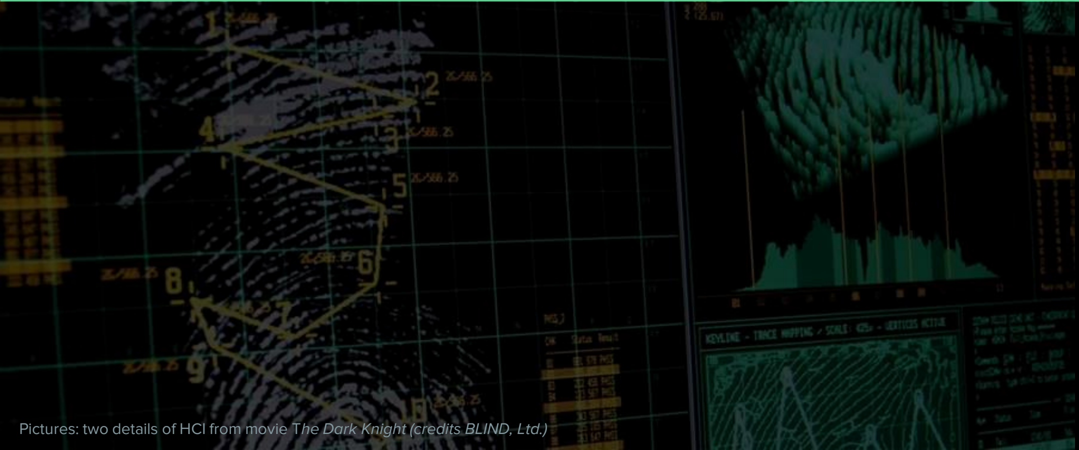
information visualization



Advanced Topics in Interaction and Multimedia

v20230918

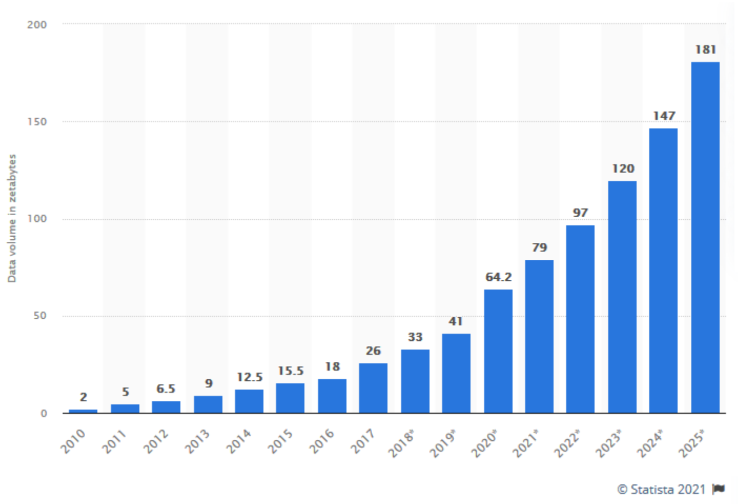
Alexandre Valle | DEI | FEUP | 18.09.2023

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Pictures: two details of HCI from movie *The Dark Knight (credits BLIND, Ltd.)*

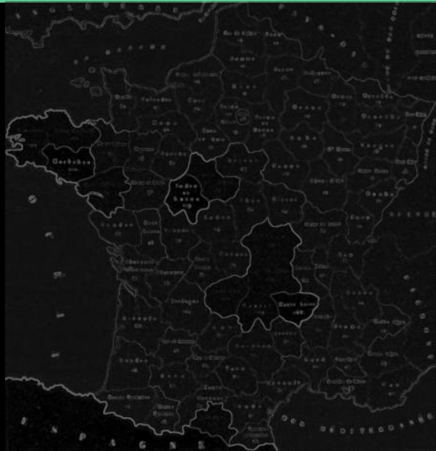
Index

Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2025



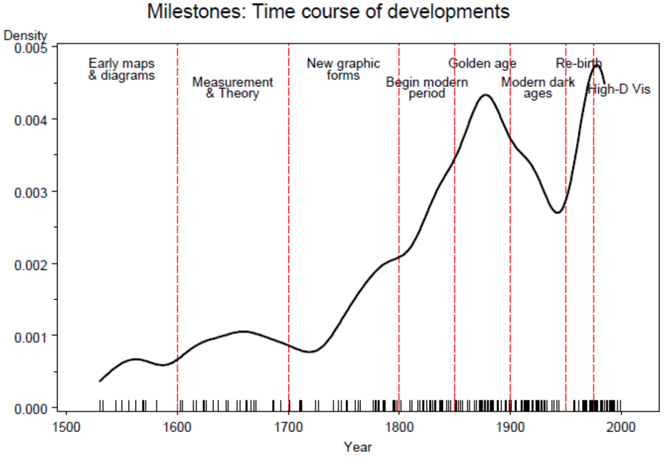
https://www.statista.com/statistics/871513/worldwide-data-created/

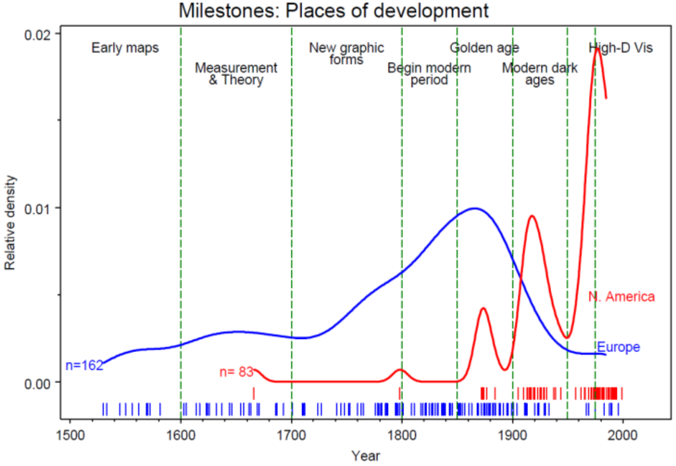
an historical perspective



Milestones

- The time distribution of events considered milestones in the history of data visualization:

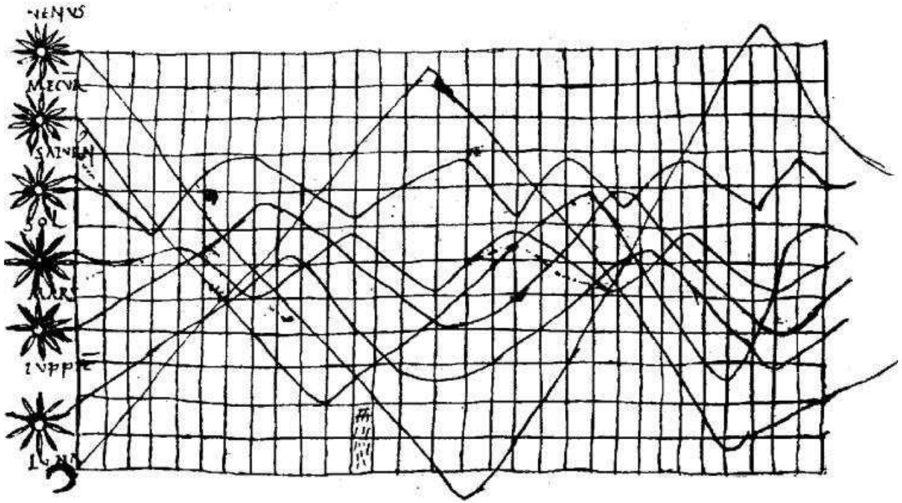




M. Friendly (2006), A Brief History of Data Visualization, Handbook of Computational Statistics: Data Visualization, Springer-Verlag

History . X Century

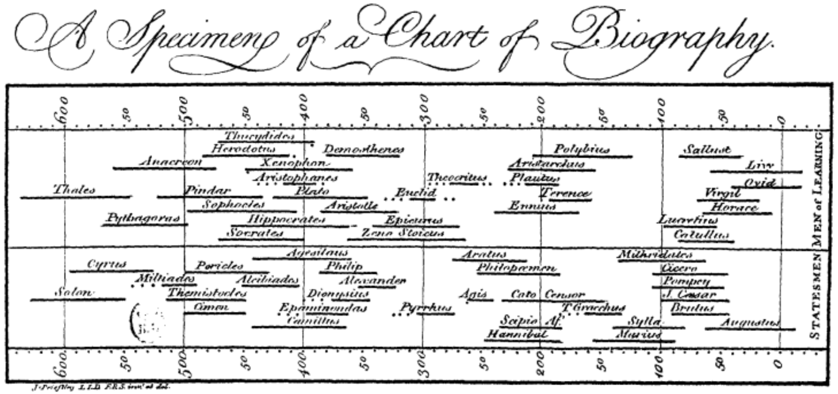
- Planetary movements shown as cyclic inclinations over time, by an unknown astronomer, appearing in a 10th century appendix to commentaries by A. T. Macrobius on Cicero's *In Somnium Scripionus*.



M. Friendly, A Brief History of Data Visualization, Handbook of Computational Statistics: Data Visualization, Springer-Verlag, 2006

History . XVIII Century

- *A Specimens of a Chart of Biography:* the lifespan of 2000 famous people, from 1200 b.C. to 1750 a.C., by Priestley (1765).



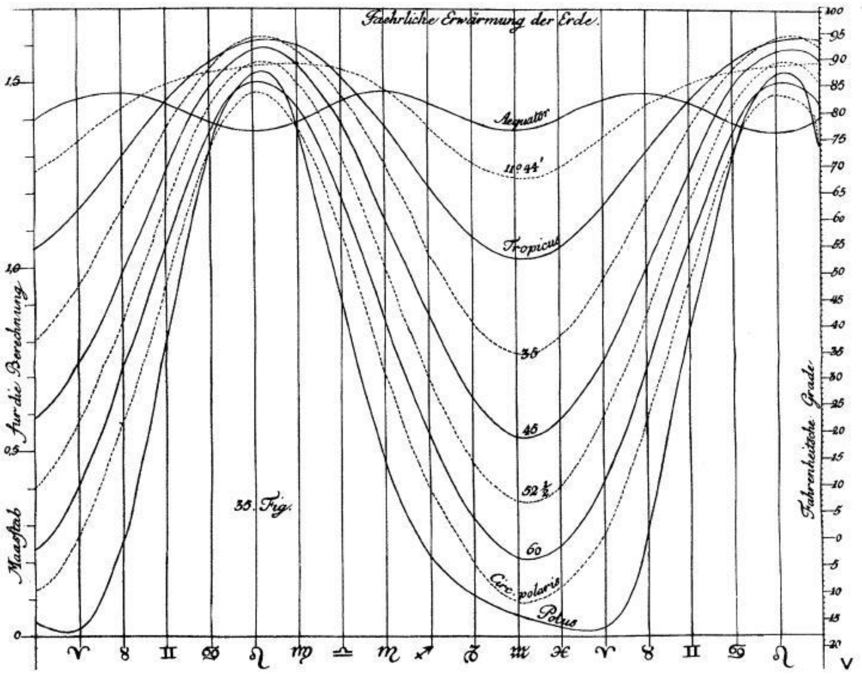
M. Friendly, A Brief History of Data Visualization, Handbook of Computational Statistics: Data Visualization, Springer-Verlag, 2006

History . XVIII Century

- *Carte chronographique* : an annotated timeline of history on a 54-foot scroll and included the names and the descriptive events, grouped thematically, with symbols denoting character (martyr, tyrant, heretic, noble, upright, etc.) and profession (painter, theologian, musician, monk, etc.) Jacques Barbeu-Dubourg (1753)

History . XVIII Century

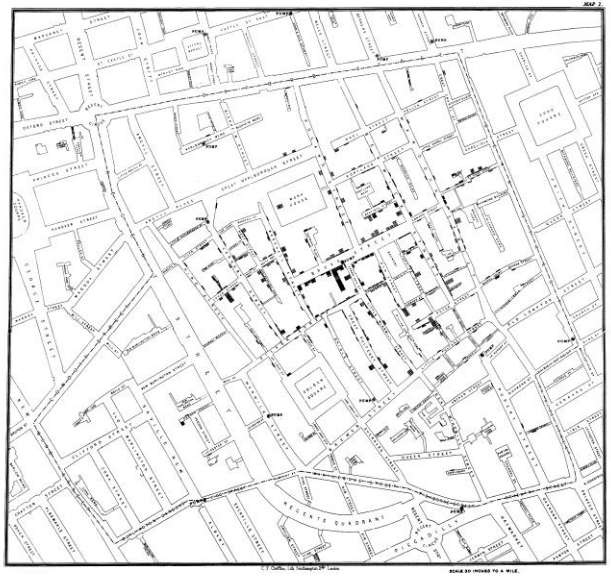
- Graphical analysis Solar Warming vs. Latitude. The first semi-graphic display combining tabular and graphical formats, Johann H. Lambert (1779)



www.infovis.info

History . XIX Century

- London map depicting cluster of cholera cases, John Snow (1854)

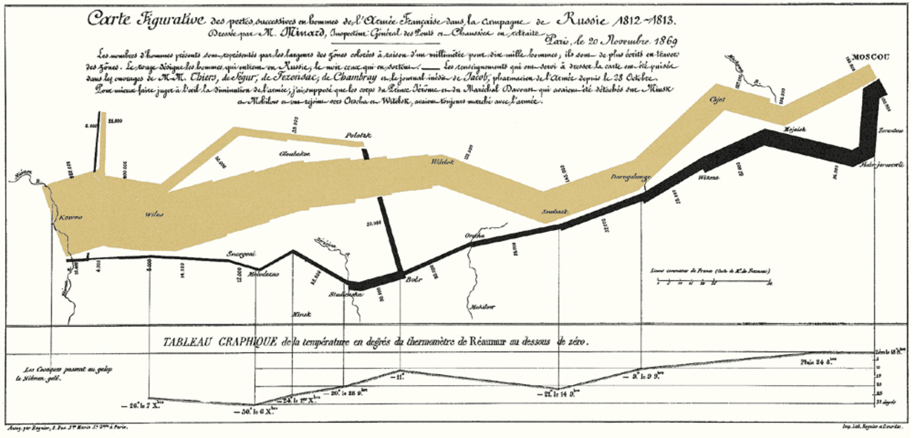


REF TO PICTURE

History . XIX Century

- Illustrated disastrous result of Napoleon's failed Russian campaign of 1812, Minard (1869)

- The graphic is notable for its representation in two dimensions of six types of data:
    - the number of Napoleon's troops;
      distance;
    - temperature;
    - the latitude and longitude;
    - direction of travel;
    - location relative to specific dates

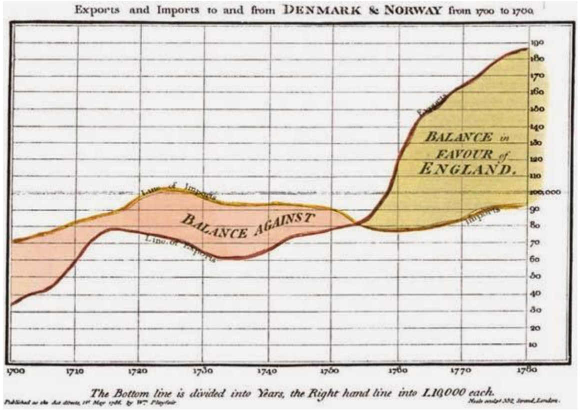


Tufte, E. (2001) *The Visual Display of Quantitative Information*. Cheshire, Conn. :Graphics Press

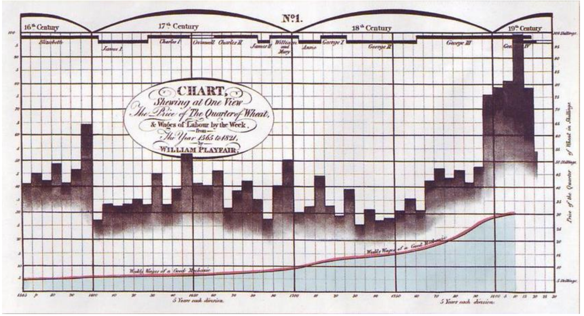
site: en.m.wikipedia.org/wiki/Charles_Joseph_Minard

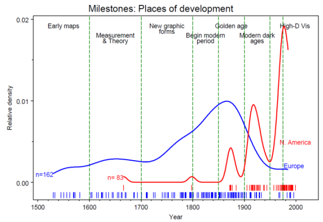
History . XIX Century

- Trade-balance time-series chart, The Commercial and Political Atlas and Statistical Breviary. **Playfair** (1786)



- Price of wheat and weekly wages. **Playfair** (1821)





History . XIX Century

- Train schedule designed by Ibry showing the time schedules of trains from Paris to Lyon (Marey 1885). This design makes it easier to determine the fastest trains (steeper slopes), layovers (line breaks), and the intersection points of south-bound and north-bound trains. Published by Marey 1878

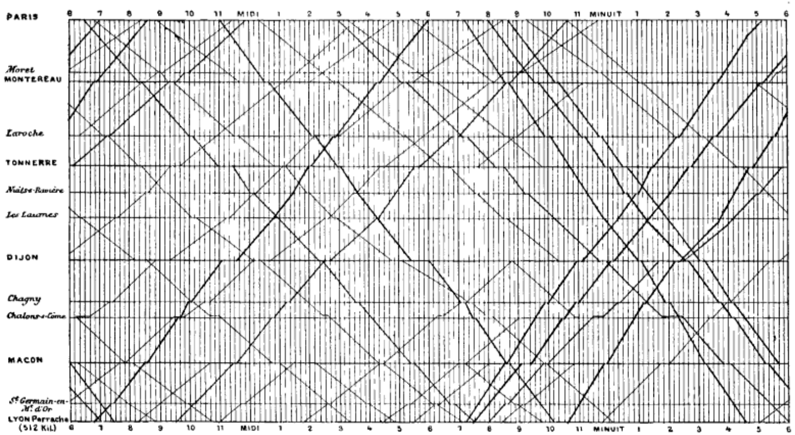
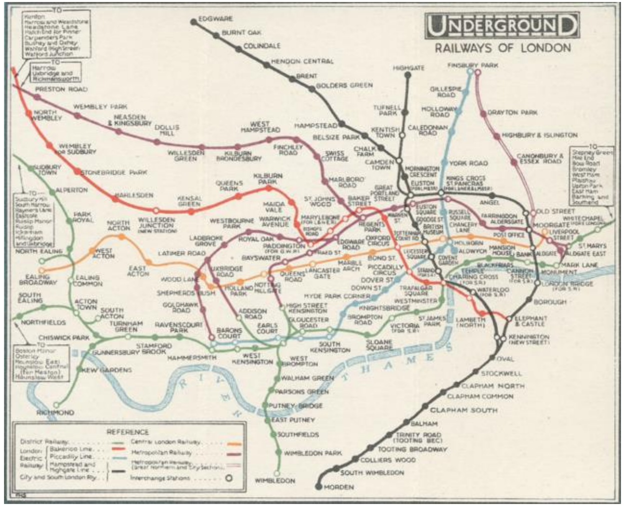
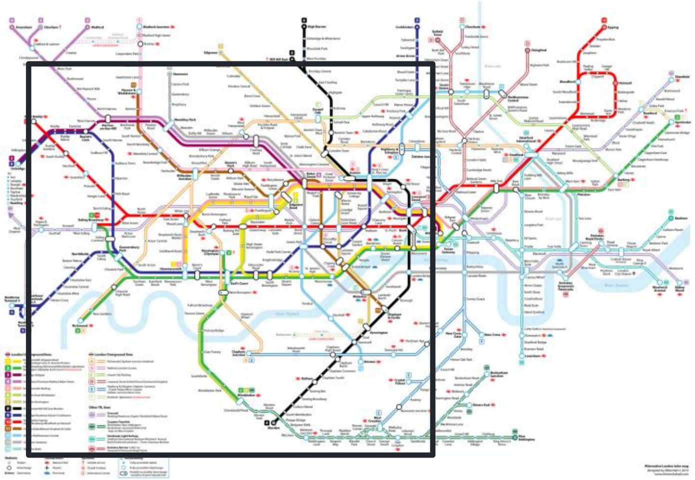


Fig. 5. — Graphique de la marche des trains sur un chemin de fer, d'après la méthode de Ibry.

History . XX Century



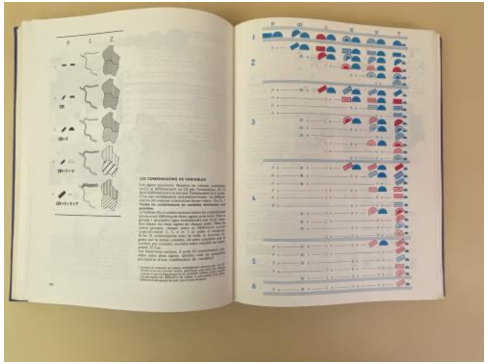
1927



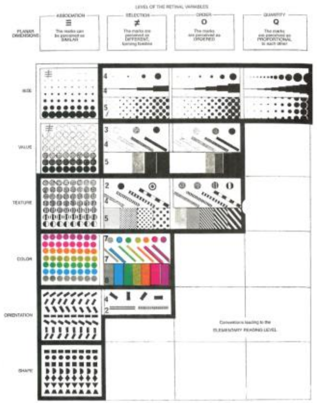
now

History . XX century

- Bertin, J., (1968). Semiologie Graphique, *Les diagrammes, les réseaux, les* cartes. Archives de sociologie des religions, n°26, pp. 176-177.



- Bertin, J., (1983). Semiology of graphics, diagrams, networks, maps.: University of Wisconsin Press



Further reading on history of InfoVis...

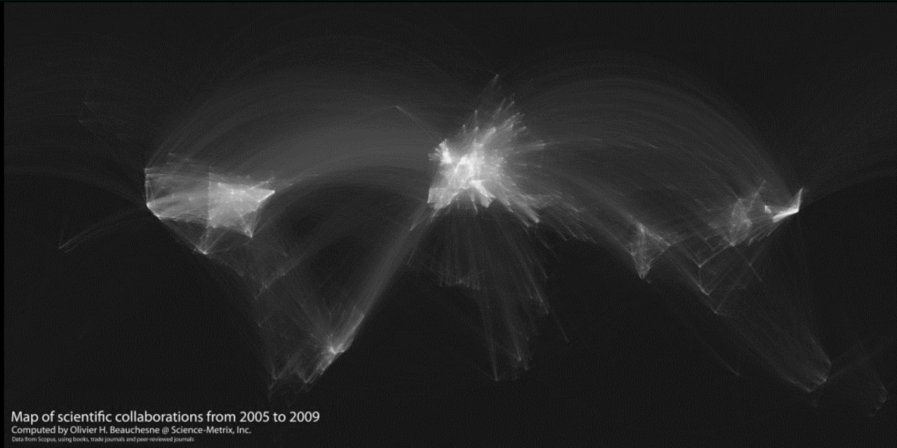
- Tufte, E., (2001). ***The visual display of quantitative information***. Cheshire, Conn. :Graphics Press

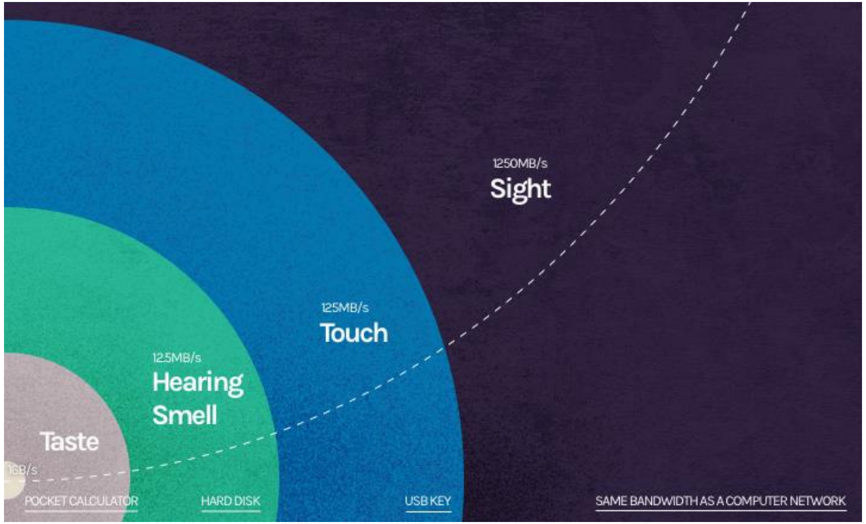
- M. Friendly, (2006). ***A Brief History of Data Visualization***, ***Handbook of Computational Statistics: Data Visualization***, Springer-Verlag

- ***Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization*** (http://euclid.psych.yorku.ca/SCS/Gallery/milestone/)

General principles:

Definitions





Infographic representation of work by Tor Norretranders “Bandwidth of Senses”

General definitions of Infovis

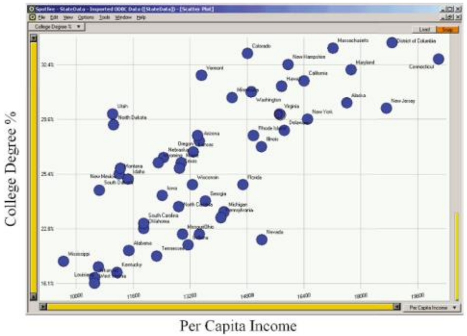
- Use of **interactive visual representations** of data to **amplify cognitive performance**.... (Card, 2008)
- ...interactive visual representations of **abstract data** .... (Card et *al.* 1999)
- ... **efficiently map** data variables onto visual dimensions in order to create graphic representations (Gee et al., 2005)
- **Interaction** is important for **constant redefinition of goals** when new insight ...has been gained (Card et al., 1998)

General definitions of Infovis

- **Compactness:** the ability to **graphically compact large amounts of information** in such a manner that allows the observer discover, make decisions or provide explanations about patterns, individual or groups of information items.

State	College Degree %	Per Capita Income
Alabama	20.6%	11486
Alaska	30.3%	17610
Arizona	27.1%	13461
Arkansas	17.0%	10520
California	31.3%	16409
Colorado	33.9%	14821
Connecticut	33.8%	20189
Delaware	27.9%	15854
District of Columbia	36.4%	18881
Florida	24.9%	14698
Georgia	24.3%	13631
Hawaii	31.2%	15770
Idaho	25.2%	11457
Illinois	26.8%	15201
Indiana	20.9%	13149
Iowa	24.5%	12422
Kansas	26.5%	13300
Kentucky	17.7%	11153
Louisiana	19.4%	10635
Maine	25.7%	12957
Maryland	31.7%	17730
Massachusetts	34.5%	17224
Michigan	24.1%	14154
Minnesota	30.4%	14389
Mississippi	19.9%	9648
Missouri	22.3%	12989
Montana	25.4%	11213
Nebraska	26.0%	12452
Nevada	21.5%	15214
New Hampshire	32.4%	15959
New Jersey	30.1%	18714
New Mexico	25.5%	11246
New York	29.6%	16501
North Carolina	24.2%	12885
North Dakota	28.1%	11051
Ohio	22.3%	13461
Oklahoma	22.8%	11893
Oregon	27.5%	13418
Pennsylvania	23.2%	14068
Rhode Island	27.5%	14981
South Carolina	23.0%	11897
South Dakota	24.6%	10661
Tennessee	20.1%	12255
Texas	25.5%	12904
Utah	30.0%	11029
Vermont	31.5%	13527
Virginia	30.0%	15713
Washington	30.9%	14923
West Virginia	16.1%	10520
Wisconsin	24.9%	13276
Wyoming	25.7%	12311

(a) A thousand words



(b) A picture

"A picture is worth a thousand words"

Fekete, J, van Wijk, J, Stasko, J. North, C. (2008). The Value of Information Visualization. DOI: 10.1007/978-3-540-70956-5_1.

General definitions of Infovis

So why is visualization useful before the modeling? Because, there are cases when we have no clear idea on the nature of the data and have no model.

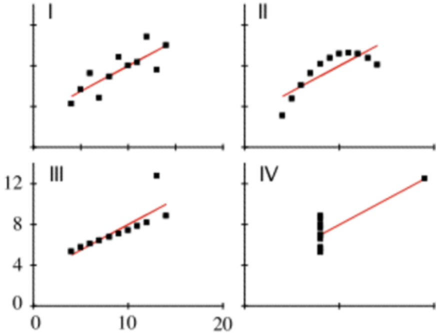
To show why visualization can help finding a model, Anscombe in [1] has designed four datasets that exhibit the same statistical profile but are quite different in shape, as shown in Figure 6. They have the following characteristics[12]:

- mean of the x values = 9.0
- mean of the y values = 7.5
- equation of the least-squared regression line is: y = 3 + 0.5x
- sums of squared errors (about the mean) = 110.0
- regression sums of squared errors (variance accounted for by x) = 27.5
- residual sums of squared errors (about the regression line) = 13.75
- correlation coefficient = 0.82
- coefficient of determination = 0.67.

Visualization is much more effective at showing the differences between these datasets than statistics. Although the datasets are synthetic, Anscombe's Quartet demonstrates that looking at the shape of the data is sometimes better than relying on statistical characterizations alone.

I		II		III		IV	
x	y	x	y	x	y	x	y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

(a) Four datasets with different values and the same statistical profile



(b) Dot Plot of the four datasets

Fig. 6. Anscombe's Quartet

Fekete, J, van Wijk, J, Stasko, J. North, C. (2008). The Value of Information Visualization.
DOI: 10.1007/978-3-540-70956-5_1.

General definitions of infoviz:

5 dimensions of interest

Maletic *et al.* consider five dimensions to be addressed by (software) visualization:

- **Tasks** – why is the visualization needed?
- **Audience** – who will use the visualization?
- **Target** – what is the data source to represent?
- **Representation** – how to represent it?
- **Medium** – where to represent the visualization?

Maletic, Jonathan & Marcus, Andrian & Collard, Michael. (2002). A Task Oriented View of Software Visualization.

General definitions of infoviz:
effective visualization solution

According to Tufte (2001):

- present the information **undistorted** regarding its original meaning
- keep **coherency** when presenting great amounts of information
- to present the information through mechanisms which facilitate the visualization at progressively **distinct levels of detail**
- to be **well integrated with other descriptions of the information set**, such as verbal or statistical
- (among other)

Tufte, Eduard, The visual display of quantitative information, Graphic Press, 2001

General definitions:

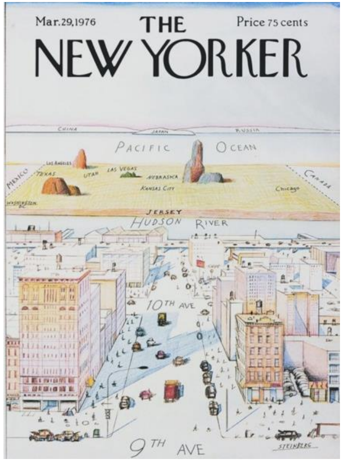
Too much visual data?

- Semantic depth of field: “blur” an object based on its current relevance to a particular visualization.

- Multiple representations: more detail when in focus

- Abstraction and thresholding

  “Parochial New Yorker's view of the World”, drawn by Steinberg in March 29, 1976: how new yorkers see the USA from their perspective where, according to their subjective perceptions.



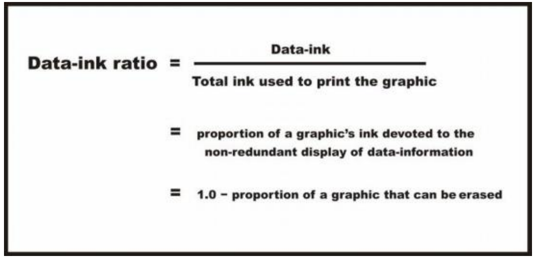
keep spatial and temporal coherence along what the user sees

General definitions:

An example of measure of effectiveness: the data-ink ratio

- Ink that fails to depict statistical information does not have much interest to the viewer
- Above all else, show the data

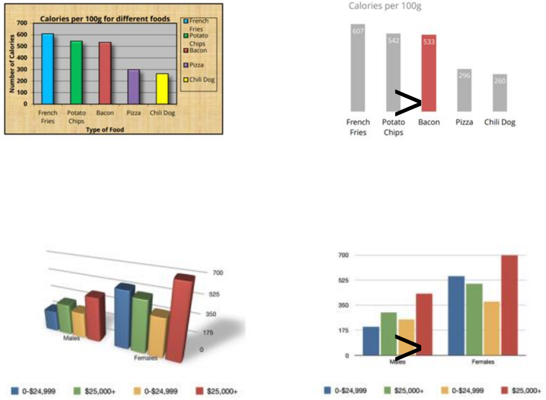
(Tufte 1983)



Data-ink ratio = $\frac{\text{Data-ink}}{\text{Total ink used to print the graphic}}$

= proportion of a graphic's ink devoted to the non-redundant display of data-information

= 1.0 − proportion of a graphic that can be erased

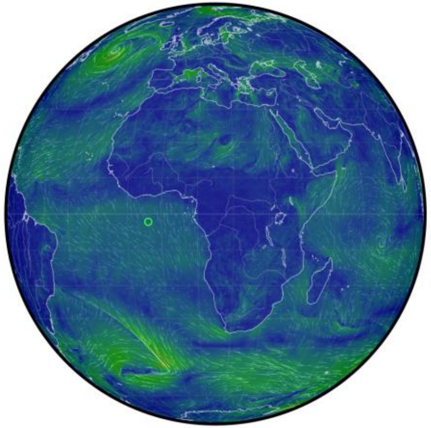


General definitions:

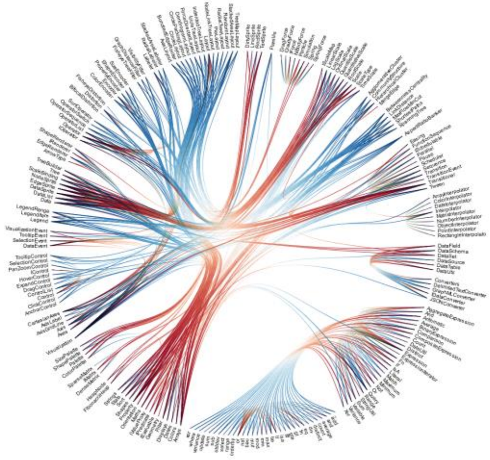
Infovis and Scientific visualization

- In scientific visualization, **data** is defined **in reference to a coordinate system**, which makes it relatively easy to visualize it in an intuitive way. "*Information visualization should be seen in contrast to scientific visualization, since the second deals with physically-based data*" (Card *et al.*, 1999).

- In contrast ....information visualization typically deals with non-numeric, nonspatial, and high-dimensional data (Chen, 2005)



https://earth.nullschool.net



https://observablehq.com/@d3/hierarchical-edge-bundling/2

General principles:

Low level perception

The human visual system

- **Pre-attentive** processing extracts simple features of patterns, colors, closure, line ends, contrast, tilt, curvature

- **Attentive** processing needs focused attention.

Where is  ?

The human visual system

Where is  ?

Human visual system

- Millions of photoreceptors (and parallel processing)

It is the job of information visualization systems to set up visual representations of data so as to bring the properties of human perception to bear. At the most basic level, the visual perceptual system uses a three-level hierarchical organization to partition limited bandwidth between the conflicting needs for both high spatial resolution and wide aperture in sensing the visual environment (Resnikoff, 1987). It is possible to exploit this organization in designing visualizations.

Figure 1.27 shows the human eye. A movable lens is imaged onto a substrate of 125 million photoreceptors, comprising 6.5 million color-detecting cones and the rest black and white detecting rods. Distribution of these photoreceptors is nonuniform (Figure 1.28). In a central area, called the *fovea*, cones are dense. In outlying areas, rods with larger receptive fields predominate.

Figure 1.29 shows a logical map of the eye. The first level of the visual system (see Resnikoff, 1987) is the retina. The retina has an area of about 1000 mm² = 10⁹ μm² and covers a visual field of about 160° wide (since the two eyes are set horizontally and their visual fields only partly overlap, together they cover a visual field at the extremes roughly 200° horizontally and 135° vertically). The density of cones in the nonfoveal portions of the retina is about 0.006 cones/μm².

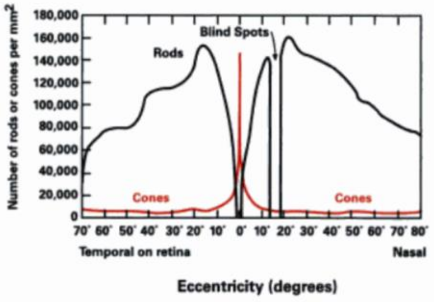


FIGURE **1.28**

Distribution of photoreceptors in the human eye. By permission of Resnikoff (1987, Figure 5.3.3).

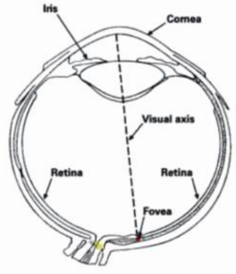


FIGURE **1.27**

The human eye. By permission of Resnikoff (1987, Figure 5.3.2).

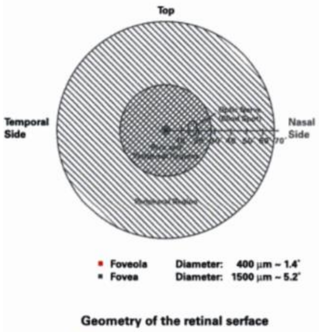
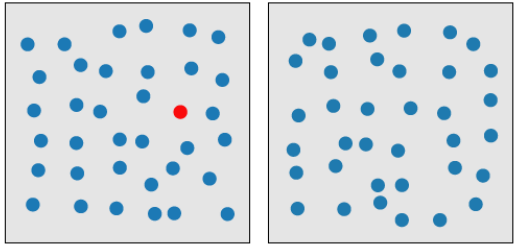


FIGURE **1.29**

Logical map of photoreceptors in the eye. By permission of Resnikoff (1987, Figure 5.3.4).

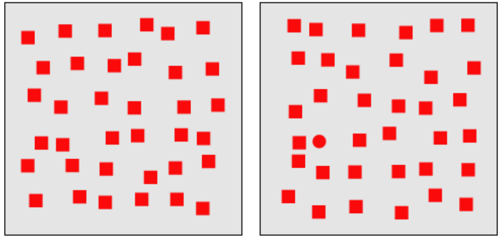
Card, S. K., Mackinlay, J. D., and Shneiderman, B., editors (1999). Readings in Information Visualization: Using Vision to Think. Morgan Kaufmann, San Francisco

Pre-attentive processing



(a) (b)

An example of searching for a target red circle based on a difference in hue: (a) target is present in a sea of blue circle distractors; (b) target is absent. **Hue** is the pre-attentive feature in this case.



(a) (b)

An example of searching for a target red circle based on a difference in curvature: (a) target is absent in a sea of red square distractors; (b) target is present. **Shape** is a pre-attentive feature.

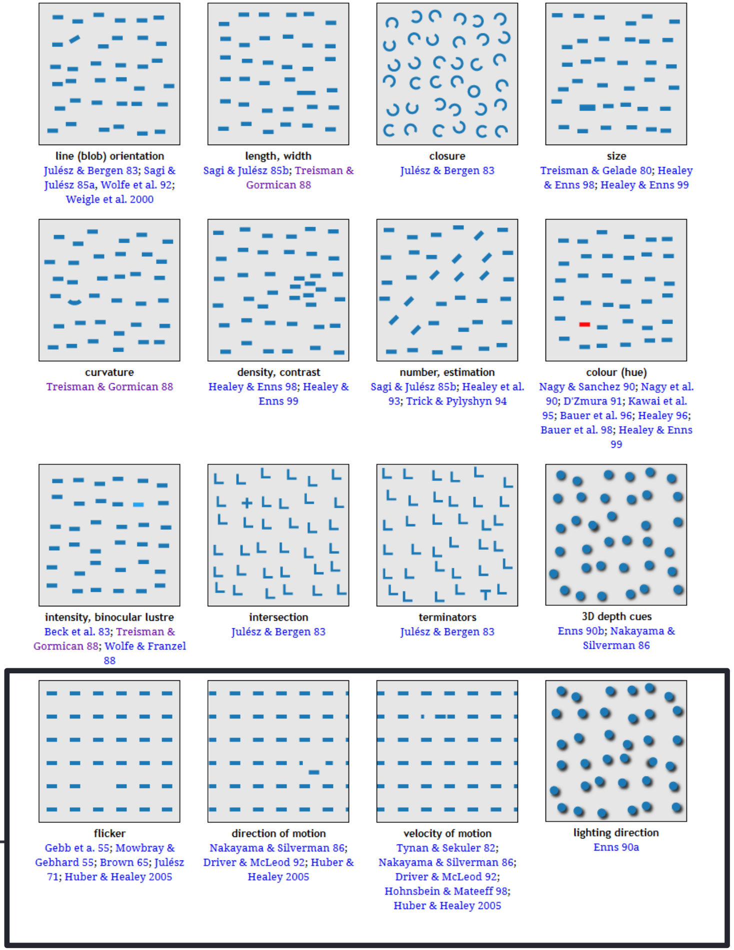
Typically, you should find the features in 200ms.

Healey, C. Perception in Visualization, https://www.csc2.ncsu.edu/faculty/healey/PP , Visited September 2021

Pre-attentive processing

Simple features (patterns, colors, closure, line ends, contrast, tilt, curvature and size) can be extracted by the pre-attentive system and later joined in the focused attention system into coherent objects (Treisman, 1985).

Treisman, A. (1985). Pre-attentive processing in vision. *Computer Vision Graph. Image Process.* 31, 2, pp 156–177



Healey, C. Perception in Visualization, https://www.csc2.ncsu.edu/faculty/healey/PP , Visited September 2021

Follow link to see effect

General principles:

high level perception

Gestalt ("form") theory

To perceive entire patterns or configurations and not individual components.

Principles:

Proximity: elements close together are perceived as a group

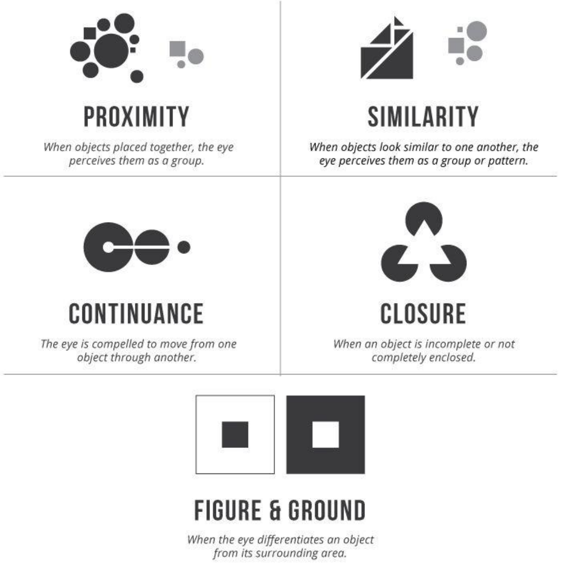
Similarity: similar elements tend to be grouped together

Continuity: elements that are smoothly connected or continuous tend to be grouped;

Symmetry: two symmetrically arranged visual elements are more likely to be perceived as a whole;

Closure: a closed contour tends to be seen as an object;

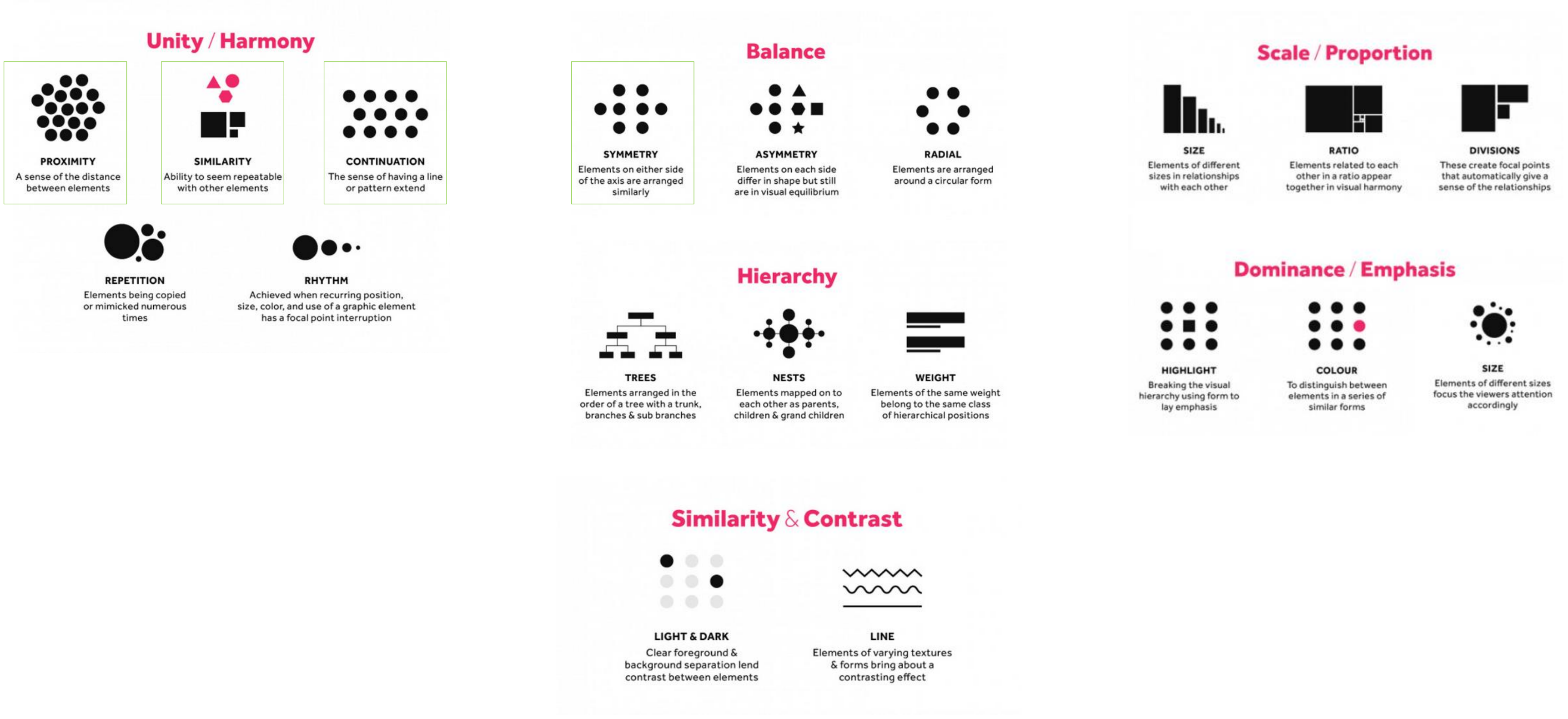
Relative Size: smaller components of a pattern tend to be perceived as objects whereas large ones as a background.



Kobourov, S., Mchedlidze, T., Vonessen, L. (2015). *Gestalt Principles in Graph Drawing*, Graph Drawing and Network Visualization, Springer International Publishing

Picture credits: https://pixelpixiewebdesignanddevelopment.wordpress.com/2018/11/16/the-gestalt-grouping-laws-with-examples/

Gestalt (“form”) theory applied to design



Picture credits: https://visual.ly/community/Infographics/education/6-principles-design

General principles:

Pipeline (workflow)

Infovis pipeline

Reference model for visualization by Card *et al.*

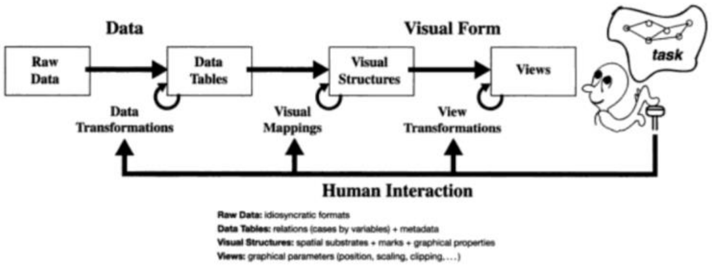


FIGURE **1.23**

Reference model for visualization. Visualization can be described as the mapping of data to visual form that supports human interaction in a workspace for visual sense making.

Card, S. K., Mackinlay, J. D., and Shneiderman, B., editors (1999). Readings in Information Visualization: Using Vision to Think. Morgan Kaufmann, San Francisco

Infovis pipeline

Data state reference model for visualization by Chi

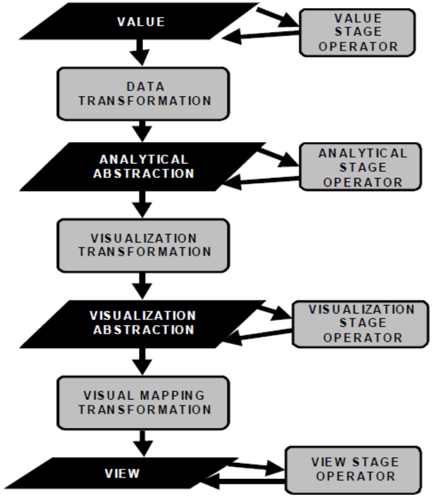


Figure 1: Information Visualization Data State Reference Model

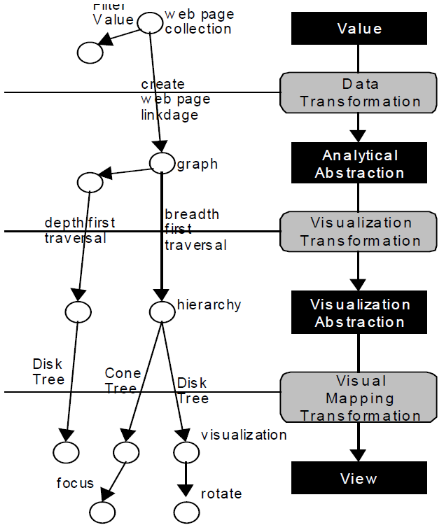
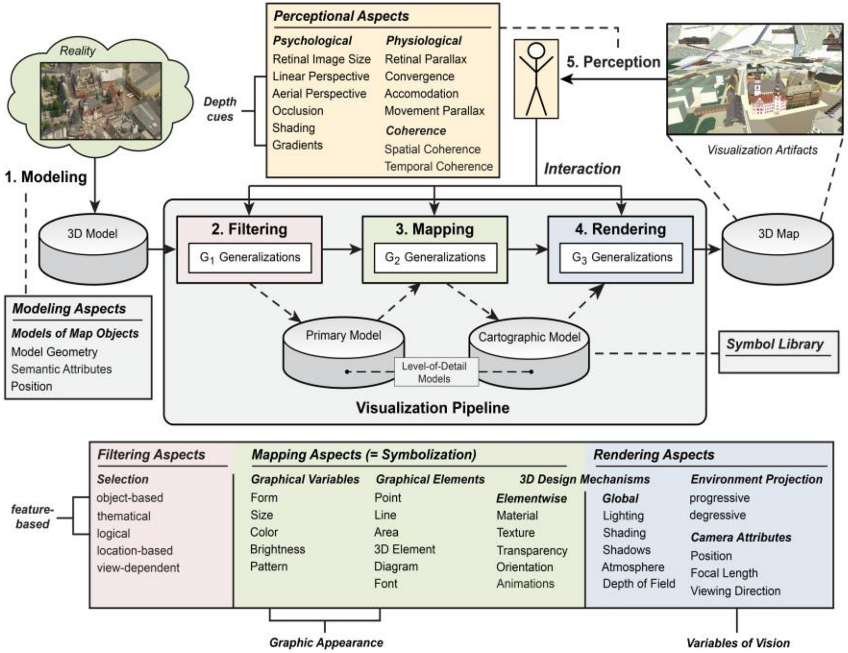


Figure 2: Data State Model applied to Web sites

Chi, E. (2000). A Taxonomy of Visualization Techniques using the Data State Reference Model. In Proceedings of IEEE Symposium on Information Visualization (InfoVis'00), pages 69–75. IEEE Computer Society Press

Infovis pipeline

visualization pipeline and related aspects, by Semmo *et al.*



Semmo, A. Trapp, M., Jobst, M. Döllner, J. (2015). Cartography-Oriented Design of 3D Geospatial Information Visualization – Overview and Techniques. The Cartographic Journal. Taylor & Francis

Infovis pipeline

data analysis stage

Data analysis stage

- computer-centred task
- **outcomes from:**
  - data mining techniques,
  - machine learning techniques,
  - deep learning techniques
- retrieve, parse, transform (interpolate, scale, interpolation functions, etc).

Because this mathematical treatment omits descriptive information that is important for visualization, we create the notion of a *Data Table*. A Data Table (see Table 1.4) combines relations with *metadata* that describes those relations:

TABLE **1.4**

A depiction of a Data Table.

	$Case_i$	$Case_j$	$Case_k$	
$Variable_x$	$Value_{ix}$	$Value_{jx}$	$Value_{kx}$	...
$Variable_y$	$Value_{iy}$	$Value_{jy}$	$Value_{ky}$	...
...	...	...	...	...

TABLE **1.6**

A Data Table about films.

FilmID	230	105	540	...
Title	Goldfinger	Ben Hur	Ben Hur	...
Director	Hamilton	Wyler	Niblo	...
Actor	Connery	Heston	Novarro	...
Actress	Blackman	Harareet	McAvoy	...
Year	1964	1959	1926	...
Length	112	212	133	...
Popularity	7.7	8.2	7.4	...
Rating	PG	G	G	...
Film Type	Action	Action	Drama	...

Card, S. K., Mackinlay, J. D., and Shneiderman, B., editors (1999). Readings in Information Visualization: Using Vision to Think. Morgan Kaufmann, San Francisco

Infovis pipeline

filtering stage

Filtering stage

- Filtering:
  - select data of interest (by item, by set, by range)
  - dynamic queries (Ahlberg, 1994)
  - brushing (Cleveland & McGill, 1984)

Fisher, Brian. (2005). Illuminating the Path: An R&D Agenda for Visual Analytics. Visual Representations and Interactions Technologies, IEEE Press

Infovis pipeline:

mapping stage

Mapping stage

Concepts: marks (or visual elements)

- Marks are one of the **building blocks** of the visual representation / metaphor at the core of the mapping stage

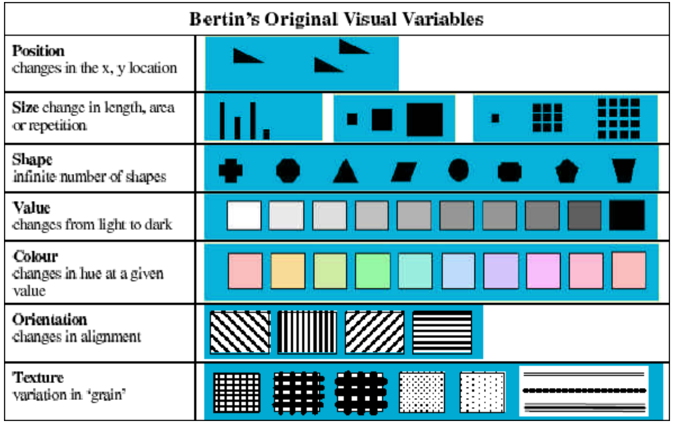
- Represent a piece of information (semiology of graphics, Bertin 1967)

    - Points
    - Lines
    - Areas
    - Surfaces
    - Volumes

Mapping stage

Concepts: visual variable

- Are applied to marks
  - position
  - size
  - shape
  - Value
  - color
  - orientation
  - texture
  - Motion
  - other



Mapping stage

Concepts: visual representation / metaphor

- The core idea that encompasses these of rules defining the transformation from data to a visual representation:

- These rules involve data variables, marks and visual variables

- **expressiveness**, refers to the capability of the metaphor to visually represent all the information it is desired to visualize

- **effectiveness**: how good is the visual metaphor as a way of representing such information

Infovis pipeline:

mapping stage | visual representation techniques

Visual representation techniques

Classified by data structure or by task (among other taxonomy systems):

- **Task-by-data-type** taxonomy (Shneiderman 1996): 1D (linear), 2D, 3D data, temporal and multi-dimensional data, tree and network data. **Seven tasks**: overview, zoom, filter, details-on-demand, relate, history, and extract

- **Data State Model** - provided a data-oriented taxonomy (Card and Mackinlay 1997) which was subsequently expanded in (Card, Mackinlay et al. 1999)

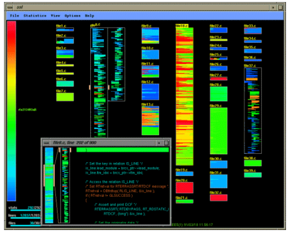
- **Tufte's 4 classes** - data maps, time-series , space-time narratives, relation graphics

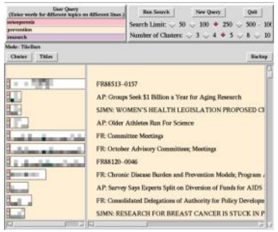
Linear visual structures

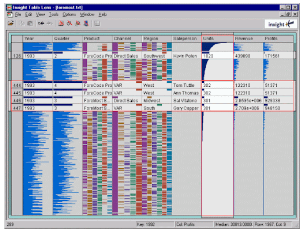
Tables, sequential lists, ordered items, stories

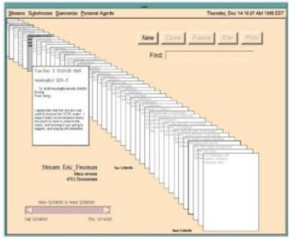
- View specific results for further searches
- View global data about the character of the list they are viewing
- View how a particular element in the list compares to others
- Access individual elements in long lists

- Exploratory work: **SeeSoft**, **TileBars**, **TableLens**, **Lifestream**, **perspective wall**, document lens, words eye







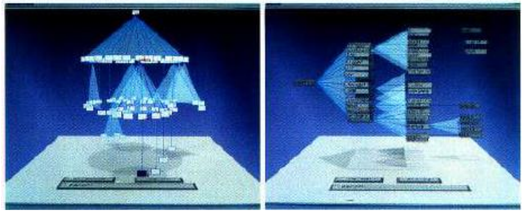


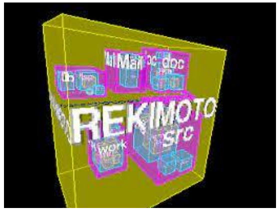
Hierarchical visual structures

Collections of data nodes where each node has a unique parent but may have many siblings. Trees.

- examine overall structure and relations
- find a particular node
- view a node in the context of the entire hierarchy
- find duplicates or anomalies

- Exploratory work: WebTOC (Nation, Plaisant et al. 1997), **Cone Tree Treemap** (Johnson and Shneiderman 1991) (Wattenberg 1999), **Information Cube** (Rekimoto and Green 1993), **Hyperbolic Browser** (Lamping and Rao 1994), **3D Hyperbolic Browser** (Munzner and Burchard 1995)





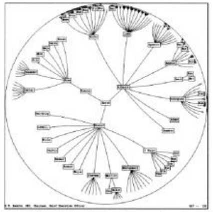
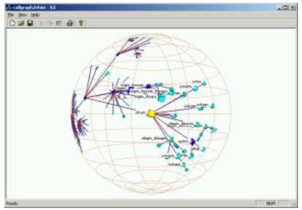


Figure 1. A partial organization chart of Xerox (ca. 1988)

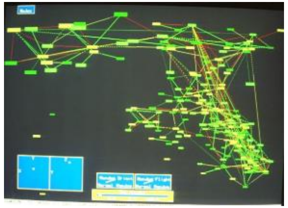


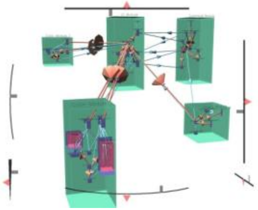
Network visual structures

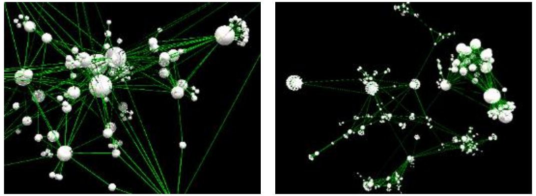
Collections of data nodes where each node can be connected to one or more nodes: graphs (hypermedia, semantic networks, webs)

- examine overall structure and relations
- find a particular node
- view a node in the context of the entire hierarchy
- find duplicates or anomalies

- Exploratory work: **The SemNet** (Fairchild, Poltrock *et al.* 1988), **GraphVisualizer3D** (Ware *et al.* 1994), Narcissus (Hendley, Drew et al. 1995), **Hyperspace** (Wood, Beale et al.1995), SHriMP (Storey and Müller 1995)







Spatial visual structures

Information about the shape and the spatial relationships among entities that are associated with a location, defined by coordinates in a spatial reference system. Inherently 2D or 3D information.

Abstract-based information can be overloaded.

- Exploratory work: centuries of mapmaking, GIS, [1960…now[, Geovisualization [1992…now[

Multidimensional visual structures

- show all dimensions and all variates visually in one display
- *direct manipulation graphics*: the user interactively selects subsets.
    - **reduce the complexity by making one or more independent variables constant**.

Exploratory work: Grand tour methods: an outline (Buja and Asimov 1986), parallel coordinates (Inselberg, Reif et al. 1987), iconography (Pickett and Grinstein 1988), worlds within worlds (Feiner and Beshers 1990) , dimension stacking (LeBlanc, O.Ward et al. 1990), hierarchical axis (Mihalisin, Gawlinski et al.), Hyperbox (Alpern and Carter 1991), various ideas collected in (Cleveland 1993; Cleveland, McGill et al. 1993), XmdvTool (Ward 1994), (Ahlberg and Wistrand 1995), relations among the variables in multivariate datasets as hyper-surfaces (Inselberg 1997)

Time-dependent visual structures

Time intervals and timepoints, sequences, patterns and temporal behaviours.

- According to (MacEachren 2004), a well design visualization can help answer:
    - Does a data element exist in a specific time? **(temporal existence**)
    - When does a data element exists on time? (**temporal location**)
    - How long is the time span from the beginning to the end on the data element? (**temporal**
    - **interval**)
    - How often does a particular data element occur? (**temporal texture**)
    - How fast is a data element changing or how much difference is there? (**rate of change**)
    - In what order do data elements appear? (**sequence**)
    - Do data elements exist together? (**synchronization**)

Time-dependent visual structures

- Aigner *et al.* (Aigner, Miksch et al. 2007) provide a systematic categorization for the graphical representation of time-oriented data analysis

Time	**Temporal primitives**	time points	time intervals	
	Structure of time	linear	cyclic	branching
Data	**Frame of reference**	abstract	spatial	
	Number of variables	univariate	multivariate	
	Level of abstraction	data	data abstractions	
Representation	**Time dependency**	static	dynamic	
	Dimensionality	2D	3D	

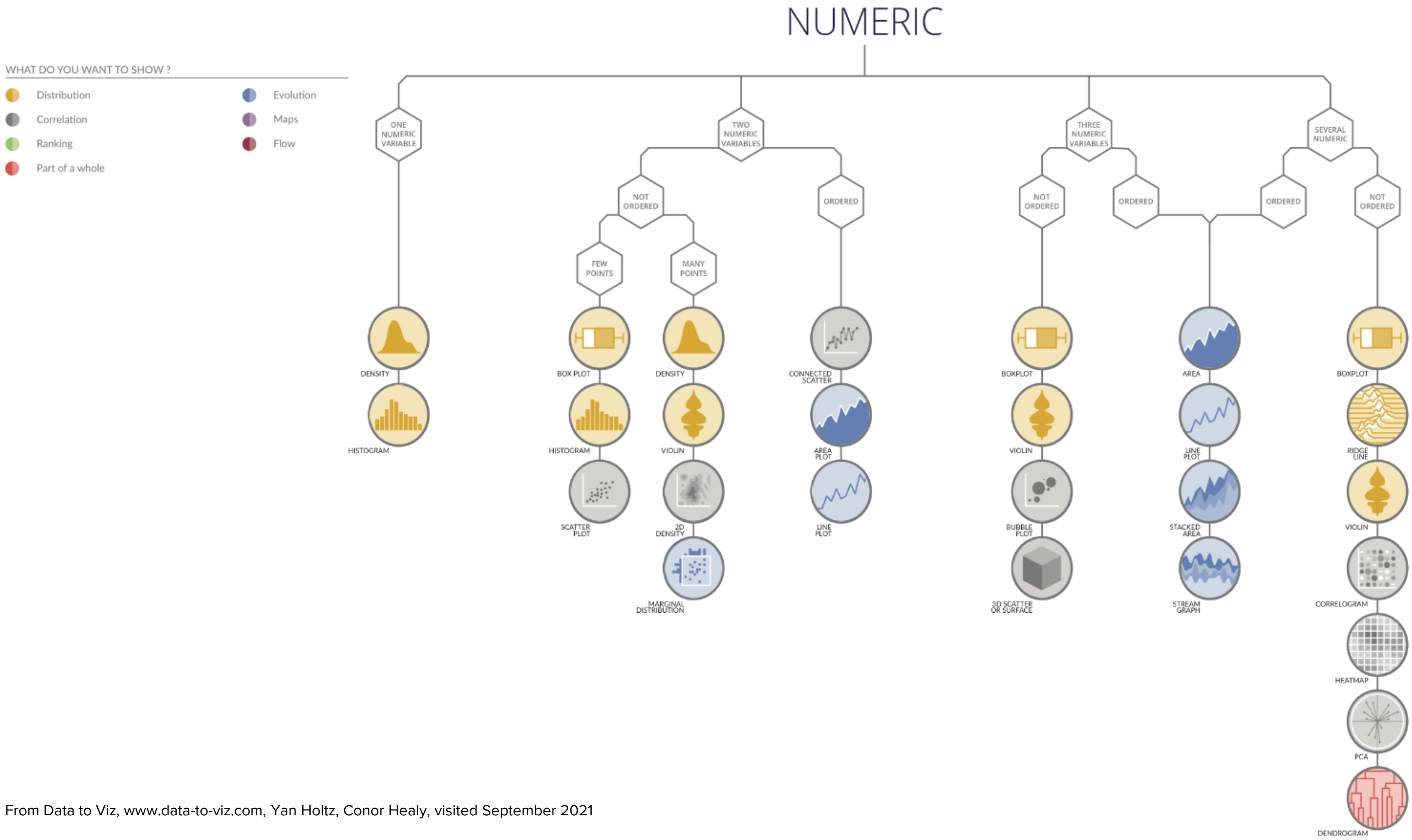
Time-dependent visual structures

- **Exploratory work**: *Time Series Graph* (Harris 1999), *Stacked Bar Chart, Parallel Coordinates, Dance maps, change maps, chess maps* (Monmonier 1990), *ThemeRiver* (Havre, Hetzler et al. 2000),*Spiral Graph (*Carlis and Konstan 1998*),Calendar View (*van Wijk and van Selow 1999*),Lexis Pencils(*Keiding 1990; Brian and Pritchard 1997), *SpiraClock* (Dragicevic and Huot 2002), *Time-Wheel* (Tominski, Abello et al. 2004), etc.

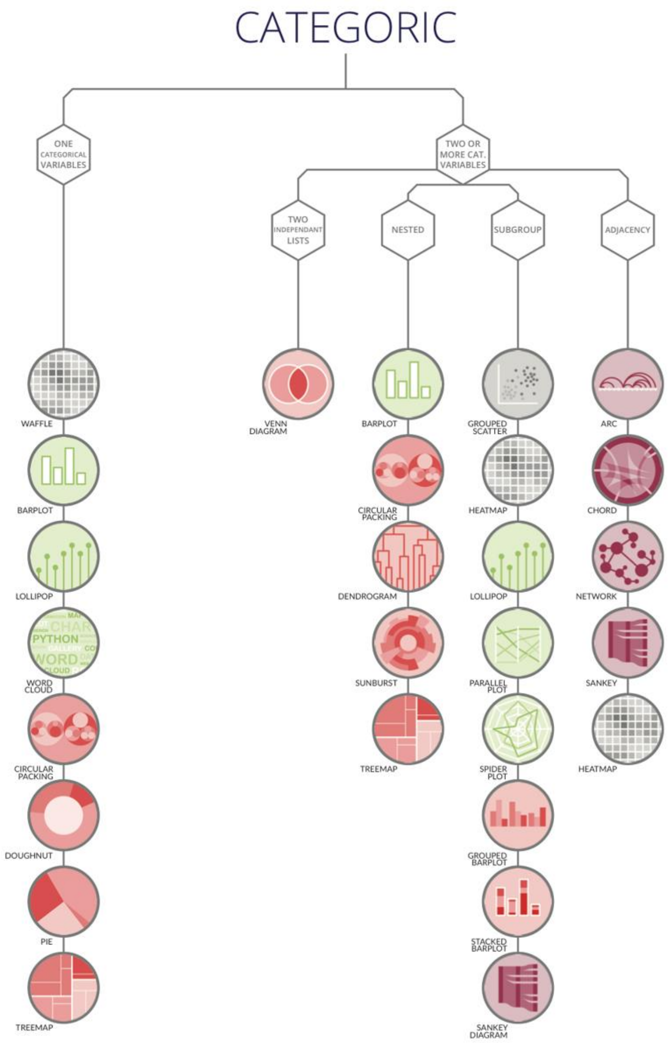
- See browser.timeviz.net for more techniques.

Visual representation techniques illustration

- Next slides show techniques organized by:
  - **Numeric**: one numeric, n numeric variables, ordered/not ordered
  - **Categoric**: one categoric.. more categoric variables
  - **Both numeric and categoric**: combination
  - **Relation**: network, nested (hierarchy)
  - **Map, time series:** one… multiple series



From Data to Viz, www.data-to-viz.com, Yan Holtz, Conor Healy, visited September 2021



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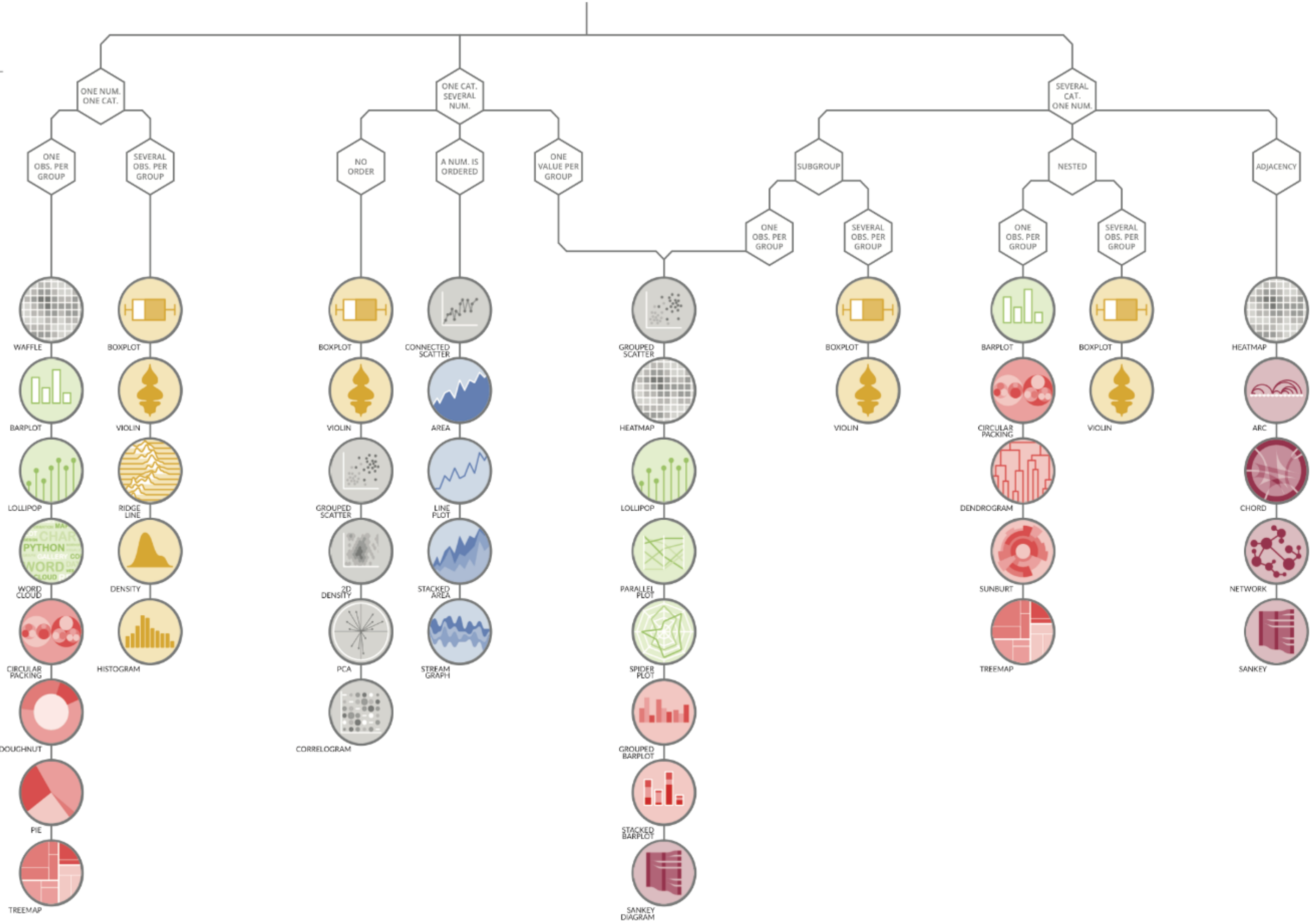
CATEGORIC AND NUMERIC

WHAT DO YOU WANT TO SHOW ?

- Distribution
- Correlation
- Ranking
- Part of a whole
- Evolution
- Maps
- Flow



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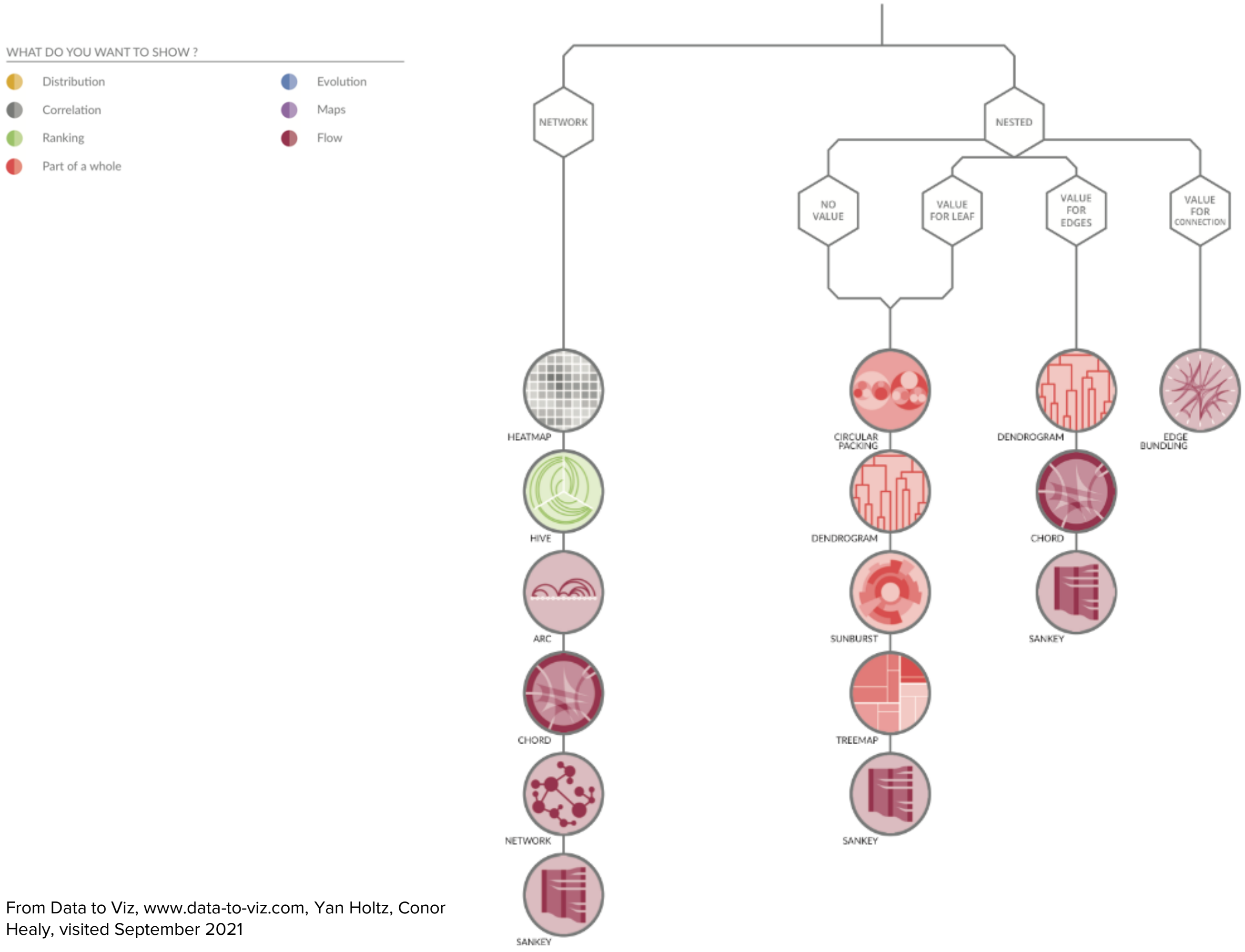
RELATIONAL



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WHAT DO YOU WANT TO SHOW ?

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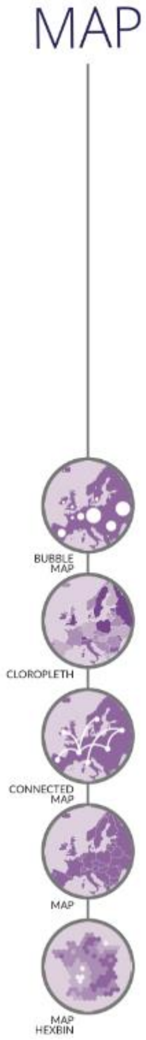
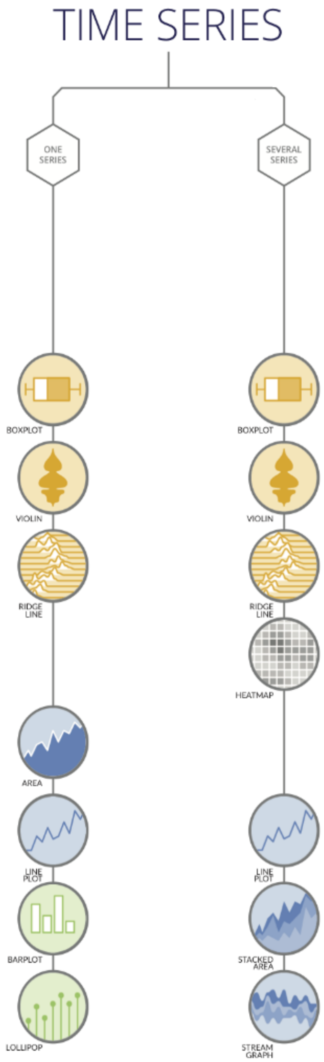




From Data to Viz, www.data-to-viz.com, Yan Holtz, Conor Healy, visited September 2021

Infovis pipeline:

rendering stage

Rendering

- The visual representation technique is rendered into image data (including geometric data)

- Typically, the scope of computer graphics

Concerns:

- projection: ortho, perspective?
- lighting?
  - Direct lighting, global illumination
  - Shadows
  - Atmosphere
  - Wireframe, stencil
- shading – solid, Gouraud, Phong, other?
- textures
- effects?
  - Contour
  - Emphasize
  - Blur
  - Etc.

Infovis pipeline:

Interaction

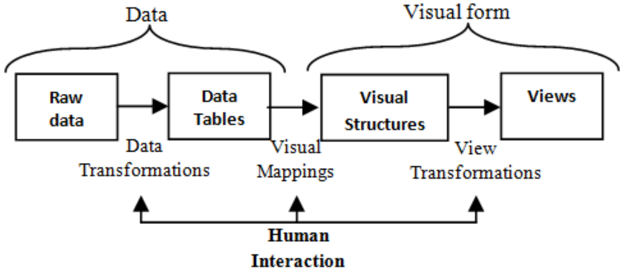
Interaction operations

Modify data transformation (filtering stage)

- Brushing (select data items by criteria) and focusing (restrict to an axis's interval)

Modify view transformation (for navigation)

- Pan and zoom (Bederson et al., 1996)
- Complex camera control techniques in 3D environments(Position, focal Length, viewing direction)



Direct selection of objects of interest

- Linking (relate information among views)

Change visual mapping (select between visual representations)

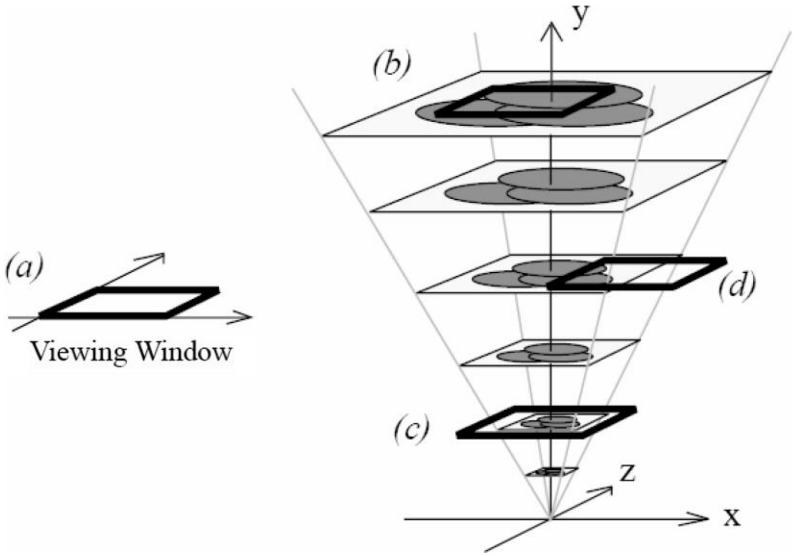
Picture credits: Fisher, Brian. (2005). Illuminating the Path: An R&D Agenda for Visual Analytics. Visual Representations and Interactions Technologies, IEEE Press

Interaction with visual information

screen-space limitation

"users need to interact with more information and with more interface components than can be conveniently displayed at one time on a single screen"

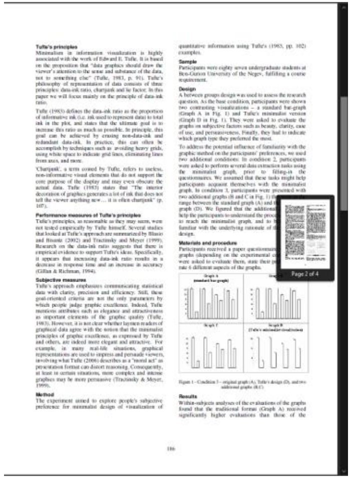
Cockburn, A., Karlson, A., Bederson, B. (2009). A review of overview+detail, zooming, and focus+context interfaces. *ACM Comput. Surv.* 41, 1, Article 2. DOI:https://doi.org/10.1145/1456650.1456652



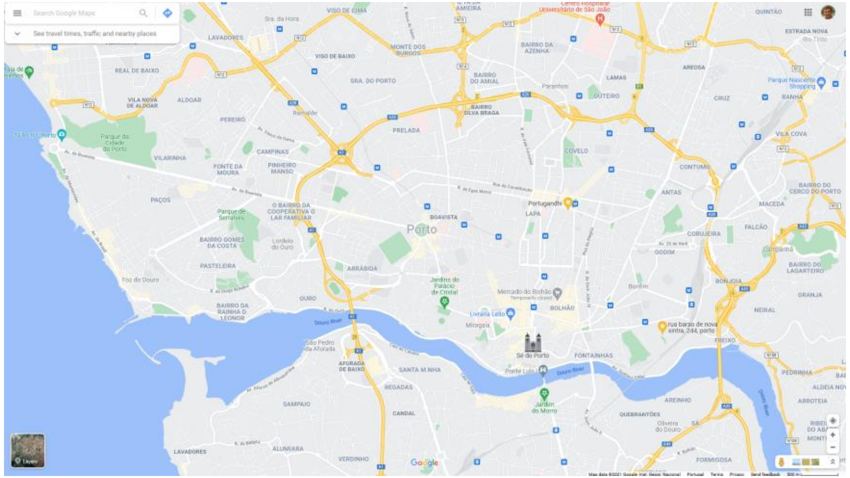
Interaction with visual information

screen-space limitation

Paging-cliping



Traditional pan/zoom (uniform scale) -> keyhole problem

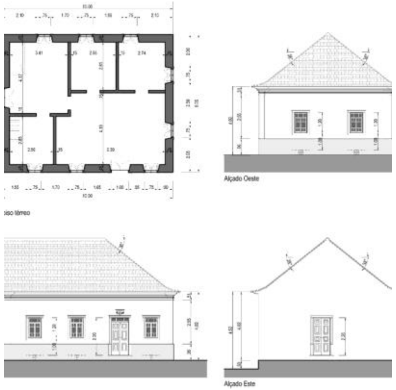


Continuous zoom: google earth

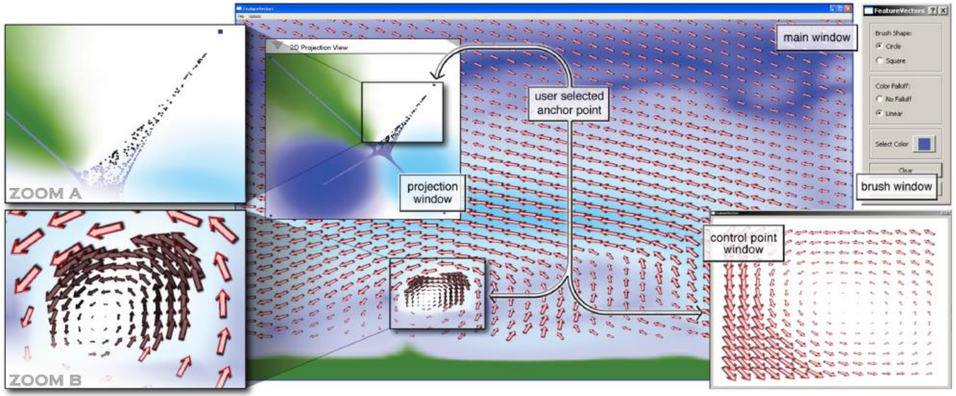
Interaction with visual information

screen-space limitation

- Multiple windows: extra space required, mental effort to integrate views



not new…

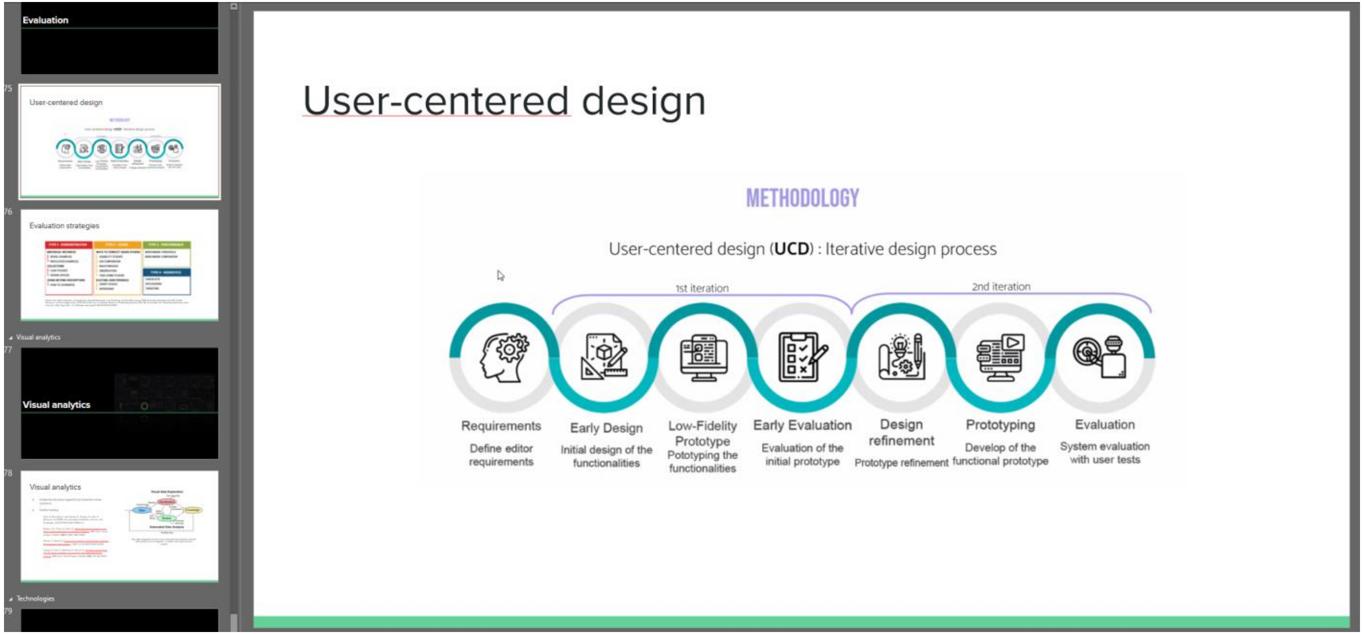


Picture credits: Daniels, Joel & Anderson, Erik & Nonato, Luis & Silva, Claudio. (2011). Interactive Vector Field Feature Identification. IEEE transactions on visualization and computer graphics. 16. 1560-8. 10.1109/TVCG.2010.170.

Interaction with visual information

screen-space limitation

Overview + detail (micro/macro readings)



Interaction with visual information

screen-space limitation

- Focus+Context with distorted views
    - Fisheye Concept (Furnas 1986): transition between views and user disorientation from excessive distortion (b)
    - Constrained fisheyes (d)

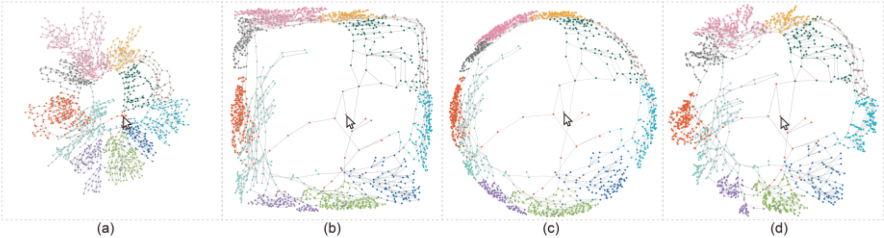


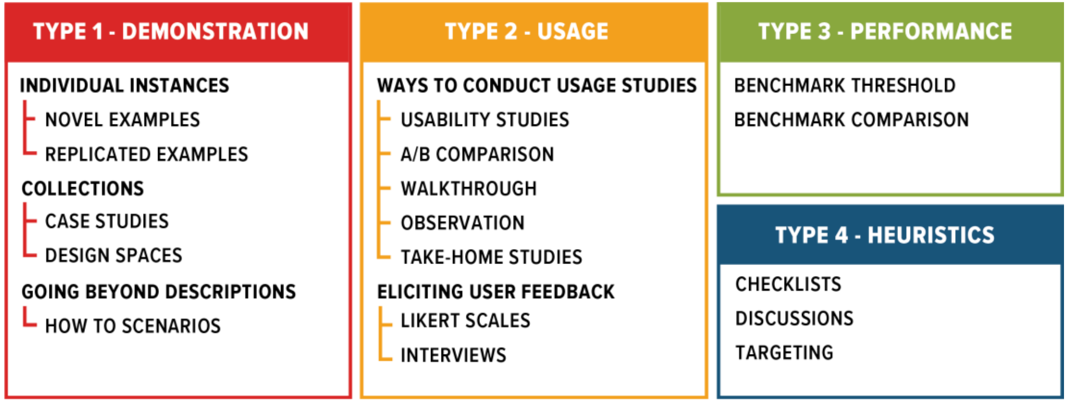
Figure 1: Magnifying a node-link diagram (a) with 11 clusters around a user-specified location (indicated by the cursor) using different fisheye lenses: (b) graphical fisheye; (c) hyperbolic fisheye; and (d) our structure-aware fisheye, which aims to maintain the shapes of almost all clusters and to minimize their distortions, such as in (b,c).

Y. Wang *et al.*, "Structure-aware Fisheye Views for Efficient Large Graph Exploration," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 25, no. 1, pp. 566-575, Jan. 2019, doi: 10.1109/TVCG.2018.2864911.

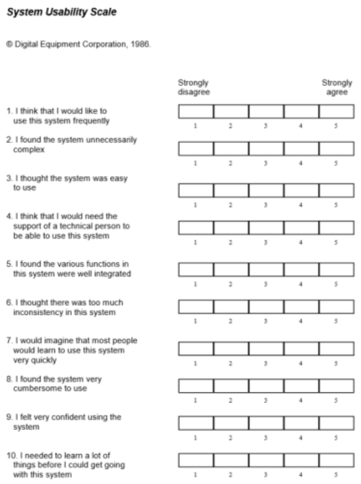
Visual representation techniques:

evaluation

Evaluation strategies



David Ledo, Steven Houben, Jo Vermeulen, Nicolai Marquardt, Lora Oehlberg, and Saul Greenberg. 2018. Evaluation Strategies for HCI Toolkit Research. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (*CHI '18*). Association for Computing Machinery, New York, NY, USA, Paper 36, 1–17. DOI:https://doi.org/10.1145/3173574.3173610



System Usability Scale

© Digital Equipment Corporation, 1986.

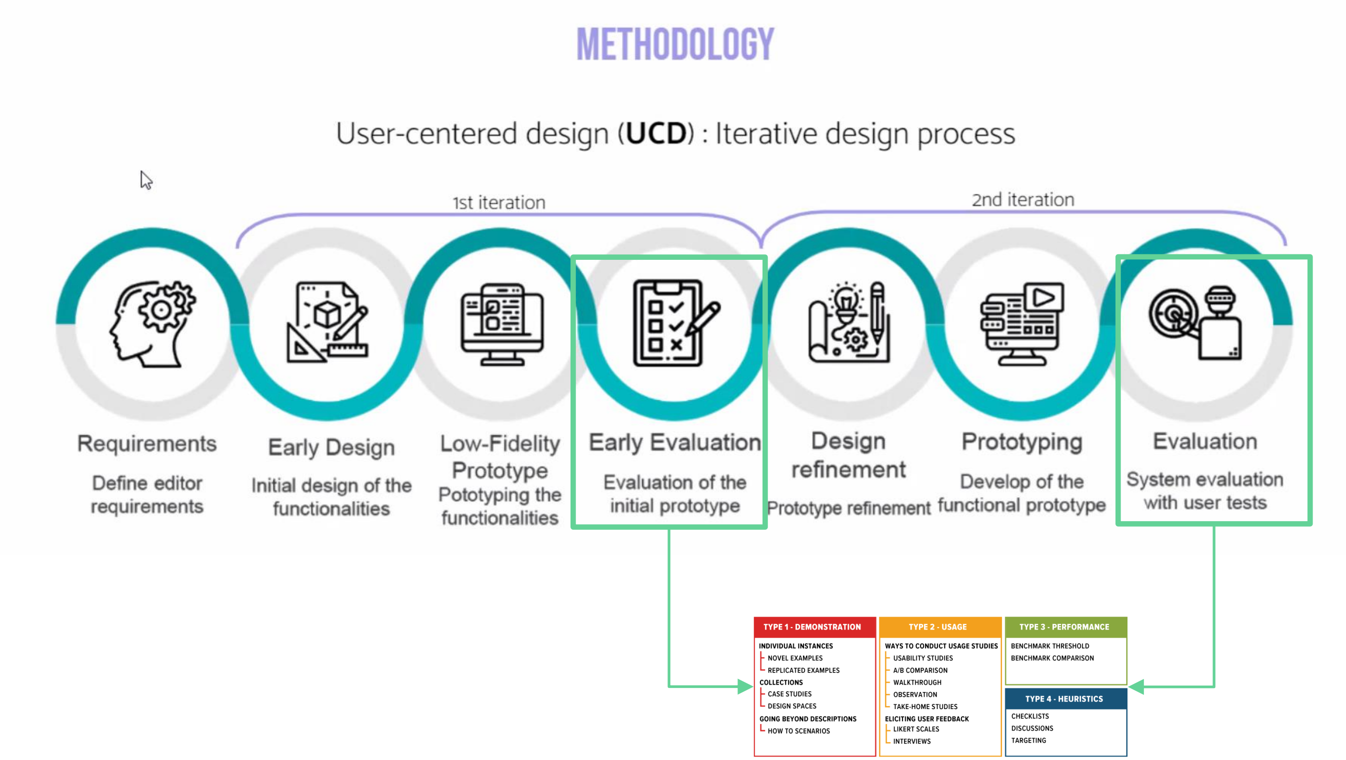
	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

Brooke, J. (1996). SUS: A 'quick and dirty' usability scale. In P. Jordan, B. Thomas, & B. Weerdmeester (Eds.), *Usability Evaluation in Industry* (pp. 189–194). London, UK: Taylor & Francis

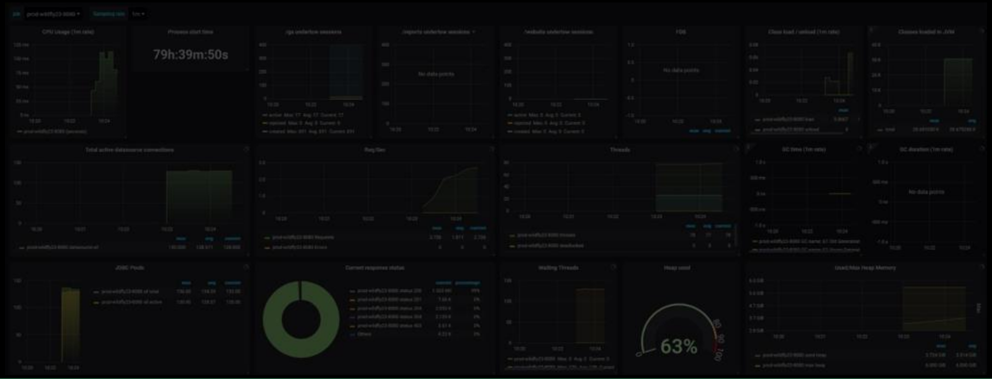
Lewis, James & Sauro, Jeff. (2017). Can I Leave This One Out? The Effect of Dropping an Item From the SUS. Journal of Usability Studies. 13. 38-46.

User-centered design method

Evaluate expressiveness, effectiveness...



Visual analytics



Visual analytics

- Analytical reasoning supported by interactive visual interfaces.
- Further reading:

Keim, D, Gennady, A., Jean-Daniel, F., Carsten, G., Jörn, K., Melançon, G. (2008). Visual Analytics: Definition, Process, and Challenges. 10.1007/978-3-540-70956-5_7.

Stolper, C.D., Perer, A., Gotz, D.: Progressive visual analytics: user-driven visual exploration of in-progress analytics. IEEE Trans. Visual Comput. Graphics **20** (12), 1653–1662 (2014)

Fekete, J., Primet, R.: Progressive analytics: a computation paradigm for exploratory data analysis. CoRR, vol. abs/1607.05162 (2016)

Turkay, C., Kaya, E., Balcisoy, S., Hauser, H.: Designing progressive and interactive analytics processes for high-dimensional data analysis. IEEE Trans. Visual Comput. Graphics **23** (1), 131–140 (2017)

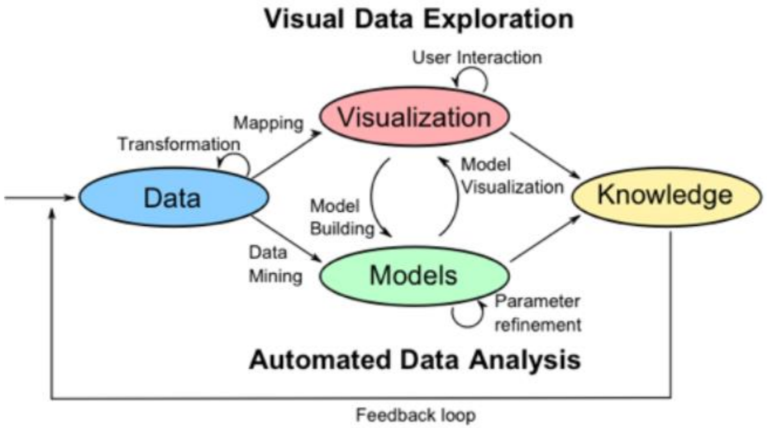
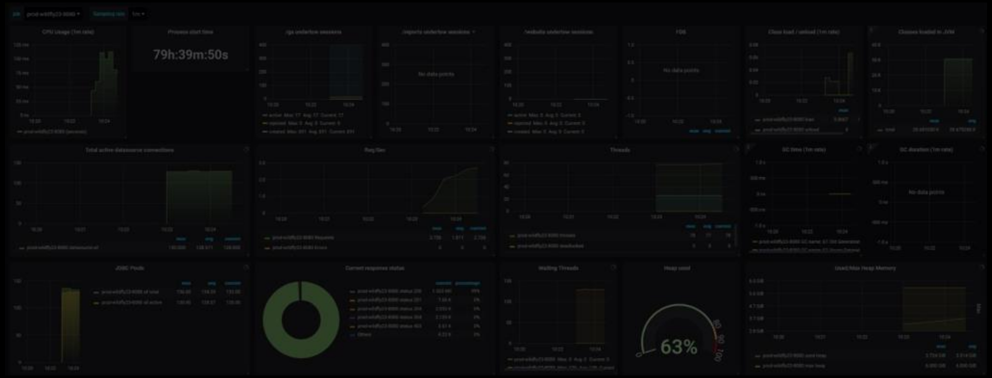


Fig: Tight integration of visual and automatic data analysis methods with database technology for a scalable interactive decision support.

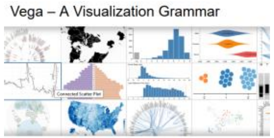
Software



Visualization software

- D3 (https://d3js.org/)
- Veja
- Highcharts (https://www.highcharts.com/
- Leaflet
- Apache charts
- Deck.gl
- IBM manyeyes
- Many more at:

  https://infovis-wiki.net/wiki/Software_Links_(InfoVis_Applications)



Thank you

advanced topics in interaction and multimedia

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