 20 | 9 | % TOURISTS |
| 70 | 70 | 75 | 74 | 69 | 68 | 74 | 75 | 68 | 68 | 64 | 75 | 10 | % DIRECT RESERVATIONS |
| 20 | 18 | 19 | 17 | 27 | 27 | 19 | 19 | 26 | 27 | 21 | 15 | 11 | % AGENCY ——〃—— |
| 10 | 12 | 6 | 9 | 4 | 5 | 7 | 6 | 6 | 5 | 15 | 10 | 12 | % AIR CREWS |
| 2 | 2 | 4 | 2 | 2 | 1 | 1 | 2 | 2 | 4 | 2 | 5 | 13 | % CLIENTS UNDER 20 YEARS |
| 25 | 27 | 37 | 35 | 25 | 25 | 27 | 28 | 24 | 30 | 24 | 30 | 14 | % —〃— 20-35 —〃— |
| 48 | 49 | 42 | 48 | 54 | 55 | 53 | 51 | 55 | 46 | 55 | 43 | 15 | % —〃— 35-55 —〃— |
| 25 | 22 | 17 | 15 | 19 | 19 | 19 | 19 | 19 | 20 | 19 | 22 | 16 | % —〃— MORE THAN 55 —〃— |
| 163 | 167 | 166 | 174 | 152 | 155 | 145 | 170 | 157 | 174 | 165 | 156 | 17 | PRICE OF ROOMS |
| 1.65 | 1.71 | 1.65 | 1.91 | 1.90 | 2. | 1.54 | 1.60 | 1.73 | 1.82 | 1.66 | 1.44 | 18 | LENGTH OF STAY |
| 67 | 82 | 70 | 83 | 74 | 77 | 56 | 62 | 90 | 92 | 78 | 55 | 19 | % OCCUPANCY |
| | | | X | X | X | | | X | X | X | X | 20 | CONVENTIONS |

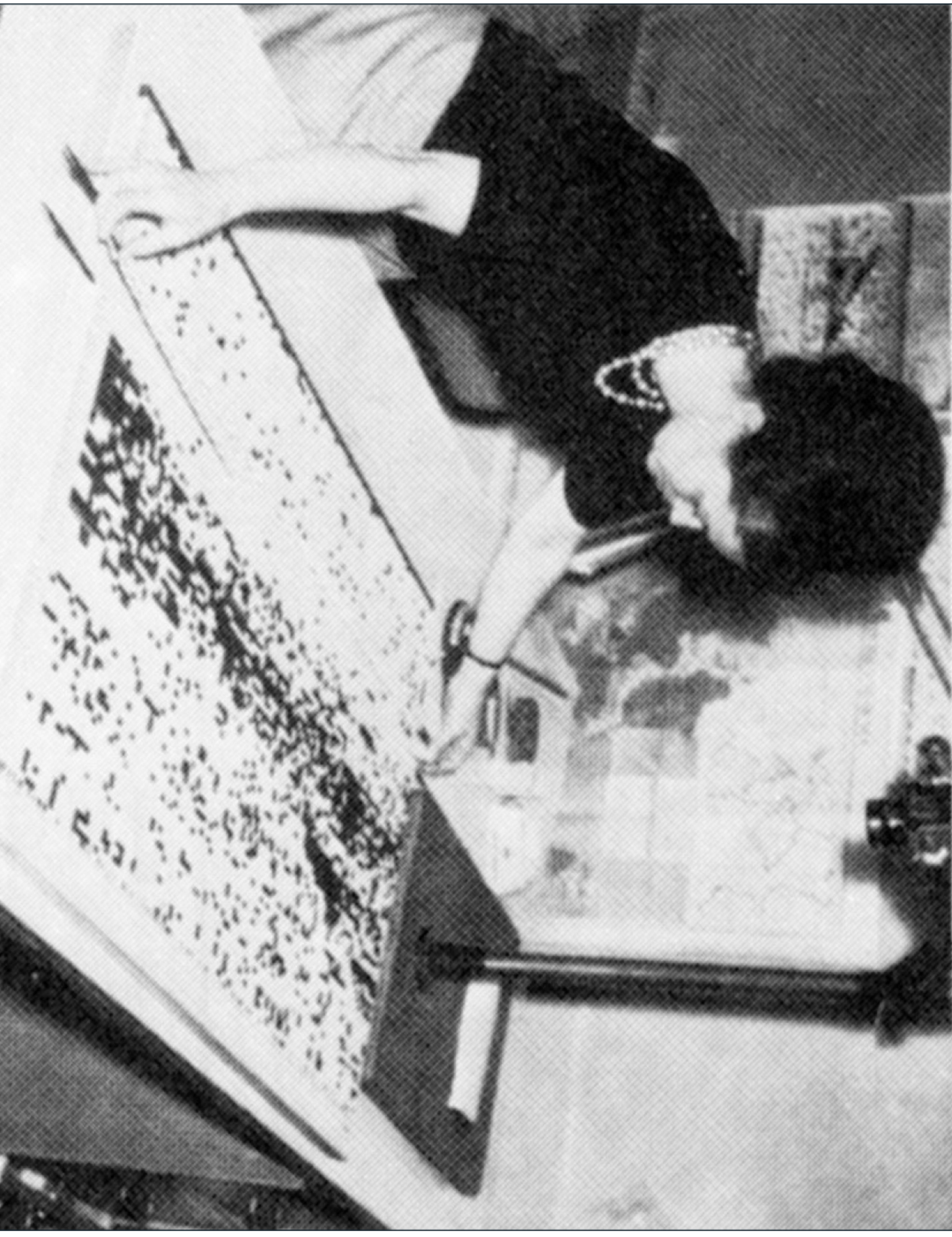
[Bertin. Graphics and Graphic Information Processing. 1981]



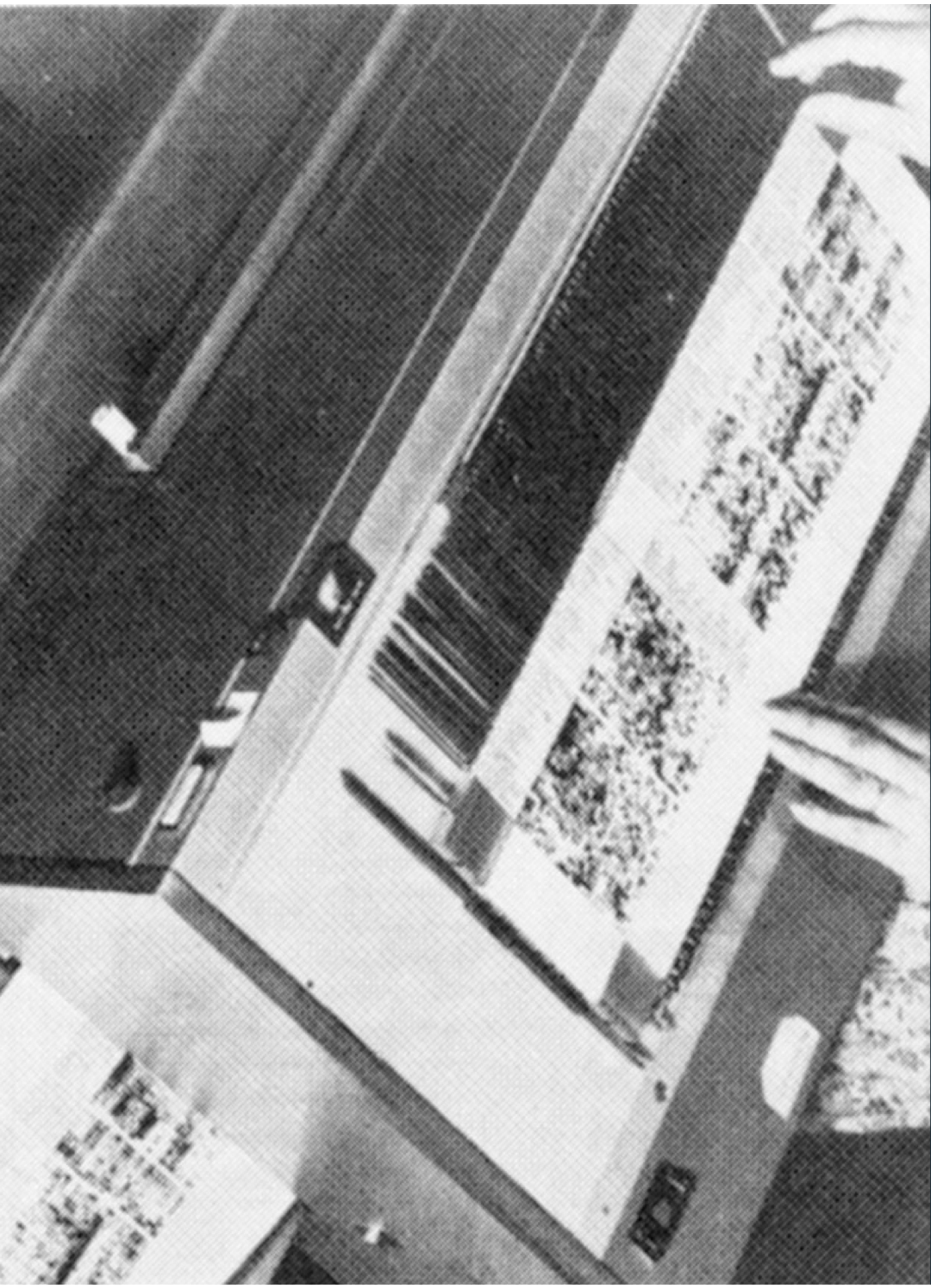
[Bertin. Graphics and Graphic Information Processing. 1981]



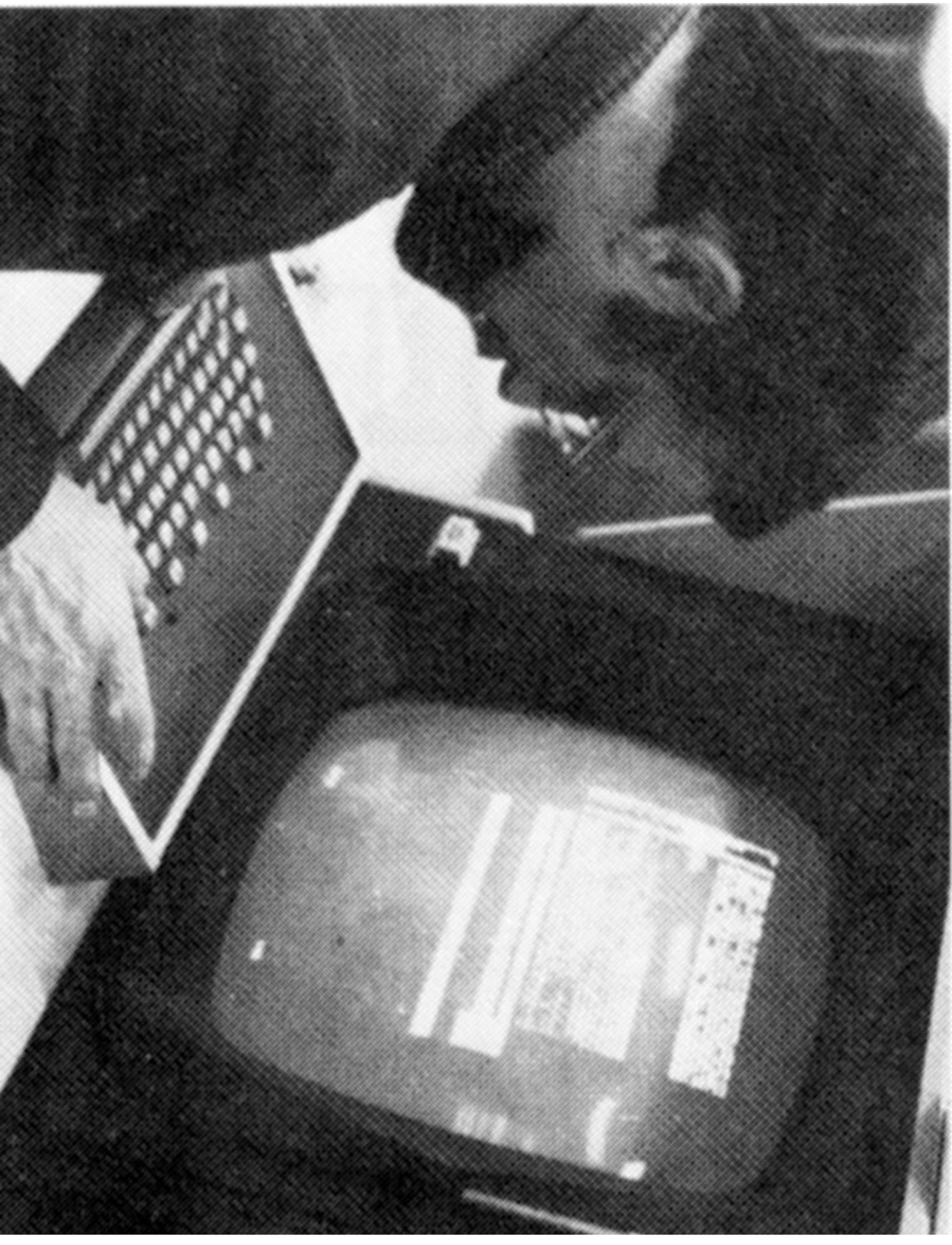
[Bertin. Graphics and Graphic Information Processing. 1981]



[Bertin. Graphics and Graphic Information Processing. 1981]

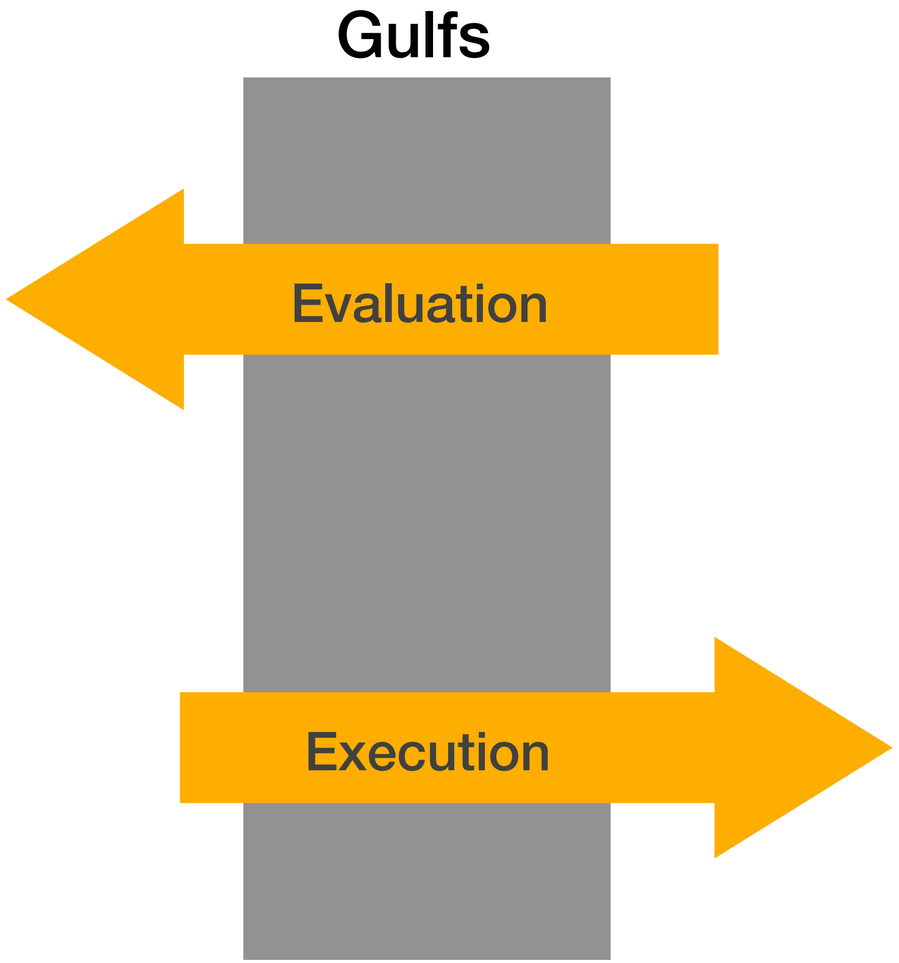


[Bertin. Graphics and Graphic Information Processing. 1981]



**Interaction** between people and machines requires mutual *intelligibility* or *shared understanding*.

# Gulfs of Execution & Evaluation




User's conceptual model

Real world

[Hutchins, Hollan, and Norman, 1985]

## Gulf of Evaluation

What’s the state of the system?

## Gulf of Execution

How do I change this system?

[Hutchins, Hollan, and Norman, 1985]

## Gulf of Evaluation

The **amount of effort** that the person must exert to interpret the state of the system and to determine how well the expectations and intentions have been met.

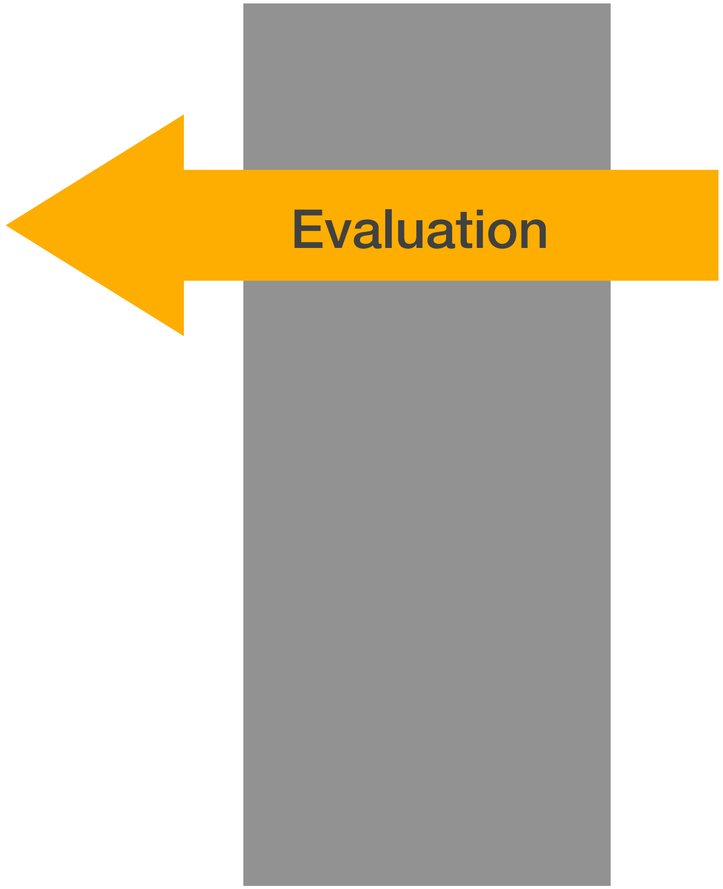
## Gulf of Execution

The **difference** between the user's intentions and the allowable actions.

[Hutchins, Hollan, and Norman, 1985]

# Gulfs of Execution & Evaluation

Gulfs




Conceptual model:

x, y related?

Real world state

| X | Y |
|---|---|
| 0.67 | 0.79 |
| 0.32 | 0.63 |
| 0.39 | 0.72 |
| 0.27 | 0.85 |
| 0.71 | 0.43 |
| 0.63 | 0.09 |
| 0.03 | 0.03 |
| 0.20 | 0.54 |
| 0.51 | 0.38 |
| 0.11 | 0.33 |
| 0.46 | 0.46 |

[Hutchins, Hollan, and Norman, 1985]

# Gulfs of Execution & Evaluation

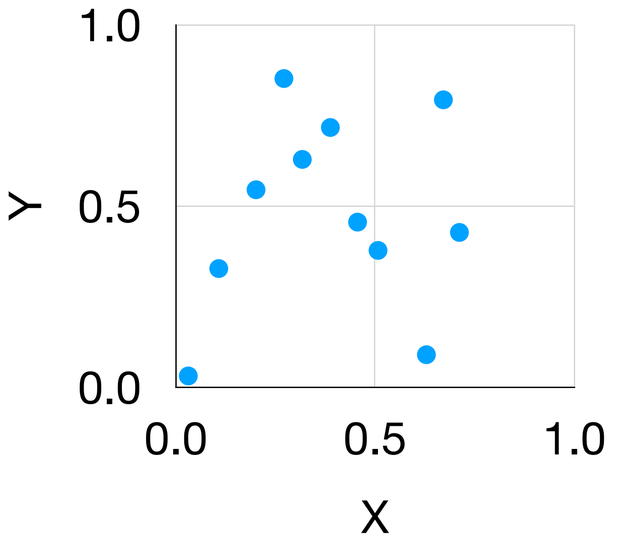
Gulfs

Evaluation

Conceptual model:

x, y related?

Real world state

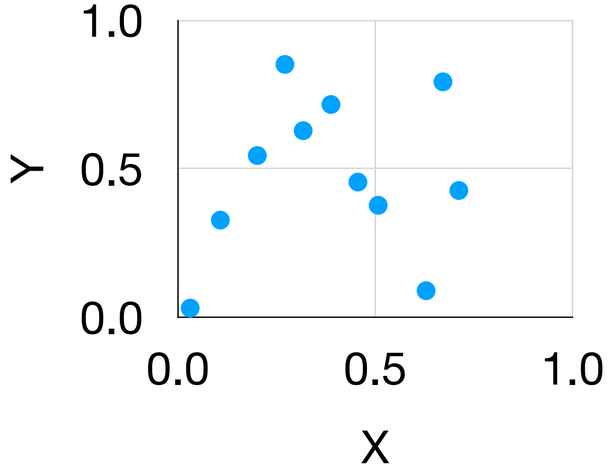



more effective visual encoding

[Hutchins, Hollan, and Norman, 1985]

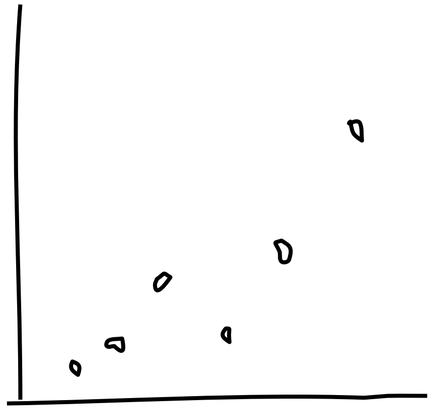
# Gulfs of Execution & Evaluation

RW target state




Gulfs

Conceptual model:



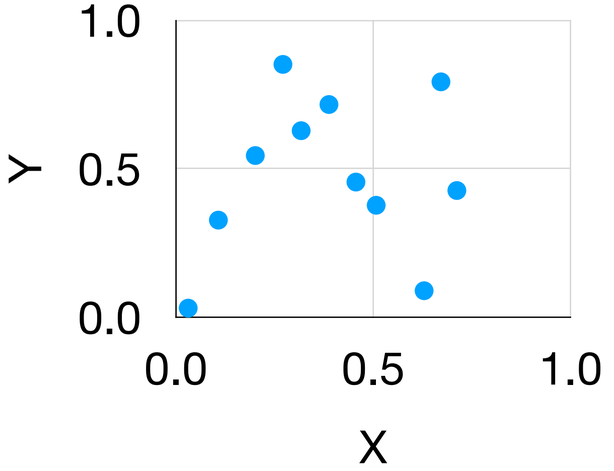
Execution

```
Move 90 30
Rotate 35
Pen down
…
```

[Hutchins, Hollan, and Norman, 1985]

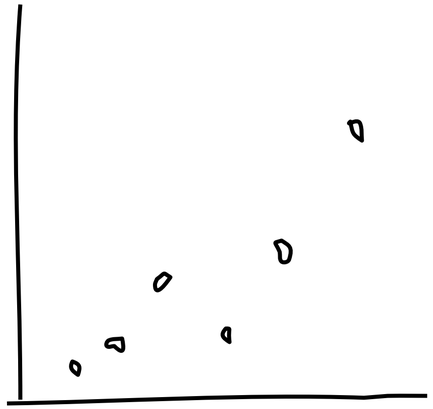
# Gulfs of Execution & Evaluation

RW target state




Gulfs

Conceptual model:

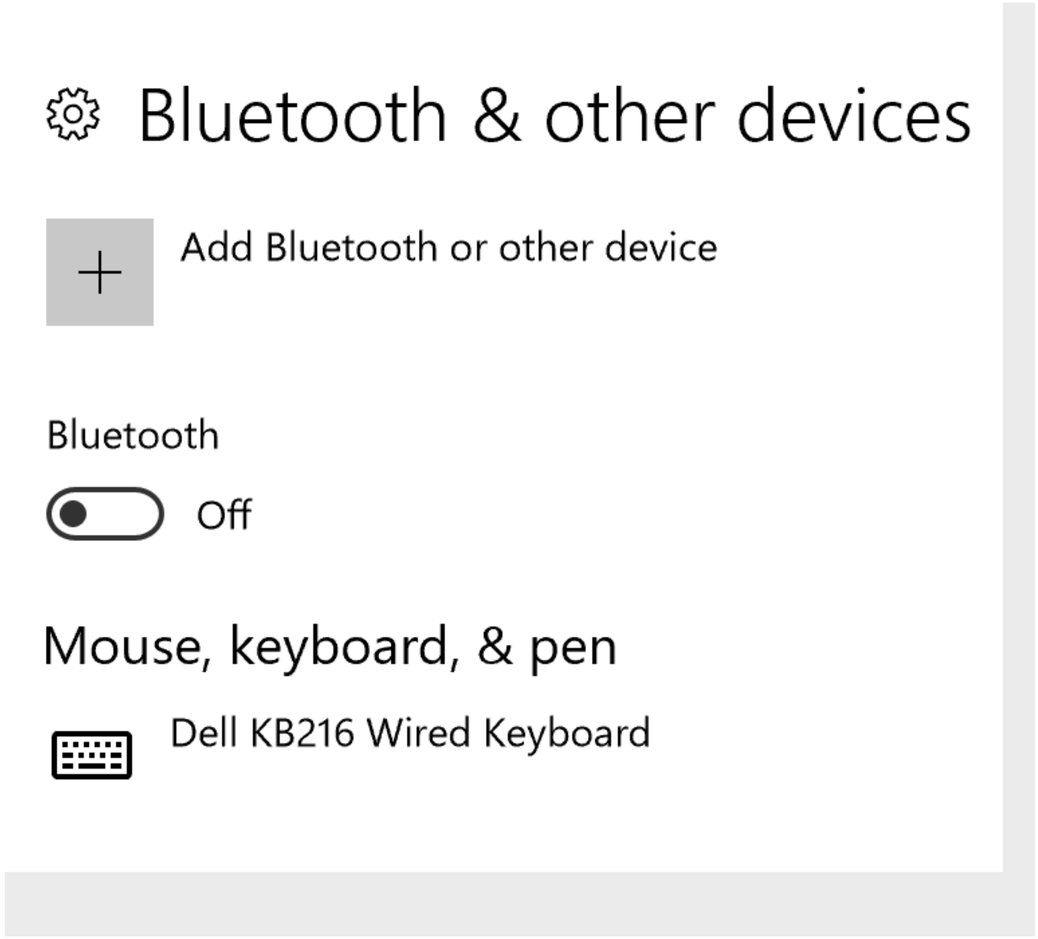


Execution

| X | Y |
|---|---|
| 0.67 | 0.79 |
| 0.32 | 0.63 |
| 0.39 | 0.72 |
| 0.27 | 0.85 |
| 0.71 | 0.43 |
| 0.63 | 0.09 |
| … | … |

[Hutchins, Hollan, and Norman, 1985]

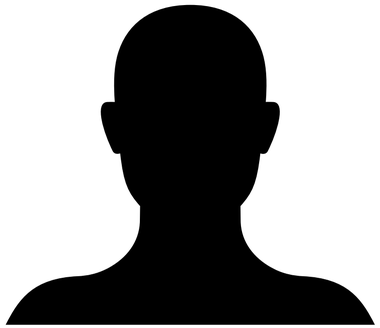
more effective interaction design





https://www.nngroup.com/articles/two-ux-gulfs-evaluation-execution/

✘ Results returned as a table.
✘ No hint on how to reformulate query.
✘ Slow question-answer loop.

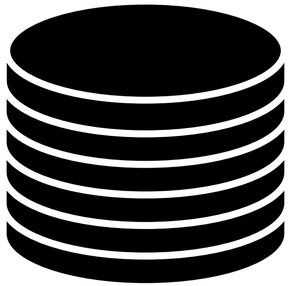


User Goals

Evaluation

# SQL

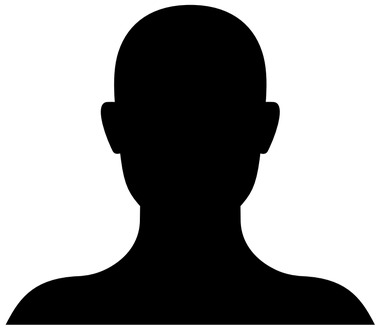
Execution



Database

✘ A rigid syntax designed by/for programmers.
✘ Difficult to do "fuzzy" matching.

✓ Visual representation of objects + actions.
✓ Immediate + continuous display of results.

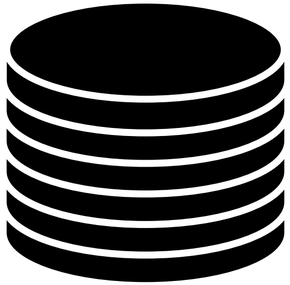


User Goals

Evaluation

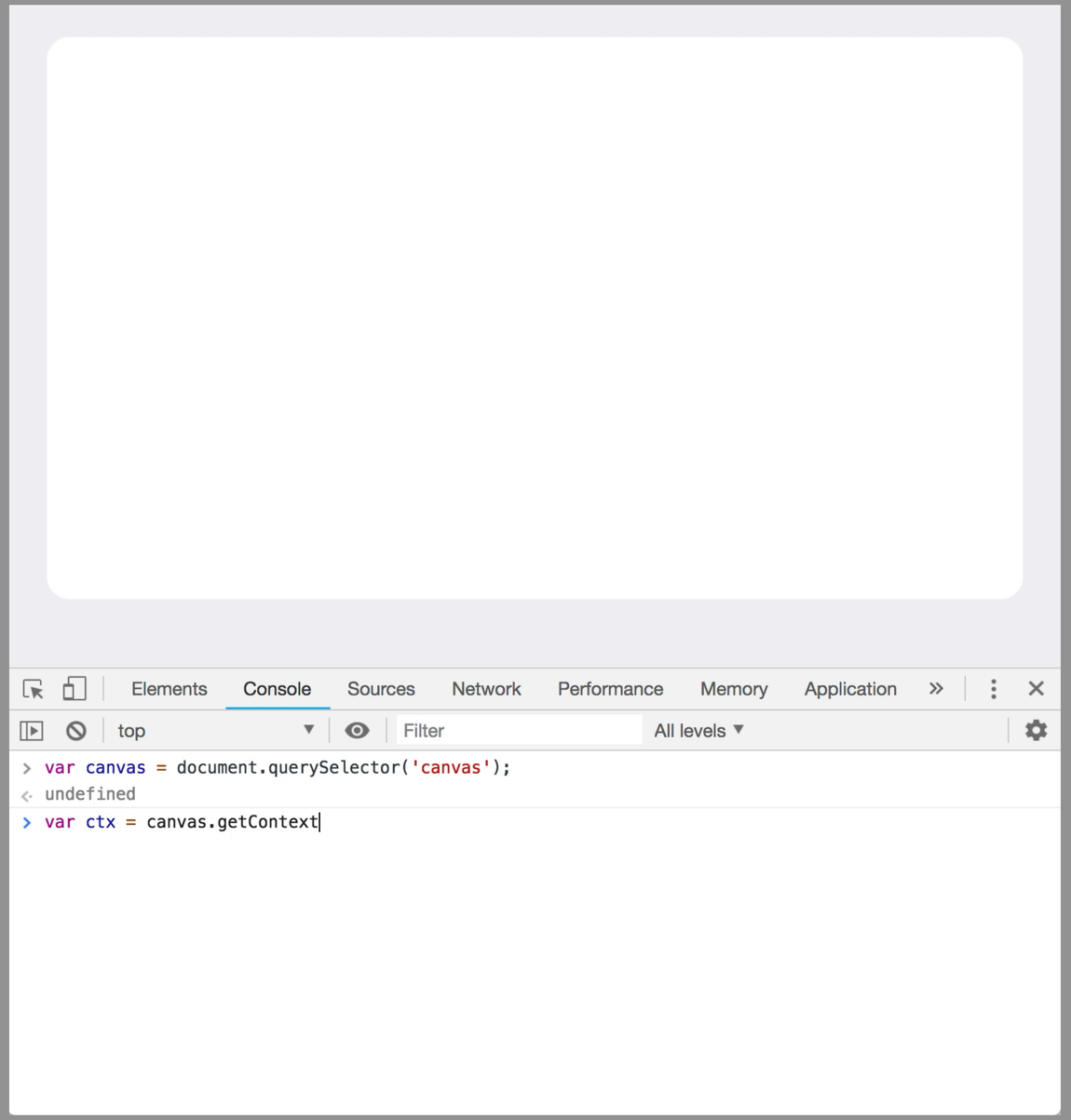
# Direct Manipulation

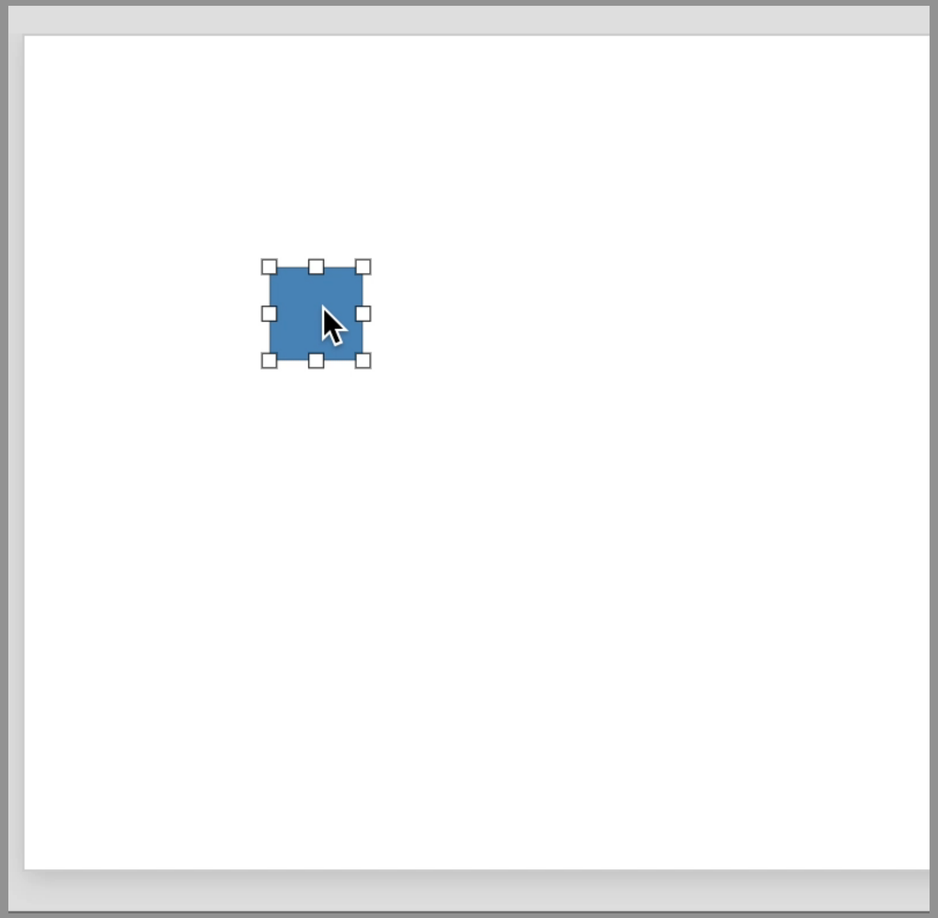
Execution



Database

✓ Physical actions or labeled buttons instead of complex syntax.
✓ Rapid, incremental, and reversible actions.


Elements
Console
Sources
Network
Performance
Memory
Application
top
Filter
All levels
var canvas = document.querySelector('canvas');
undefined
var ctx = canvas.getContext



# Interaction with Visualization

**Select** – identify something as interesting.

**Connect** – show me related items.

**Abstract/Elaborate** – show me more or less detail.

**Filter** – show me something conditionally.

**Reconfigure** – show me a different arrangement.

**Explore** – show me something else.

**Encode** – show me a different visual representation.

[Yi et al, 2009]

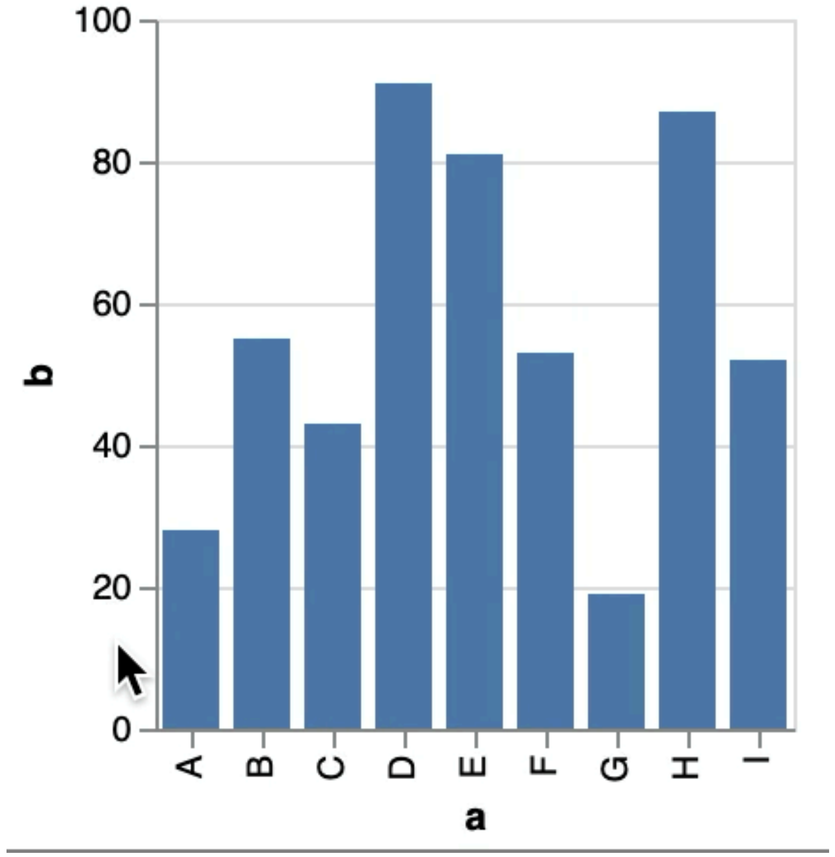
# Point Selection

## Identify something as interesting

Select discrete data values.

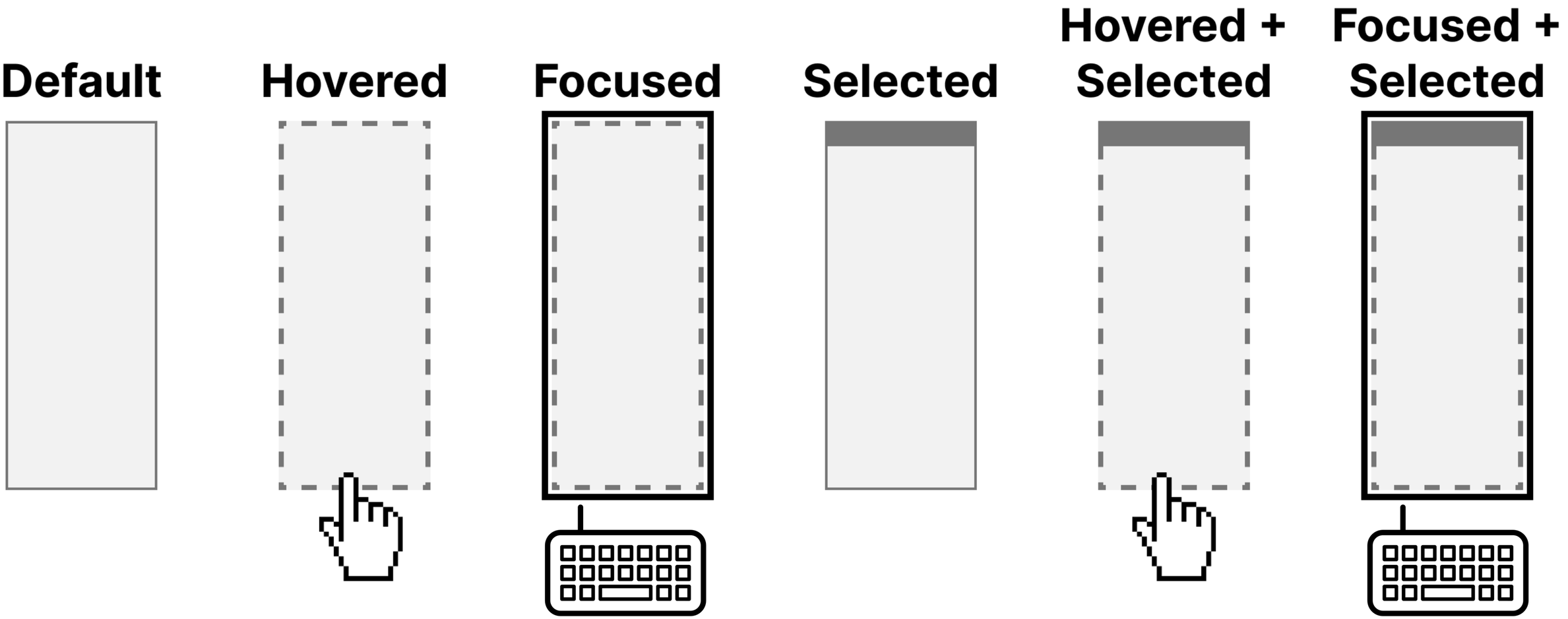
How many points are selected? 1, 2, 3, ...

How are points selected? Mouse hover, click, tap, ...




https://vega.github.io/vega-lite/examples/interactive_bar_select_highlight.html

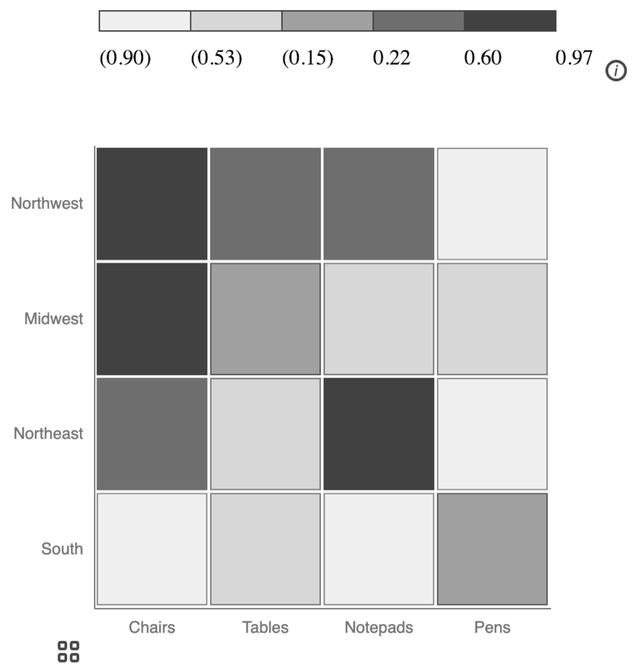
# Accessible strategies showing the state of interaction



# Show system state (visually *and* non-visually)

### Comparing how user groups correlate to approval rates of product types

A high correlation value (close to 1) indicates that these users have a high approval rate of that product. A low correlation value (close to -1) indicates a negative approval rate of those products.

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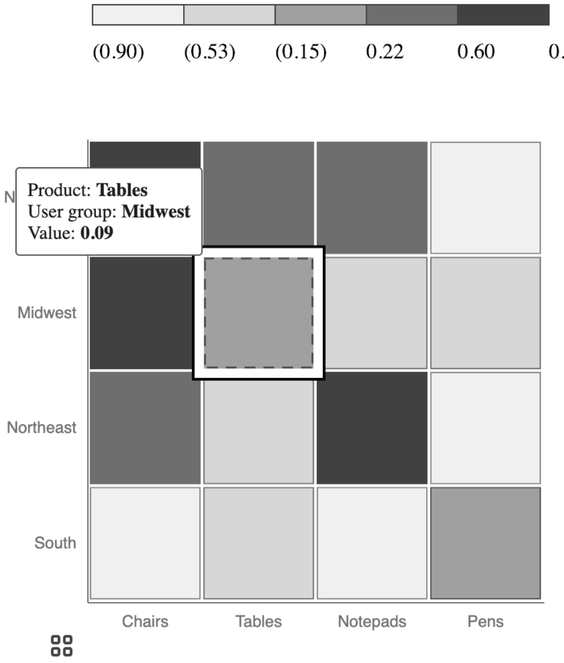
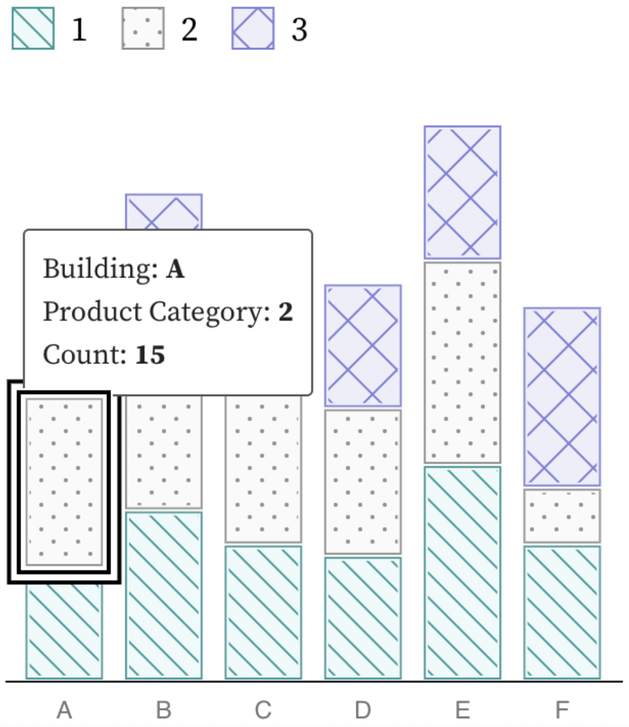


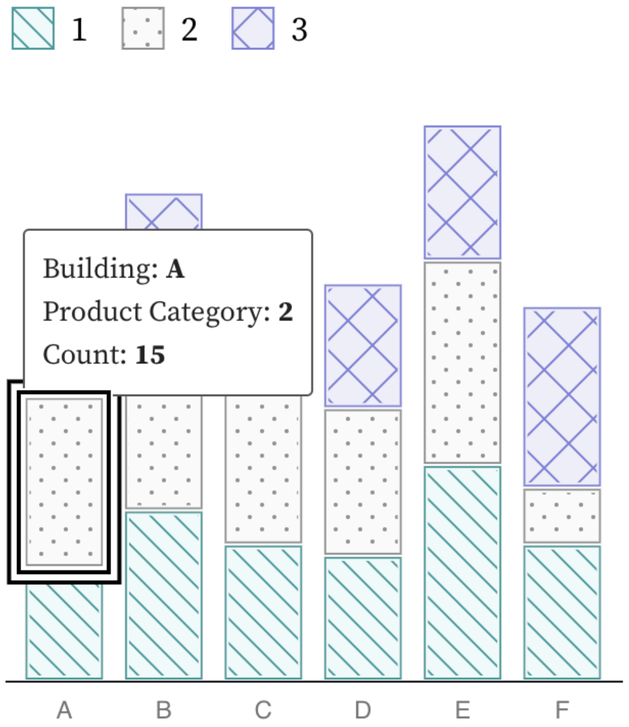

See “Fourth Chart” in my accessible demos of Visa Chart Components

# Alt text should communicate operability




Building A. Product Category 2. Count 15. Bar 2 of 3. Image.

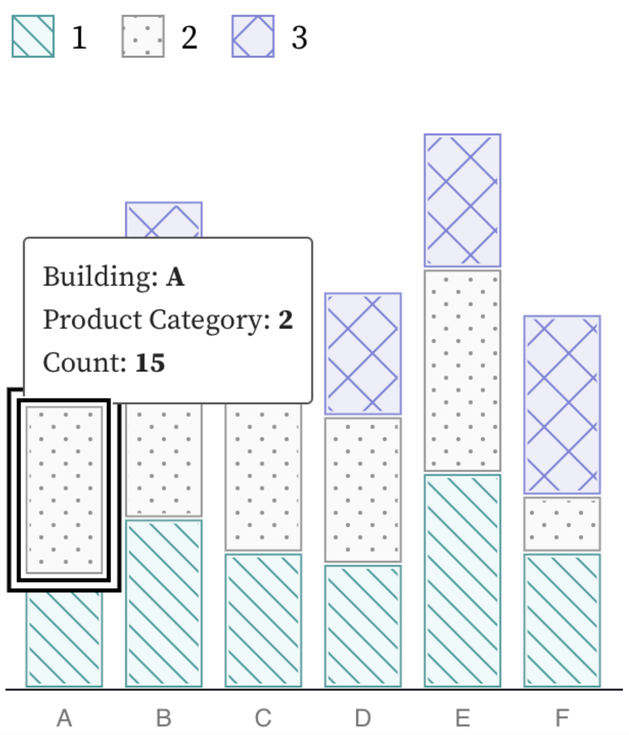
# Semantics matter



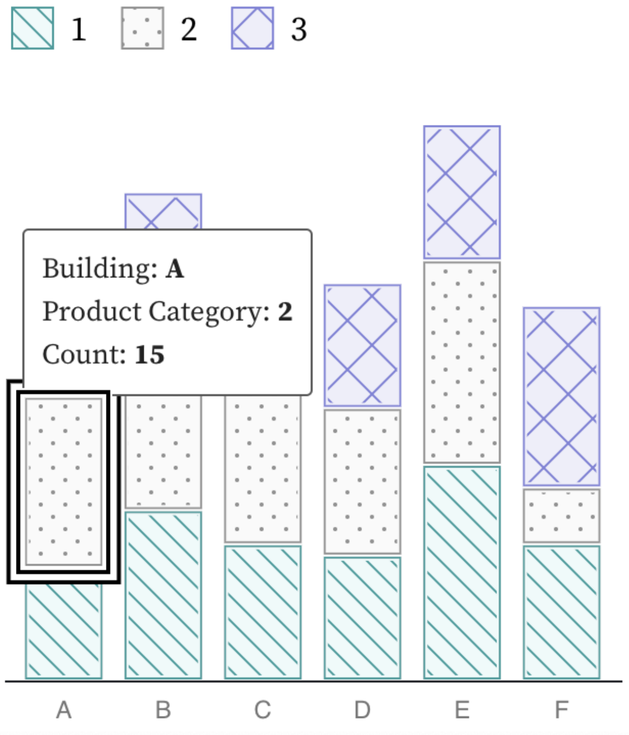

Building A. Product Category 2. Count 15. Bar 2 of 3. Image.

**“Image” doesn’t signal interactivity!**

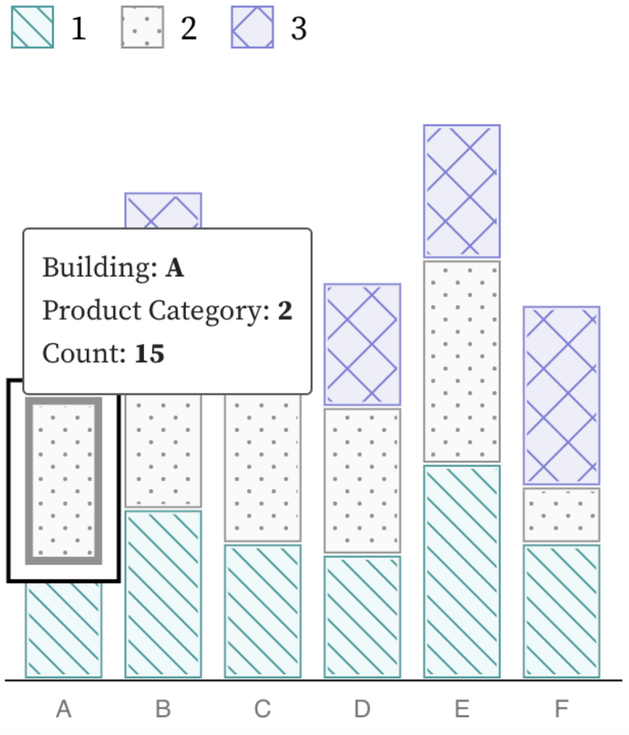
# “Aria” states and roles are standardized



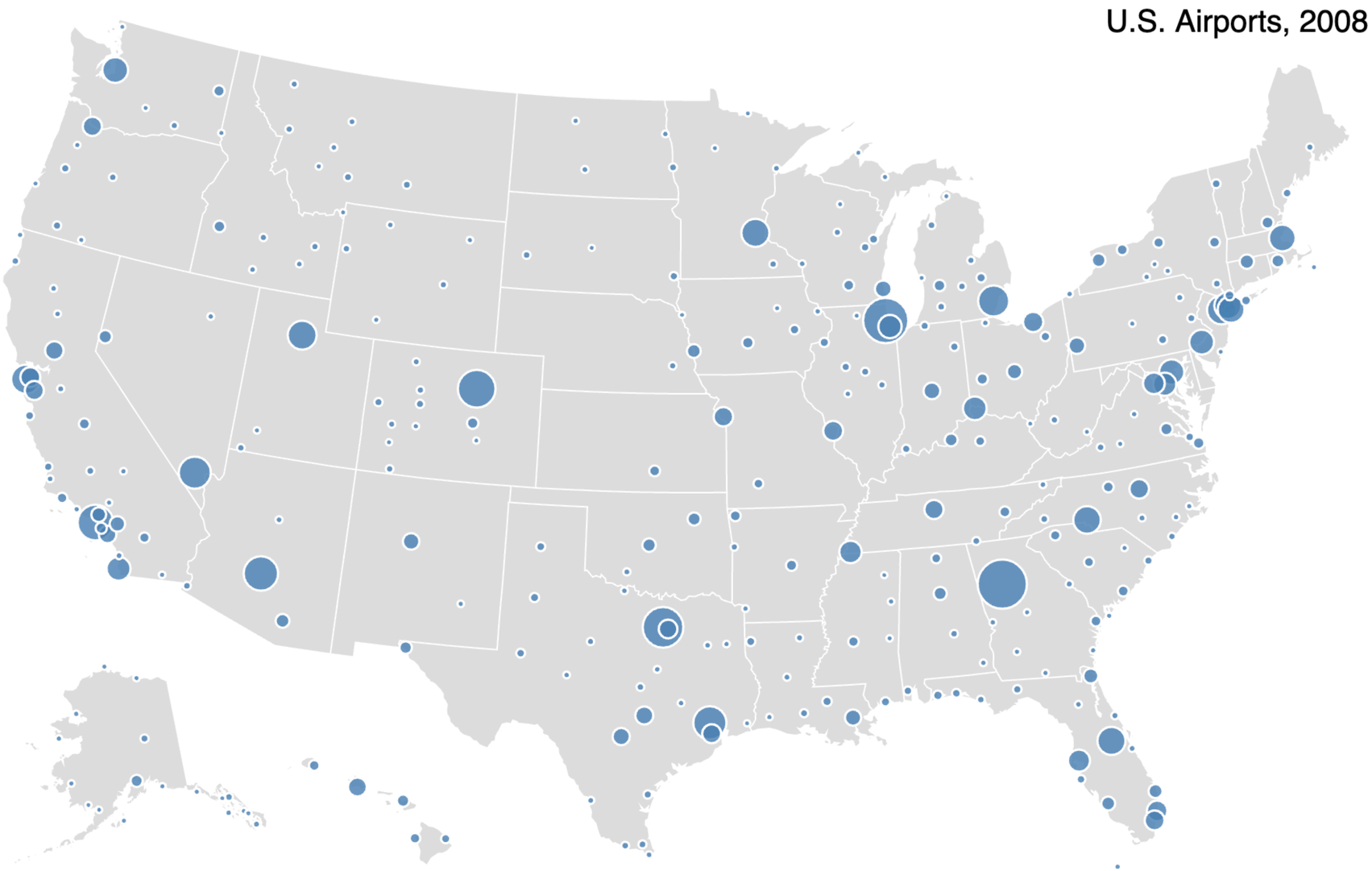

× Building A. Product Category 2. Count 15. Bar 2 of 3. Image.



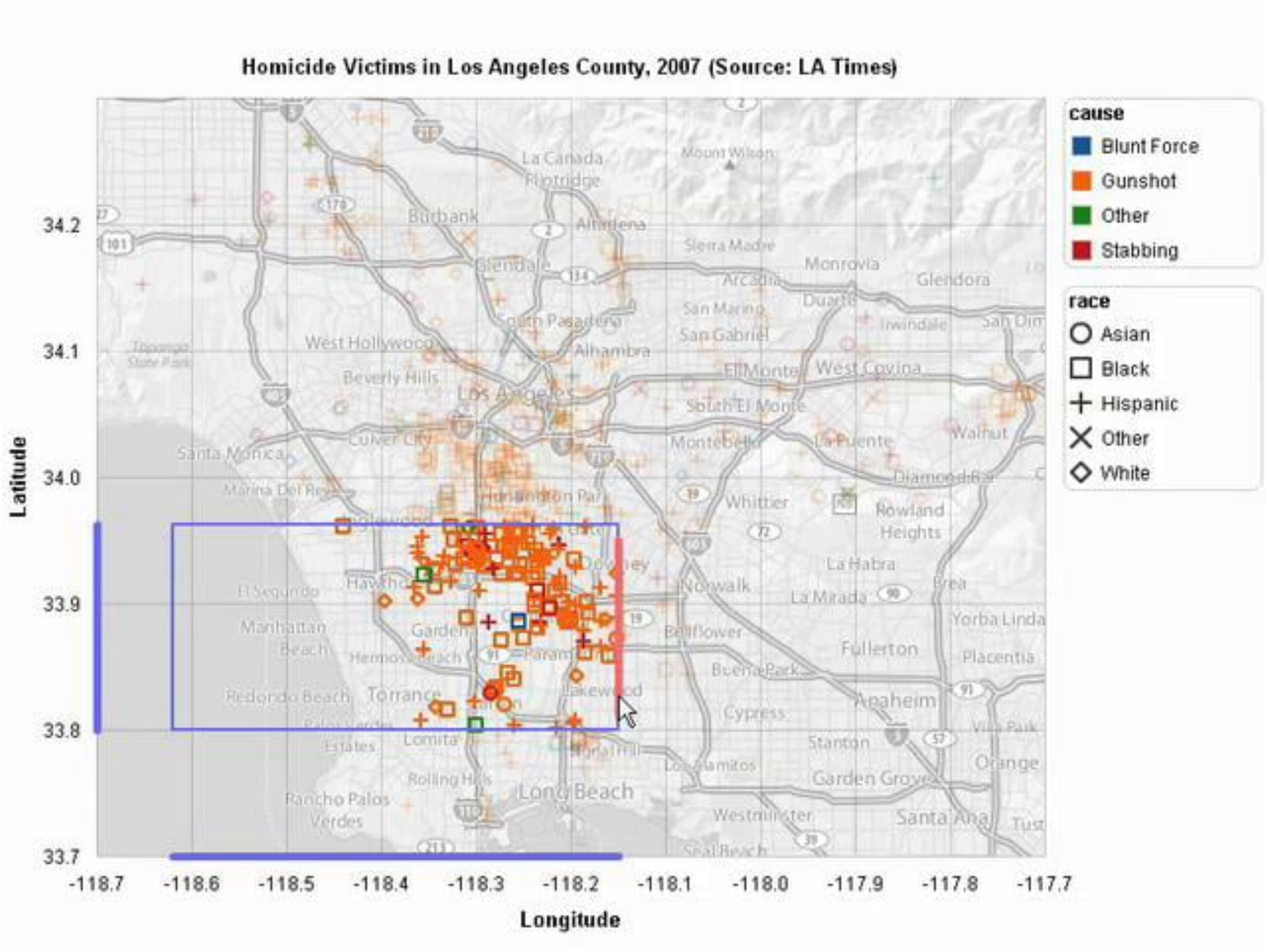

× Building A. Product Category 2. Count 15. Bar 2 of 3., toggle button




× selected, Building A. Product Category 2. Count 15. Bar 2 of 3., toggle button




https://vega.github.io/vega/examples/airport-connections/



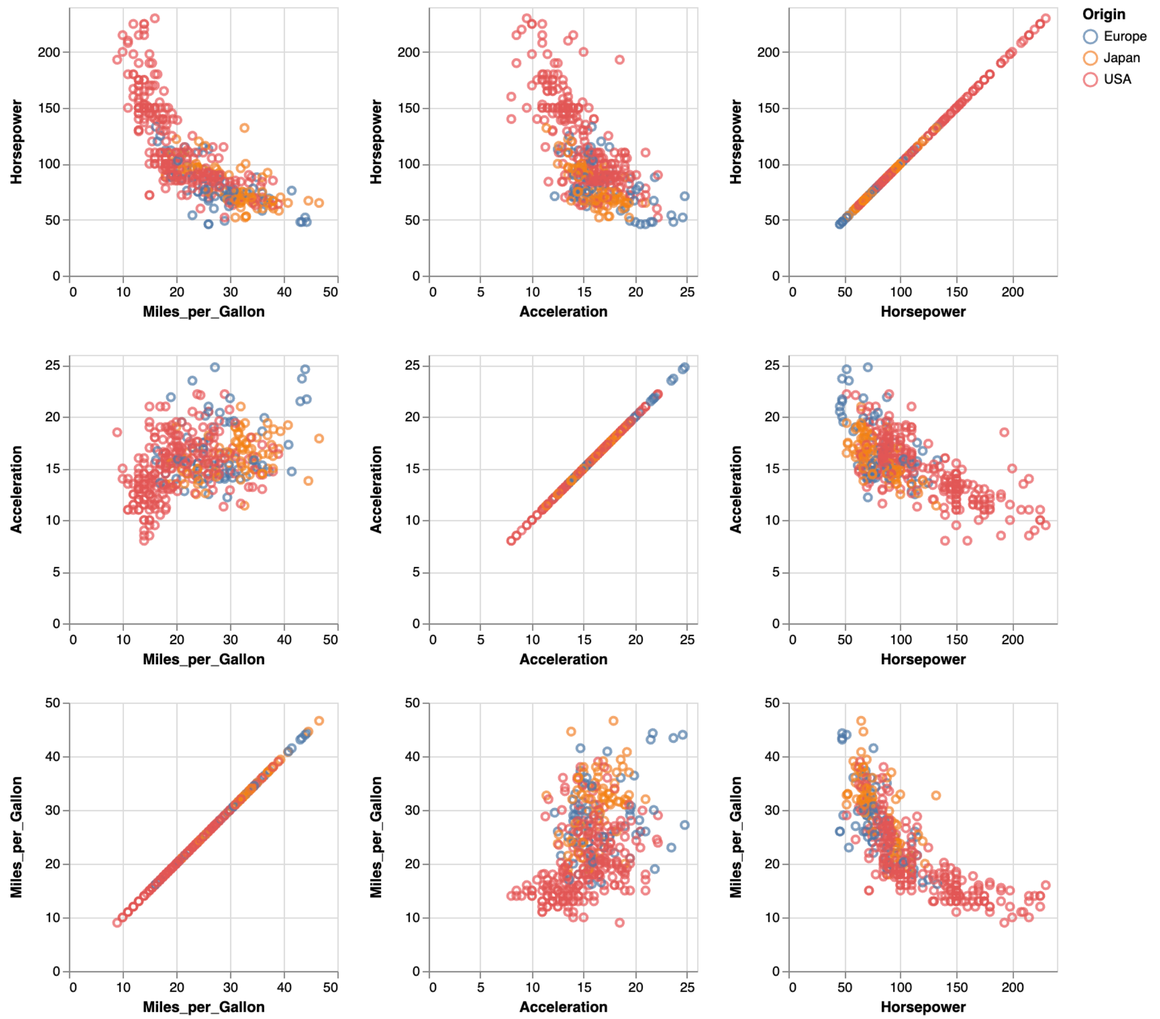

Heer et al., Generalized Selection via Interactive Query Relaxation

# Connect

## show me related items

Brushing & linking:
selection is called a "brush", and the selected data is shown ("linked") in other views.

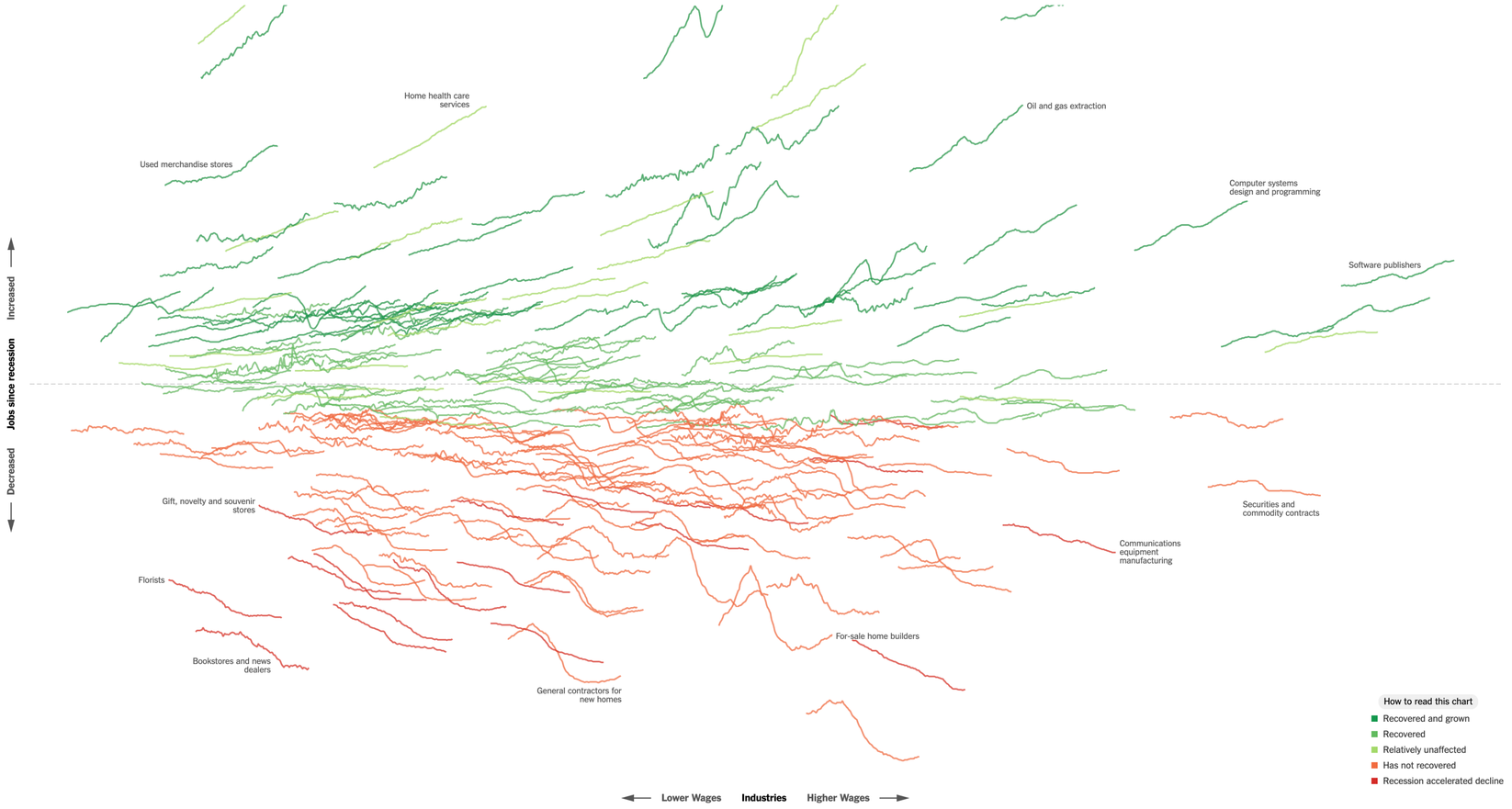
Link by *tuple* (i.e., explicitly identify and match the same data values across every view).




https://vega.github.io/vega-lite/examples/interactive_splom.html

# Abstract/Elaborate

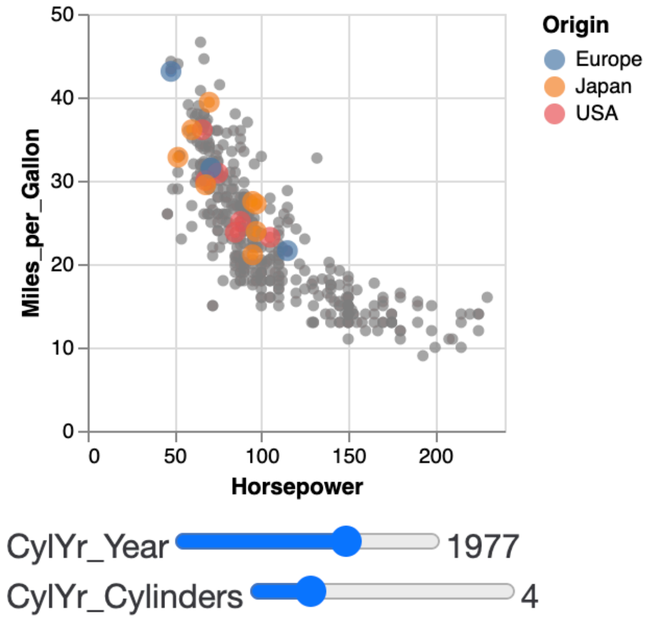
## show me more or less detail

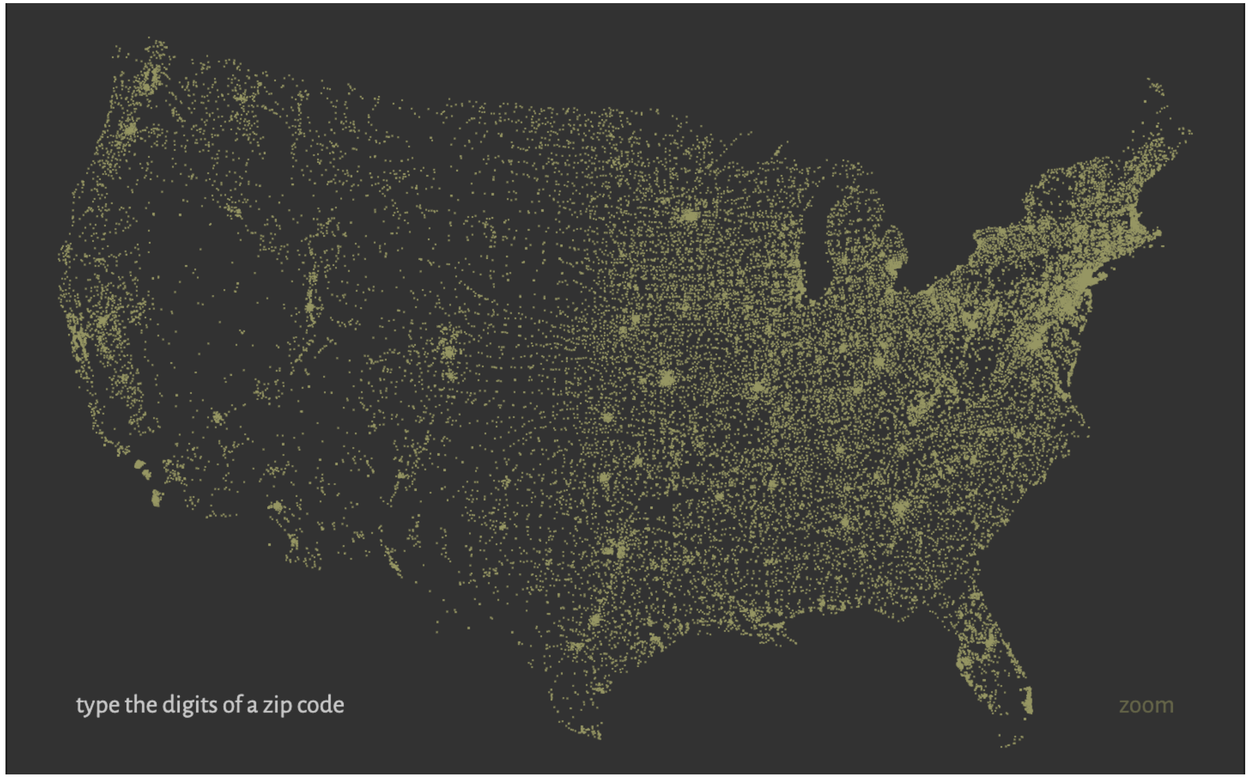



https://www.nytimes.com/interactive/2014/06/05/upshot/how-the-recession-reshaped-the-economy-in-255-charts.html

# Filter

## show me something conditionally



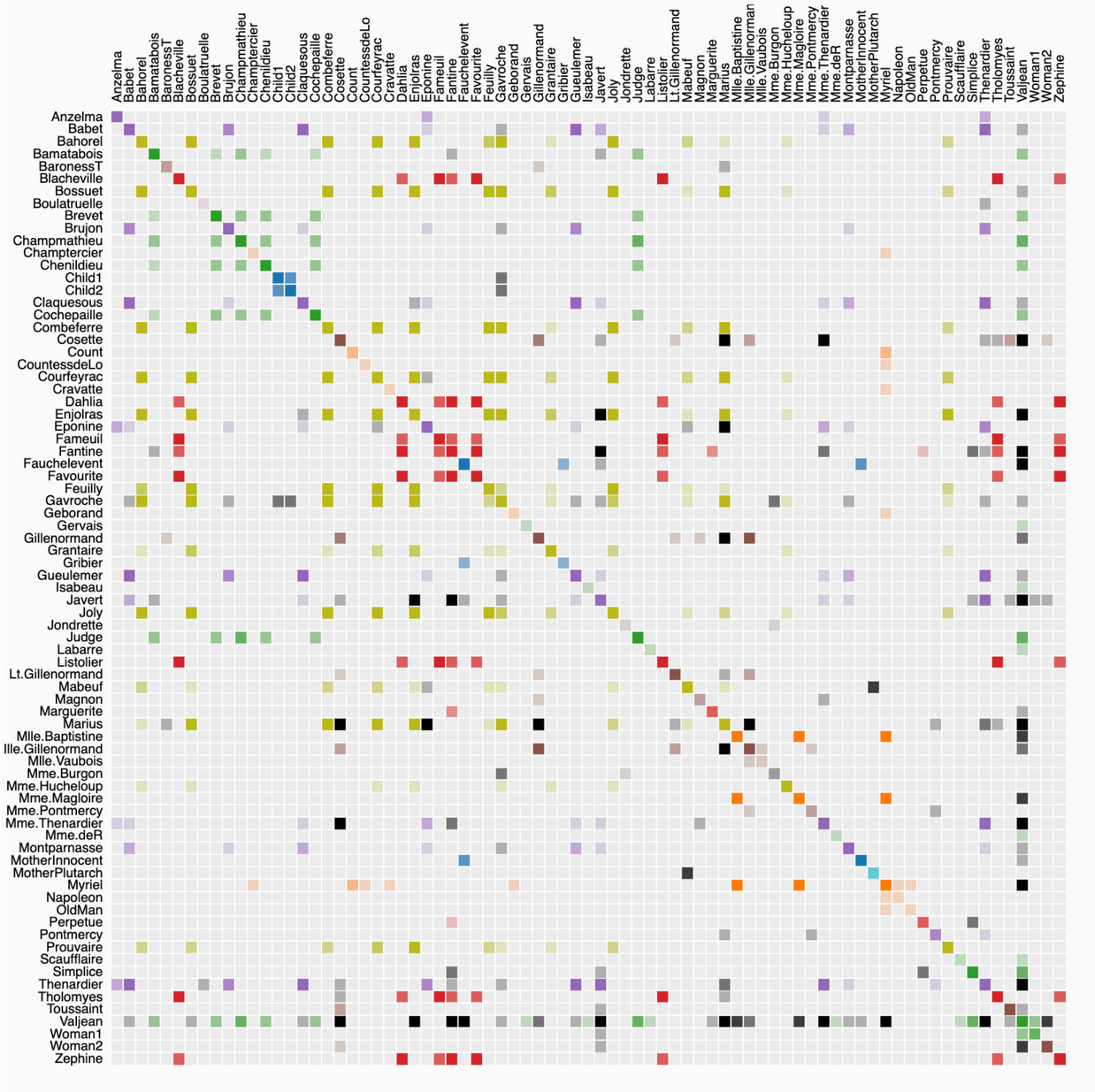




https://vega.github.io/vega-lite/examples/interactive_query_widgets.html

https://benfry.com/zipdecode/

# Reconfigure

## show me a different arrangement

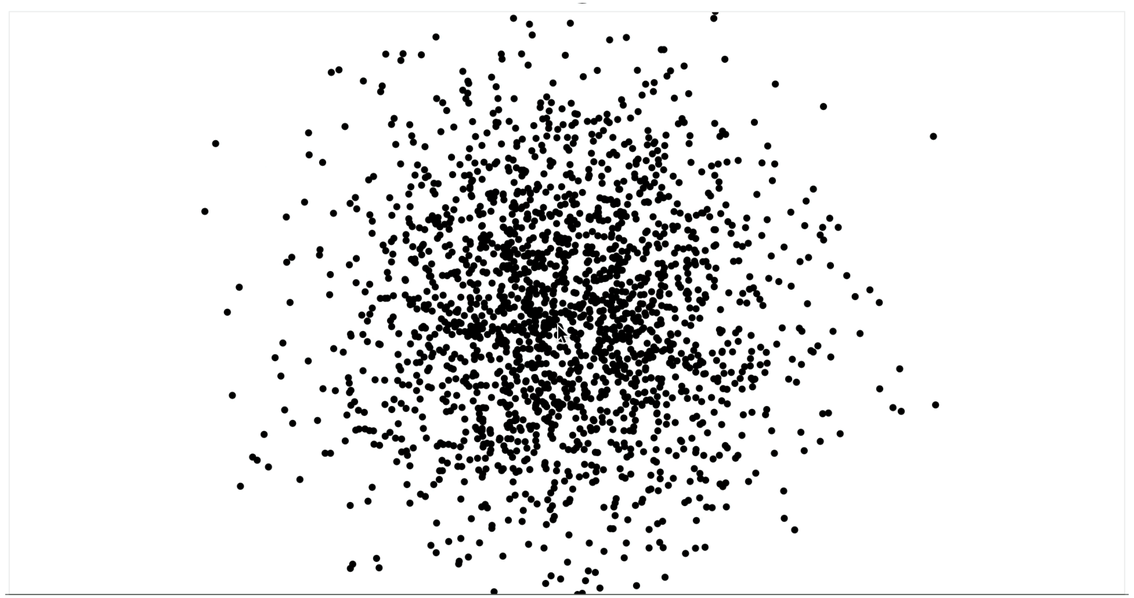



https://bost.ocks.org/mike/miserables/

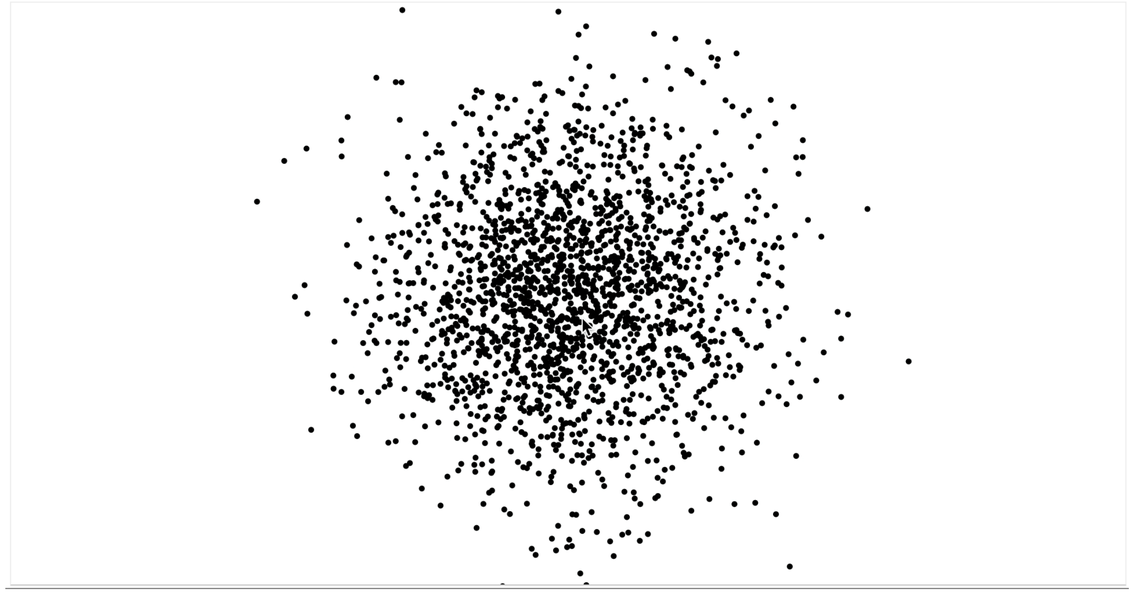
# Explore

## show me something else

Geometric Zoom



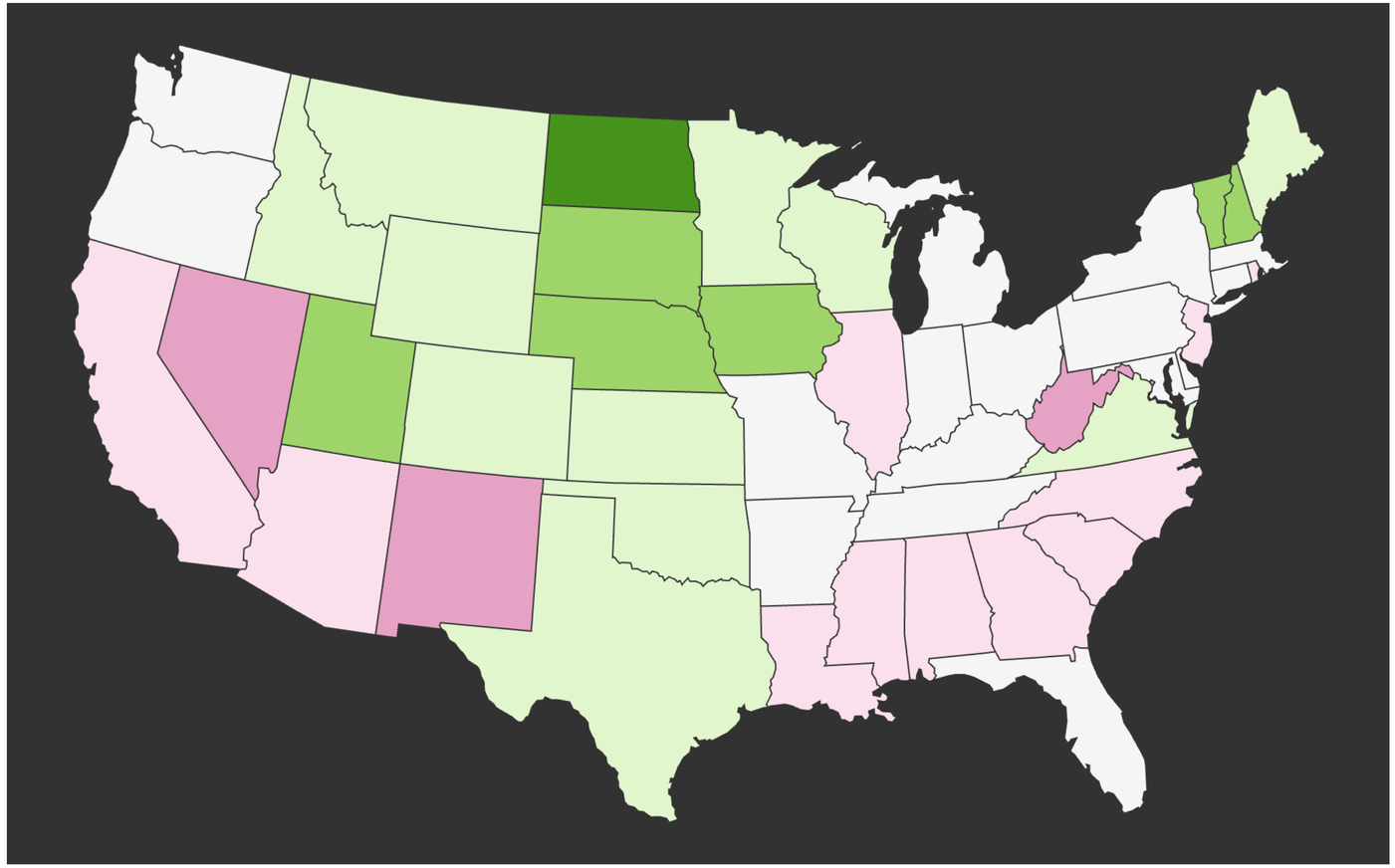
Semantic Zoom



https://bl.ocks.org/mbostock/3680957

# Explore

## show me something else

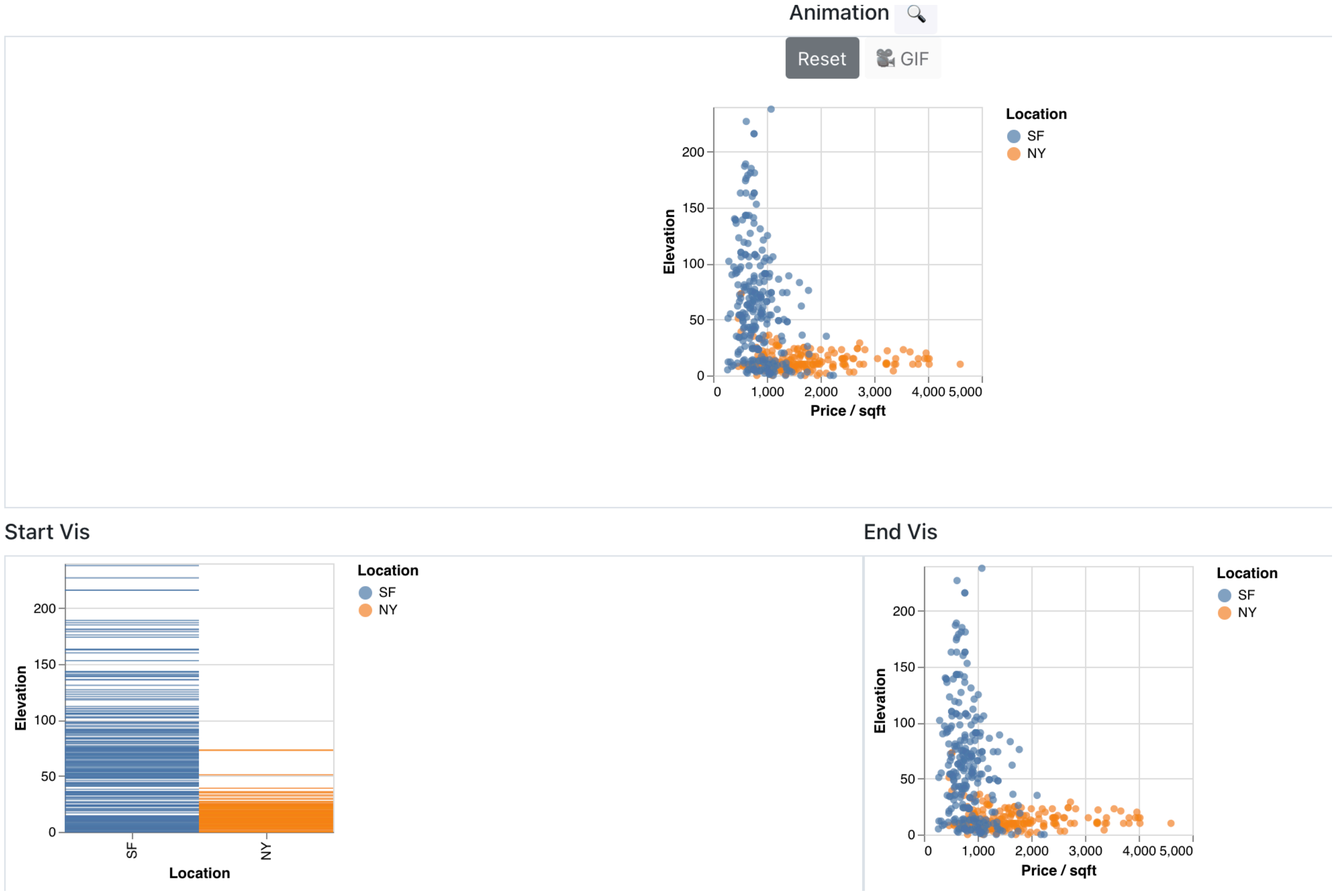


https://bl.ocks.org/cmgiven/d39ec773c4f063a463137748097ff52f

# Encode

## show me a different visual representation

https://uwdata.github.io/gemini-editor/
→ dot plot to scatter plot



# What are common ways you could enable interaction of a data table?

# Select

## to apply a group action (delete, format,…)

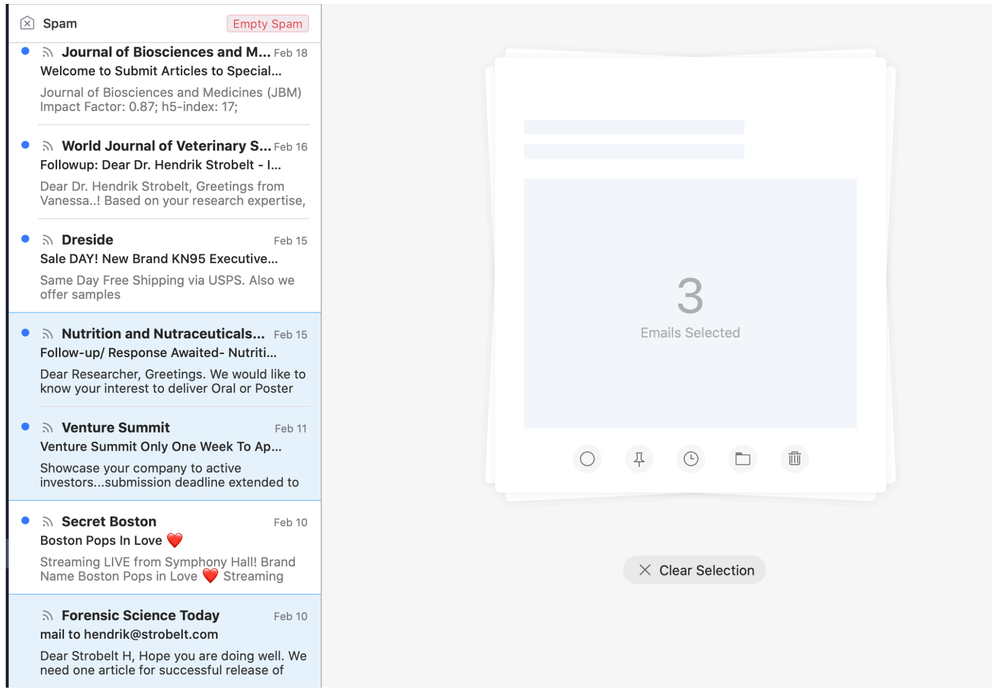
Export to CSV | +New | Delete

Search

| | ID | Product | | | In stock | Customer | |
|---|---|---|---|---|---|---|---|
| | | name (Enter name...) | price | Coupon | | name | order |
| ☐ | 0 | Item name 0 | 2100 | no | yes | Customer 0 | 0 |
| ☐ | 1 | Item name 1 | 2101 | yes | no | Customer 1 | 1 |
| ☑ | 2 | Item name 2 | 2102 | no | no | Customer 2 | 2 |
| ☐ | 3 | Item name 3 | 2103 | no | no | Customer 3 | 3 |
| ☐ | 4 | Item name 4 | 1500 | no | no | Customer 4 | 4 |
| ☐ | 5 | Item name 5 | 2105 | no | no | Customer 5 | 5 |
| ☐ | 6 | Item name 6 | 2106 | no | no | Customer 6 | 6 |
| ☑ | 7 | Item name 7 | 2107 | yes | yes | Customer 7 | 7 |
| ☐ | 8 | Item name 8 | 2108 | no | no | Customer 8 | 8 |
| ☐ | 9 | Item name 9 | 2109 | yes | no | Customer 9 | 9 |

10 ▾

1 2 3 4 5 >




http://allenfang.github.io/react-bootstrap-table/

# Reconfigure

## sorting

| Sr. No. | Book Title ▼ | Author ▼ ▲ | Price ▼ ▲ |
|---|---|---|---|
| 1 | Angels and Demons | Shivam | 890 |
| 2 | Harry Porter | Anuj | 650 |
| 3 | Hobbit | Aman | 700 |
| 4 | Lord of the rings | Sameer | 1000 |
| 5 | The little prince | Jatin | 870 |

https://www.webcodeexpert.com/2016/07/angularjs-how-to-sort-data-in-table.html

# Filter

## “Facetting”

Faceted Search

cczarski

Search... Go

Neighborhood: Bayview ✕
Room Type: Entire home/apt ✕
Private room ✕
Price: <50 ✕

Clear All

**Neighborhood** Clear

- **Bayview (9)**
- Bernal Heights (4)
- Downtown/Civic Center (10)
- Excelsior (21)
- Financial District (1)

Show More

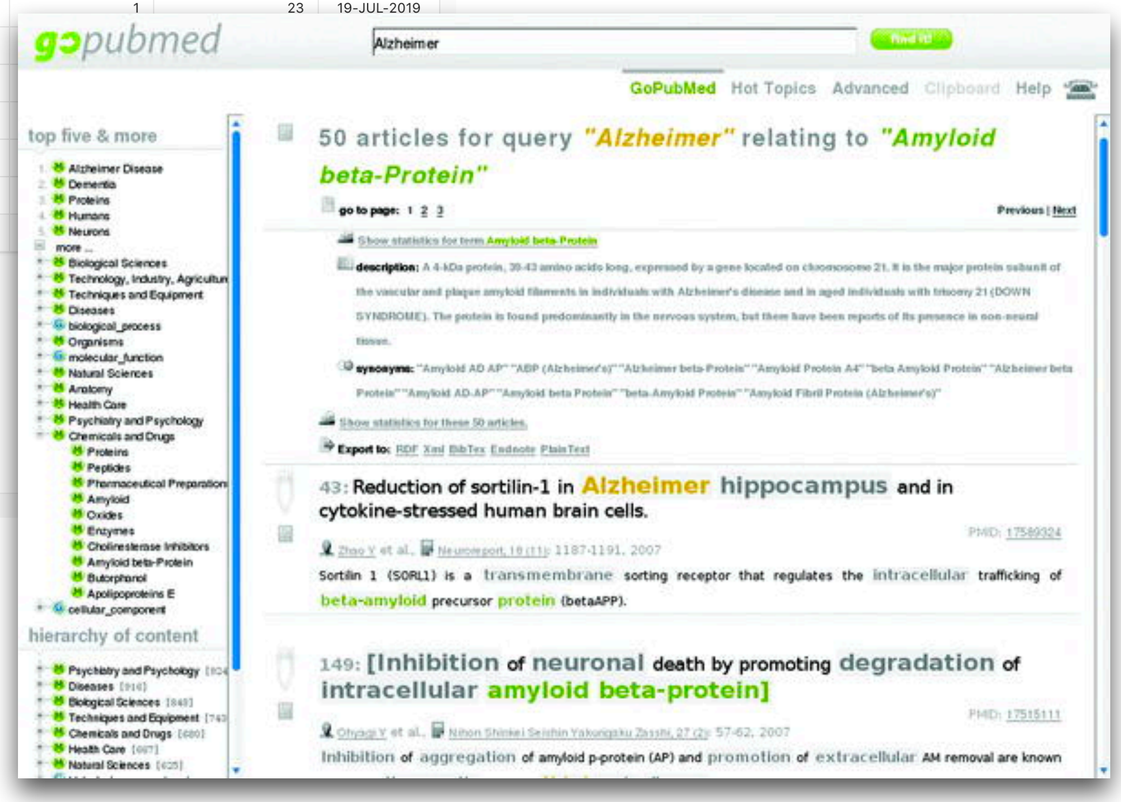
**Room Type** Clear

- **Private room (9)**
- Shared room (1)

**Price** Clear

- **<50 (9)**
- 50 - 120 (111)

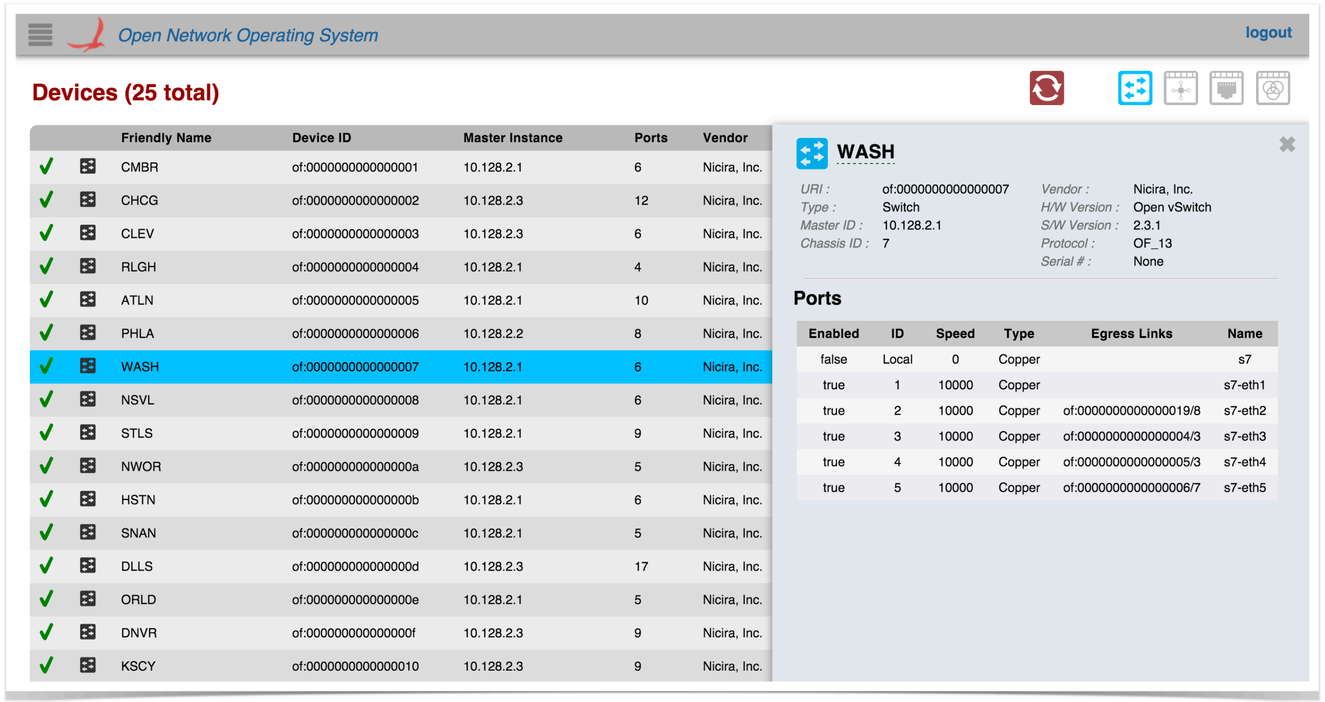
| Rental Name | Host ID | Host Name | Neighborhood | Room Type | Price | Minimum Nights | Number of Reviews | Last Review |
|---|---|---|---|---|---|---|---|---|
| Quiet Private Room in Artsy Shared Home/Urban Farm | 35151167 | Jen | Bayview | Private room | 36 | 2 | 96 | 28-JUL-2019 |
| Home Away From Home Too! Room #1 | 17572711 | James | Bayview | Private room | 44 | 1 | 29 | 18-JUL-2019 |
| Home Away From Home Too! Room #2 | 17572711 | James | Bayview | Private room | 44 | 1 | 23 | 19-JUL-2019 |
| Home Away From Home Too! Room #3 | 17572711 | James | Bayview | Private room | 44 | | | |
| Home Away From Home Too! Room #4 | 17572711 | James | Bayview | Private room | 44 | | | |
| VERY LIMITED DEAL: Cheap Clean & Central (SF City) | 58389796 | Arjun | Bayview | Private room | 49 | | | |
| THE BEST DEAL: Cheap Clean & Convenient (SF City) | 58389796 | Arjun | Bayview | Private room | 39 | | | |
| Large Bedroom Comfortable Home - Full Bed | 28502179 | Tammy | Bayview | Private room | 42 | | | |
| Large Sunny Bedroom - Queen Bed | 28502179 | Tammy | Bayview | Private room | 48 | | | |

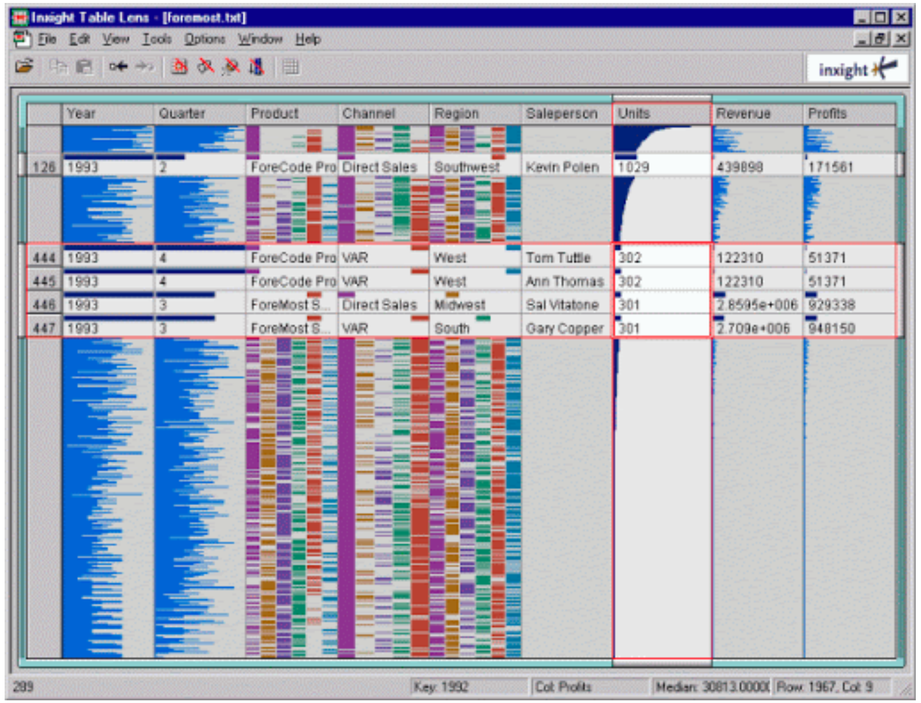



keyword filter + Facetting

# Abstract/Elaborate

## Interactive Detail View & Table Lens




https://wiki.onosproject.org/display/ONOS/GUI+Tabular+View

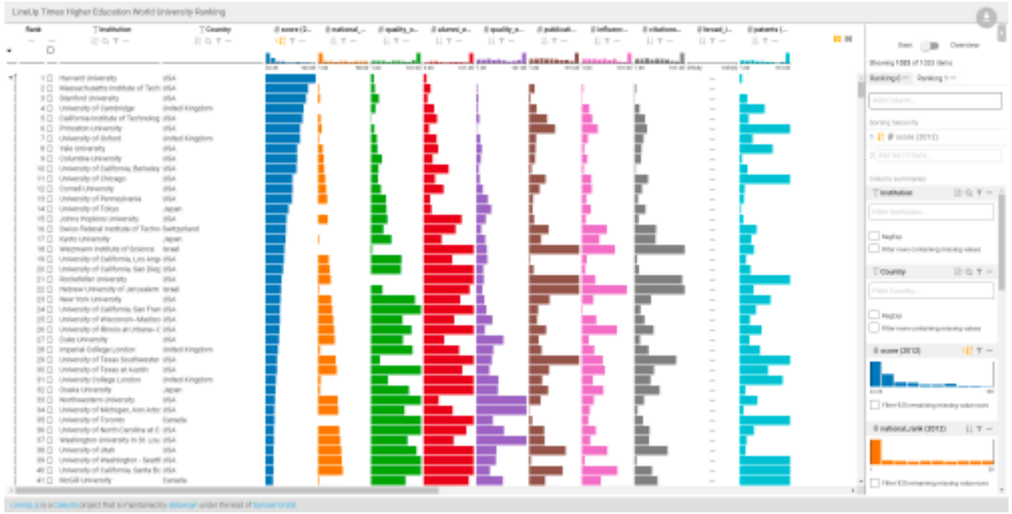
Rao, Ramana, and Stuart K. Card. "**The table lens**: merging graphical and symbolic representations in an interactive focus+ context visualization for tabular information." *CHI 1994*.

# Encode

## Conditional Formatting & LineUp

| # Tickers | 7d | 1mo | 3mo | 1yr | 1mo (2y stack) | 3mo (2y stack) | 1yr (2y stack) |
|---|---|---|---|---|---|---|---|
| 12 | -2.4% | -4.8% | -5.8% | -5.9% | -4.8% | -5.8% | -5.9% |
| 7 | -16.4% | -8.7% | -10.6% | -6.9% | -8.7% | -10.6% | -6.9% |
| 8 | -0.8% | -5.4% | -3.7% | -4.2% | -5.4% | -3.7% | -4.2% |
| 13 | 2.5% | 0.7% | 2.4% | 2.1% | 0.7% | 2.4% | 2.1% |
| 7 | -10.0% | -4.1% | -3.9% | -7.0% | -4.1% | -3.9% | -7.0% |
| 13 | -4.3% | -6.3% | -5.6% | -5.9% | -6.3% | -5.6% | -5.9% |
| 6 | -4.8% | -7.1% | -5.6% | -1.9% | -7.1% | -5.6% | -1.9% |
| 14 | -8.3% | -5.7% | -6.7% | -4.0% | -5.7% | -6.7% | -4.0% |
| 2 | 9.4% | 12.4% | 11.0% | 11.4% | 12.4% | 11.0% | 11.4% |
| 4 | 8.6% | 10.4% | 8.7% | 8.8% | 10.4% | 8.7% | 8.8% |

https://stackoverflow.com/questions/28075699/coloring-cells-in-pandas



https://lineup.js.org/app/

# They can mix well

Interpolated Samples - using **linear** interpolation

| interpol | peptide | mol | Aro | Chrg | evo_end | evo_start | HMom | Inst | MolW | z_amp | z_tox |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | YVSVPLH | | 0.1429 | 0 | -4.655 | 27.75 | 0.1165 | 36.09 | 813.9 | 0.8408 | 0.01037 |
| | YVSVPLH | | 0.1429 | 0 | -4.655 | 27.75 | 0.1165 | 36.09 | 813.9 | 0.8454 | 0.009851 |
| | YVSVPLH | | 0.1429 | 0 | -4.655 | 27.75 | 0.1165 | 36.09 | 813.9 | 0.8499 | 0.009356 |
| | YVSVPLPH | | 0.125 | 0 | -0.449 | 22.38 | 0.09246 | 56.9 | 911.1 | 0.8543 | 0.008885 |
| | YVSPVTP\|H | | 0.125 | 0 | 0.449 | 9.948 | 0.1454 | 77.14 | 899 | 0.8586 | 0.008437 |
| | YLV\|PVTLHH | | 0.1111 | 0 | 1.308 | 7.752 | 0.08646 | 42.26 | 1078 | 0.8628 | 0.008012 |
| | YL\|PPVTPHH | | 0.1111 | 0 | 3.925 | 3.876 | 0.07213 | 63.66 | 1060 | 0.8669 | 0.007608 |
| | FLPPTVFPH\| | | 0.2222 | 0 | 14.83 | -1.938 | 0.04968 | 73.09 | 1054 | 0.8709 | 0.007225 |
| | FLP\|TKTFPHH | | 0.2 | 1 | 22.13 | -2.37 | 0.105 | 59.86 | 1224 | 0.8748 | 0.00686 |
| | FLPTKTFTPH\| | | 0.2 | 1 | 29.37 | -4.267 | 0.07208 | 40.6 | 1188 | 0.8786 | 0.006514 |
| | FLPTKTFTFPH | | 0.2727 | 1 | 36.28 | -4.655 | 0.06431 | 66.55 | 1336 | 0.8823 | 0.006185 |
| | FLPTKTFTFPH | | 0.2727 | 1 | 36.28 | -4.655 | 0.06431 | 66.55 | 1336 | 0.8858 | 0.005873 |

Select x: **z_amp** y: **z_tox**


Molecule ( click on to display here)

https://peptide-walk.mybluemix.net/

# Interaction with Visualization

**Select** – identify something as interesting.

**Connect** – show me related items.

**Abstract/Elaborate** – show me more or less detail.

**Filter** – show me something conditionally.

**Reconfigure** – show me a different arrangement.

**Explore** – show me something else.

**Encode** – show me a different visual representation.

[Yi et al, 2009]

# What you will learn today

The value of interactivity

Principles of interaction design

Principles of accessible interaction design