'All computation is sorting'

'Mobile images':
- Families of curves, on transparencies
- Files of images, with thumbnails
- Maps & ordered tables

- **'Reorderable matrix'**

Perin, C., et al. DIY Bertin Matrix. CHI'15 Workshop Exploring the Challenges of Making Data Physical, authors' version, 2015.

(pertinent to Bertin, J. Semiology of Graphics: diagrams, networks, maps. University of Wisconsin Press, 1983.)
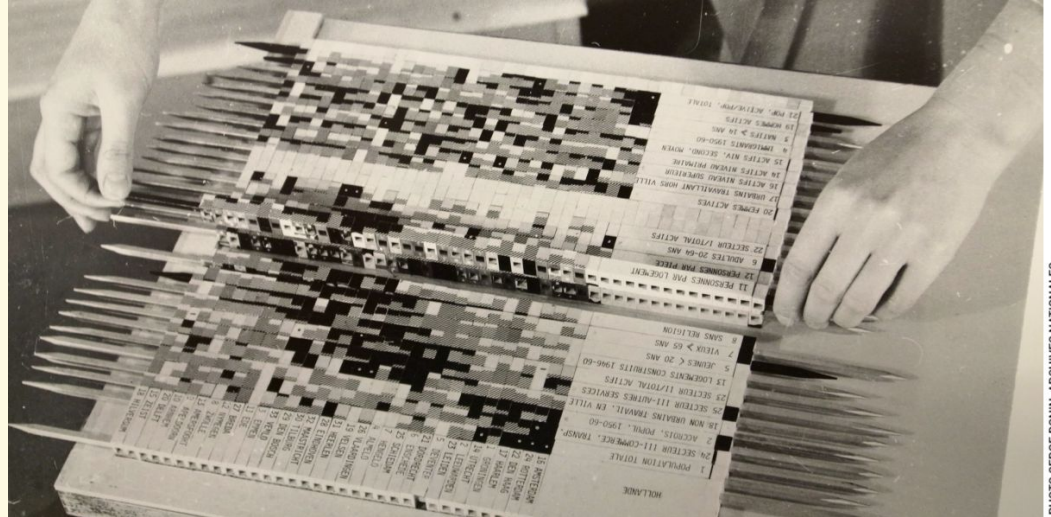

PHOTO SERGE BONIN, ARCHIVES NATIONALES

List of Physical Visualizations:
Jacques Bertin's Reorderable Matrices (1968)
http://dataphys.org/list/bertins-reorderable-matrices/

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'All computation is sorting'

~~Mobile images~~ Interactive visualization:
- Families of curves, on transparencies
  - matplotlib
- Files of images, with thumbnails
  - desktop GUIs
- Maps & ordered tables
  - 'killer apps'
- **~~'Reorderable matrix'~~**
  - **Data frame**

Hafner, M., Niepel, M., Subramanian, K., & Sorger, P. K. (2017).
Designing drug-response experiments and quantifying their results.
Current Protocols in Chemical Biology, 9, 96–116

'All computation is sorting'
+ 'graphic information processing'

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"a two-dimensional numerical table [...] when both dimensions are reorderable [e.g. not time], the appropriate visualization is a matrix"

The key idea behind the methods [Bertin] used for more than 15 years [2] [3] (in the 70's–80's) is that visual representations should be rearrangeable to reveal patterns:

"...this point is fundamental. It is the internal mobility of the image that characterizes the modern Graphique. ***We do not "draw" an image once for all. We "build" it and rebuild it*** *(we manipulate it) until all hidden relationships have been perceived."*

Perin C., Di Vozzo R., Dragicevic P., Le Goc M., Fekete J.D. (2015), DIY Bertin Matrix. CHI '15, ACM.
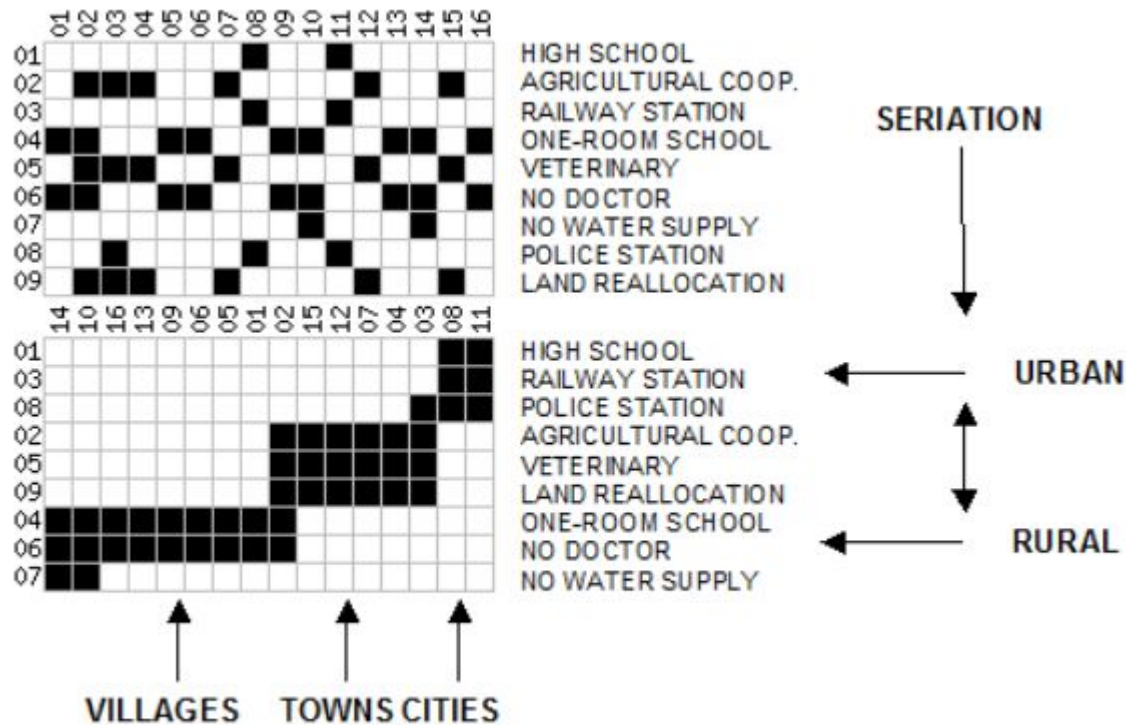
Figure 1. Bertin's [8,9] example of matrix reordering

Innar Liiv (2010). Towards Information-Theoretic Visualization Evaluation Measure: A Practical example for Bertin's Matrices. BELIV '10, ACM.

"That's right, we established a distance, a topology between [rows]."

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Figure 1. Bertin's [8,9] example of matrix reordering

SERIATION

URBAN

RURAL
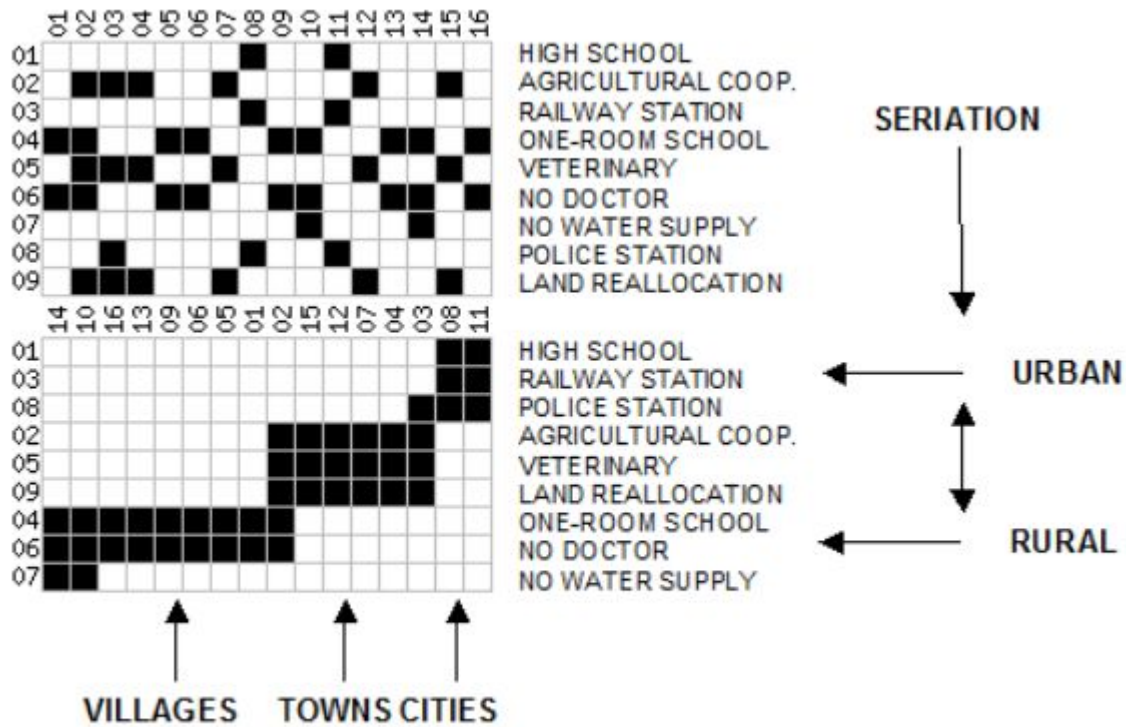
"...to link indefinable aesthetics with a mathematical framework and theory backed up by an incomputable function – a perfect match!

"...to replace a number of aesthetics issues (yet undefined) with the minimum description length principle and Occam's razor."

Innar Liiv (2010). Towards Information-Theoretic Visualization Evaluation Measure: A Practical example for Bertin's Matrices. BELIV '10, ACM.

"That's right, we established a distance, a topology between [rows]."

Bébert et la Graphique

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Bébert et la Graphique

"...ways of organizing information, knowledge."

"You will talk about computer science. Punch cards, programs, calculators. Numbers, numbers!"
("No, no.")

"And those machines, we give numbers as inputs, we get numbers again and still don't know what they mean."

COMPUTER ADAPTATIONS OF BERTIN'S METHOD

SOFTWARE — YEAR (1980, 1990, 2000, 2010), DEVELOPED IN BERTIN'S LAB, AVAILABILITY, SOFTWARE TESTED

USER INTERFACE — UI DEGREE OF COMPATIBILITY, UI SPATIAL DIRECTNESS, UI TEMPORAL DIRECTNESS, SUBJECTIVE USABILITY, UI CONSISTENCY, ANIMATED TRANSITIONS

**FEATURES**
- ENCODING — DATA TYPES SUPPORTED, NB OF ENCODINGS, CHANGE ROW/COL ENCODING, DATA CONDITIONING, SHAPE ORIENTATION, SPECIFY HEADERS
- LAYOUT — ROW/COL MANUAL REORDERING, ROW/COL AUTO REORDERING, AUTO REORDERING OF SUBSETS, SINGLE ROW/COL SORTING, TRANSPOSITION, ROW/COL RESIZING, ROW/COL SEPARATORS, ROW/COL SEPARATOR RESIZING, GLUE ROWS/COLUMNS
- COMMUNIC. — FIDELITY TO BERTIN'S STYLE, EXPORT CAPABILITIES, TEXT ANNOTATIONS, FONTS CUSTOMIZABILITY

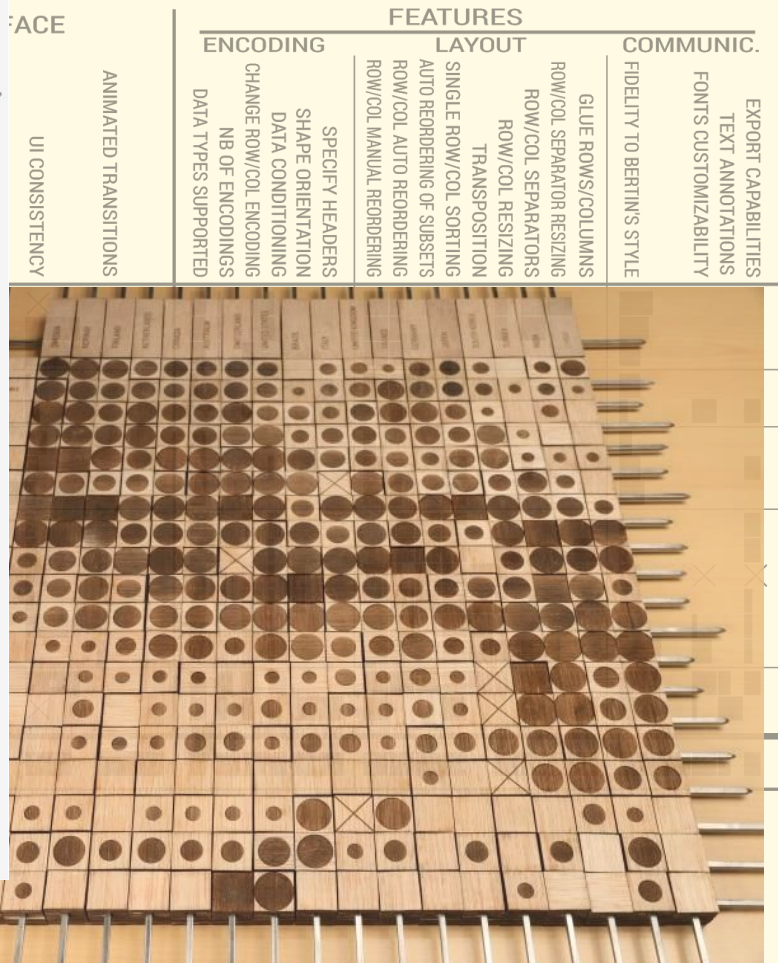| Category	Software
LIMITED FEATURES AND COMMAND-BASED	TMC / CARTAX / MATRIX
LIMITED FEATURES LIMITED INTERACTIVITY	TGINF / MATRIXEXPLORER
MOSTLY MANUAL REORDERING	STEVE RUBIN, IN D3 / CARTES & DONNÉES / THE REORD. MATRIX
RICH FEATURES WITH COMPLEX WIMP USER INTERFACE	GAP / PERMUTMATRIX / VOYAGER / VISULAB / T_ALK / AMADO
RICH FEATURES AND SCRIPT-BASED	BERTIN FOR R / CHART
THIS ARTICLE	BERTIFIER

Charles Perin, Pierre Dragicevic, Jean-Daniel Fekete (2014). Revisiting Bertin's Matrices: New Interactions for Crafting Tabular Visualizations. TVCG, VIS' 2014

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https://aviz.fr/diyMatrix/
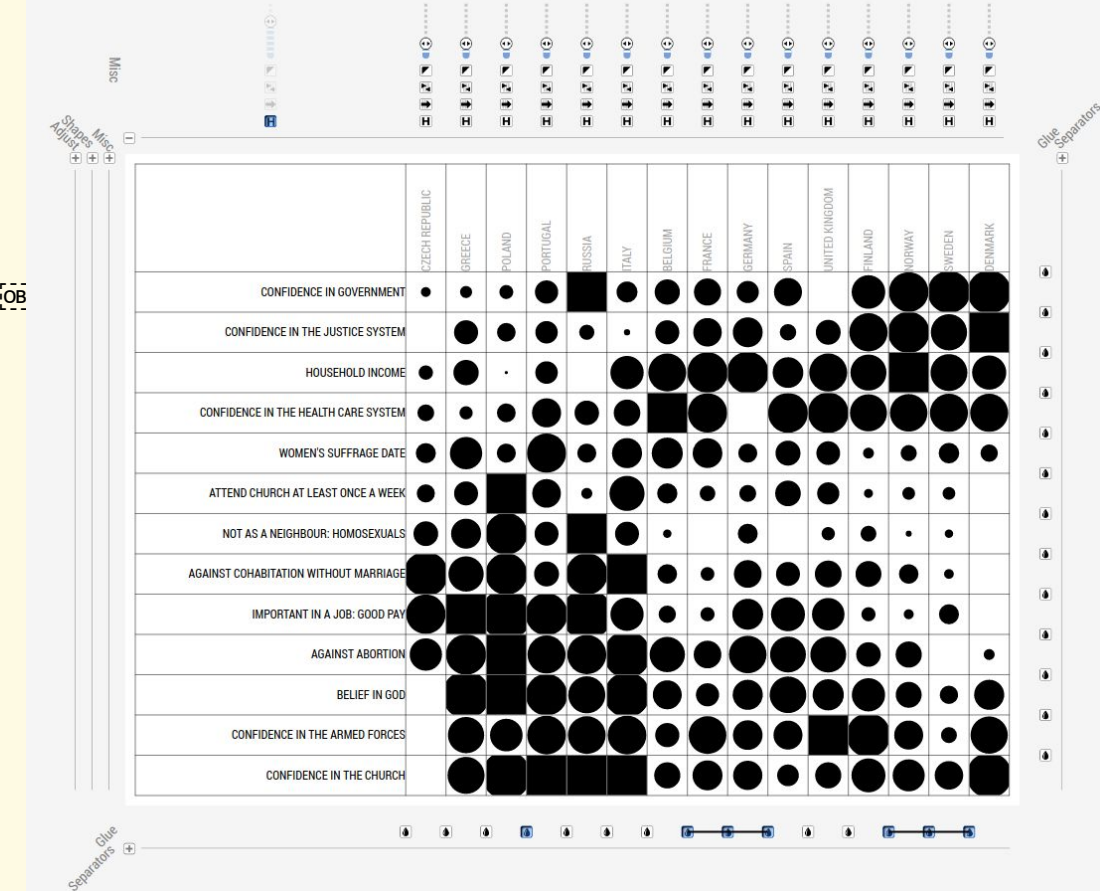
Bertifier Web App @ aviz.fr/Bertifier/Bertifier

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https://aviz.fr/diyMatrix/

'Augmented Reality above the Tabletop'

Butscher, S., et al. Clusters, trends, and outliers: How immersive technologies can facilitate the collaborative analysis of multidimensional data. CHI 2018 (Human Factors in Computing Systems). ACM, 2018.

What if I want to see data with a lot of natural order?
● Spatially sparse vs Bertin matrix

    ○ Information dense at points
    ○ Somewhat generic axes

I want to hold a (remote) meeting at a tabletop.


```
                                                    ─── time
         │                    │
         │ position           │ position
         │ color              │ color
         │ condition          │ condition
         │ ...                │ ...
         │                    │
        #0                   #0
```
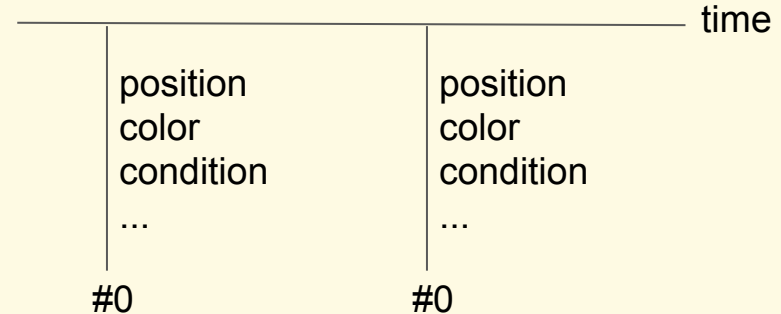
'Augmented Reality above the Tabletop'

What if I want to see data with a lot of natural order?
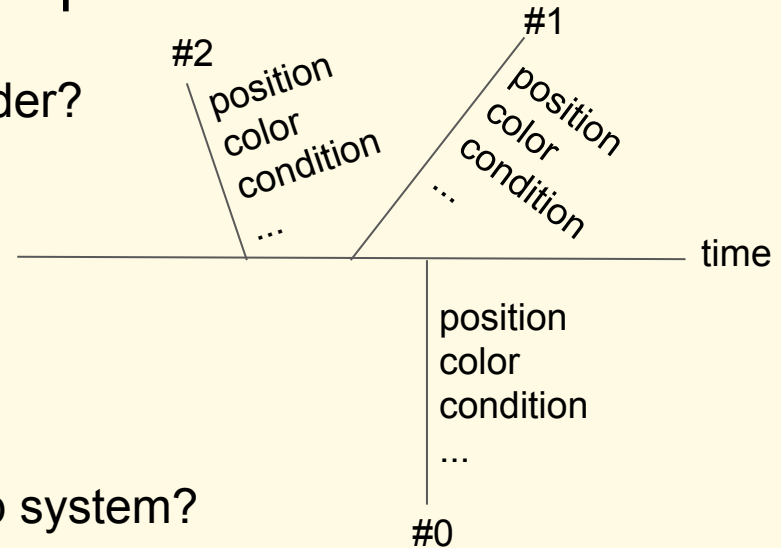● Spatially sparse vs Bertin matrix

    ○ Information dense at points
    ○ Somewhat generic axes

I want to hold a (remote) meeting at a tabletop.
● Can we squeeze science from an open-loop system?

    ○ Observations were high-dimensional.
    ○ We expect tons of indirect relationships.

#2 position color condition ...

#1 position color condition ...

time

position color condition ...

#0

Clusters, Trends, and Outliers

Why not use a clustering algorithm in a black box?
    Metric: k-means, hierarchical, etc
    No metric: t-SNE, UMAP, etc.

- Which columns contribute the most predictive value?

https://www.youtube.com/watch?v=wxLGw-DrG_0

Clusters, Trends, and Outliers

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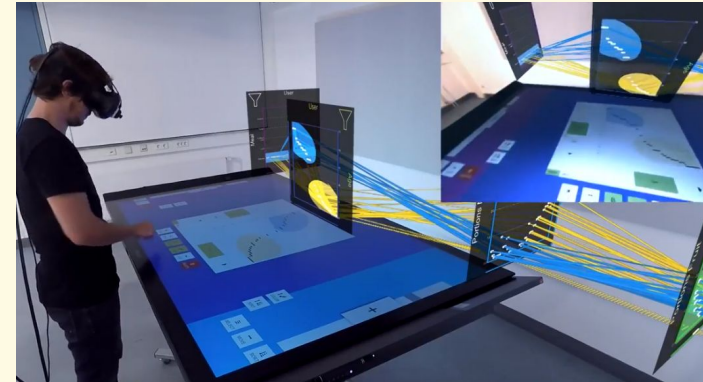
- Which columns contribute the most predictive value?

- Are other axes aware of the 'brushed' subset?
  - Ad hoc color map

- Can I 'aggregate' these clusters to one point?
  - Got average, but not variance

  - Some dimensions pre-aggregated by day/week/month, cohort, ...

https://www.youtube.com/watch?v=wxLGw-DrG_0

Clusters, **Trends**, and Outliers

Multi-relationship visualization

- Extrusion: like labels, but with visual coherence ('fiber bundle')

    - Functions with no analytic form (e.g. many-to-one)
      have topologically interesting inverses
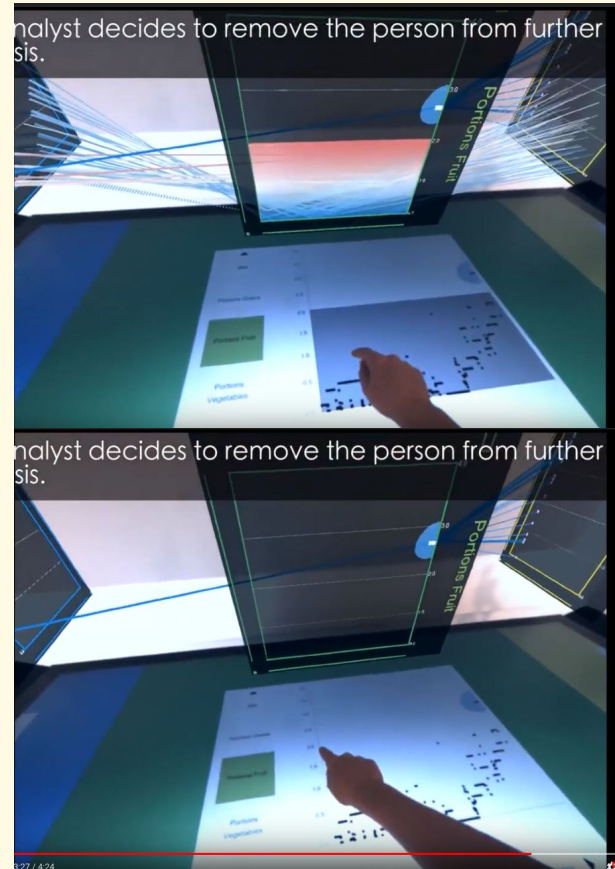
Clusters, **Trends**, and Outliers

Multi-relationship visualization

- Extrusion: like labels, but with visual coherence ('fiber bundle')

  - Functions with no analytic form (e.g. many-to-one)
    have topologically interesting inverses

- How to view torsion while constrained to input on a flat plane?

  - Videogame style: egocentric navigation, sans WASD
  - Physical style: tangible plots, rearranged while strung together

Clusters, Trends, and **Outliers**

Can I watch distributions flow through aggregation?

Can I investigate individuals?

https://www.youtube.com/watch?v=5KMH1t_N5Ow

Clusters, Trends, and **Outliers**

Can I watch distributions flow through aggregation?

Can I investigate individuals?

Can I branch the state of the analysis?

Can I point out & document features?

analyst reconfigures the plots to see how this all relates

https://www.youtube.com/watch?v=5KMH1t_N5Ow