Visualization Taxonomies

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The Eight Visual Variables

- A common way to translate data into visual representations is to map each data attribute into a different visual marker

- It is possible to use up to eight visual variables
  1. Position
  2. Shape
  3. Size
  4. Brightness
  5. Color
  6. Orientation
  7. Texture
  8. Movement

As seen previously!

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Effects of Visual Variables

- Selective visual variables:
  (spontaneously divided by humans)
  - Size (length/area)
  - Brightness
  - Texture
  - Color
  - Direction
- Associative visual variables
  (for nominal values)
  - Texture
  - Color
  - Direction
  - Shape
- Ordinal visual variables
  (spontaneously ordered by humans)
  - Texture
  - Size
  - Brightness
- Proportional visual variables
  (direct association of relative size)
  - Size
  - Direction
  - Brightness
- Separating visual variables
  (separation for visible/not visible)
  - Texture
  - Color
  - Direction
  - Shape

I.E., for example…

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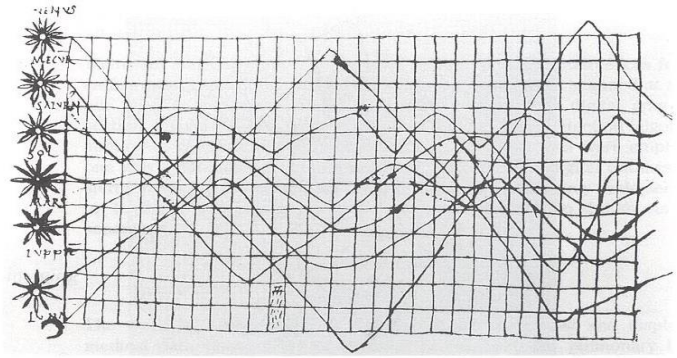
"Pre-computer" Visualization:

One of the oldest known Visualizations



Inclination of orbits along the time - Xth century (Tufte,1983)

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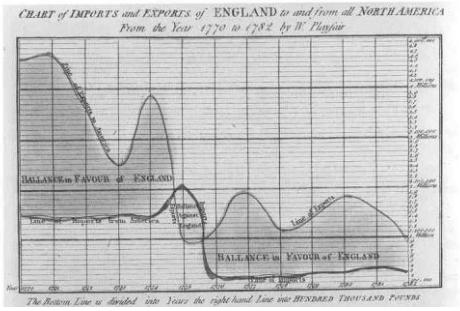
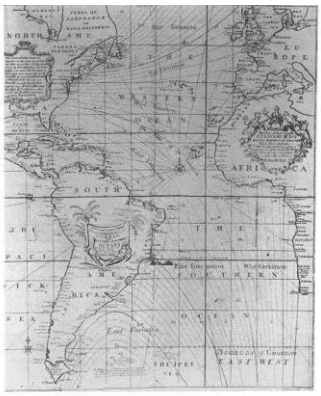
One of the first Visualizations used in "business"



Import/export during the period from1770 to1782 by William Playfair (Tufte, 1983)

One of the first visualizations using contours (isolines)



Magnetic declination 1701 Edmund Halley (Tufte,1983)

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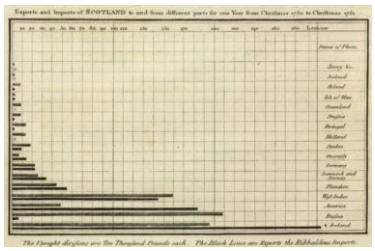
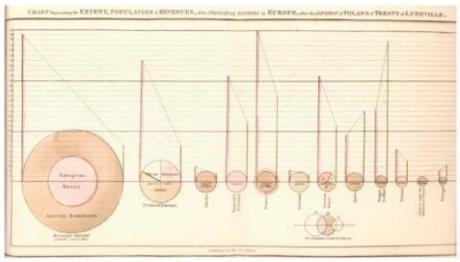
"Ancestors" of simple representations of univariate data

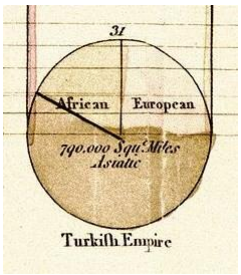


Exports and Imports of Scotland to and from different parts for one
W. Playfair's *The Commercial and Political Atlas, 1871*

https://en.wikipedia.org/wiki/William_Playfair



W. Playfair, *Statistical Breviary*, 1801



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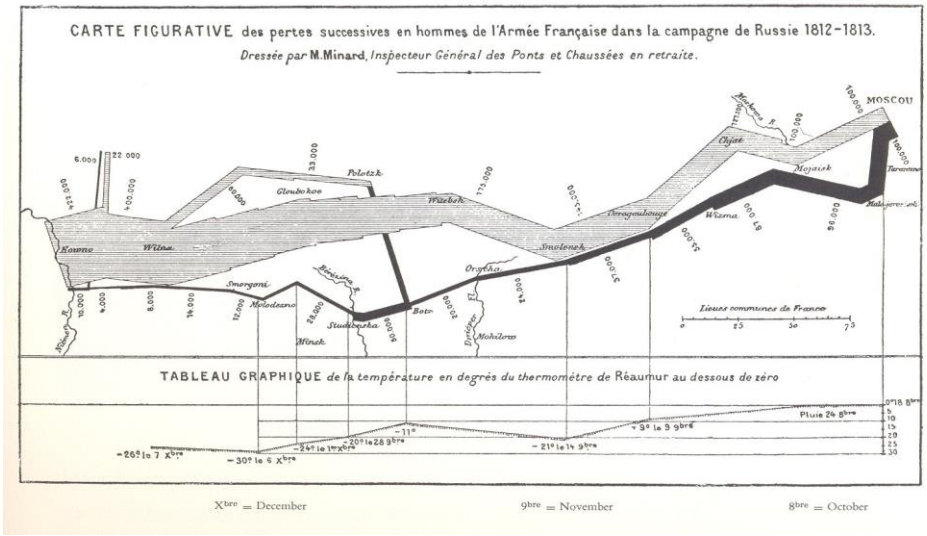
Multidimensional Visualization

6 dimensions: place (2), n. of men and direction of the army, date, temperature



Russia campaign of Napoleon 1861 by Charles Minard (Tufte,1983)

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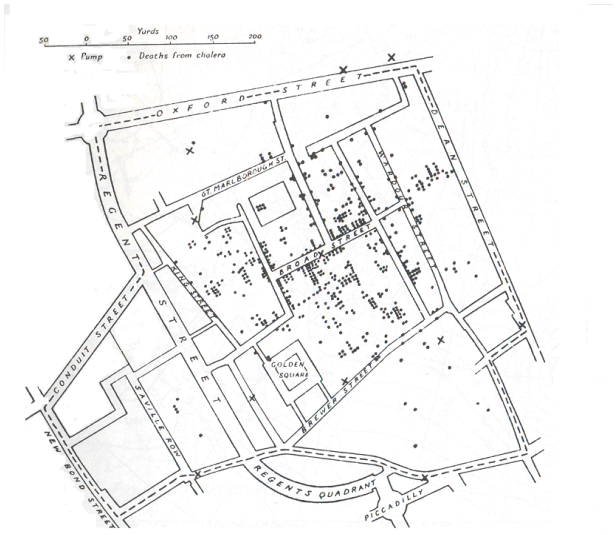
Visualization in scientific discovery



Discovering the cause of the London cholera out brake, 1853-54 (Wikipedia)

Dr. John Snow

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Medicine (education)

- Human anatomy
- Using volume rendering
- VOXELman (University of Hamburg)

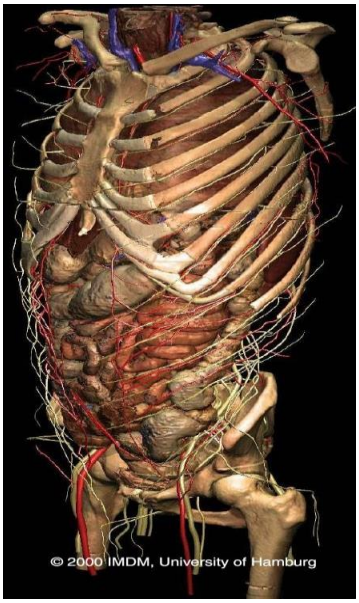
• Visible Human project (National Library of Medicine-USA)

https://www.visiblebody.com/

http://www.voxel-man.de/3d-navigator/inner_organs/

http://www.nlm.nih.gov/research/visible/visible_human.html

https://www.nlm.nih.gov/research/visible/applications.html



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Medicine

(e.g. surgery training)

VOXELman,
University of Hamburg

- Temporal bone surgery
- Movement of the drill is controlled with a force feedback device

https://www.voxel-man.com/simulators/tempo/

https://www.youtube.com/watch?v=CUOm6fxCJqI

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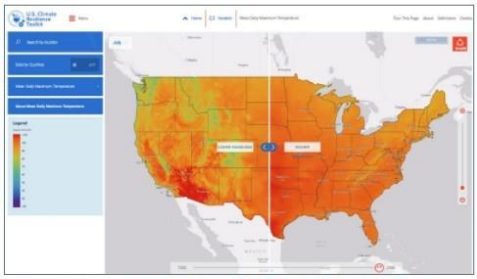
Example in Climate research (by NOAA)

- The Climate Explorer offers graphs, maps, and data of observed and projected temperature, precipitation, and related climate variables for every county in the contiguous US

- The tool shows projected conditions
- for two possible futures:
  - one in which humans make a moderate attempt to reduce global emissions of heat-trapping gases,
  - one in which we go on conducting business as usual.

https://www.climate.gov/maps-data/primer/visualizing-climate-data



View by Variable interface. View Maximum Daily Temperature variable in Climate Explorer.

https://toolkit.climate.gov/tools/climate-explorer

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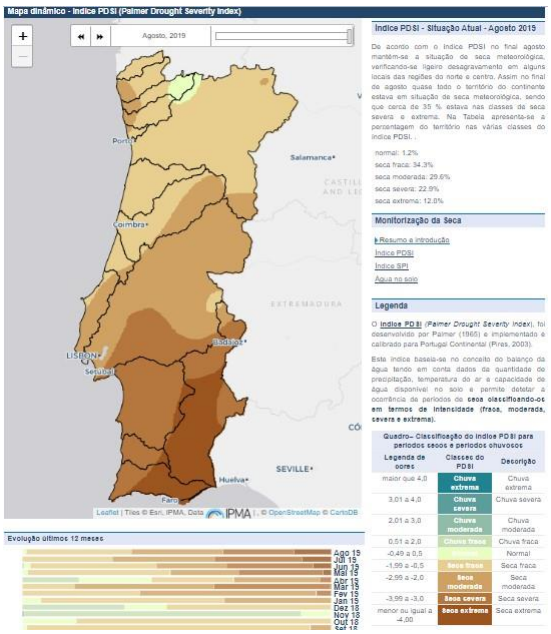
Example in Climate monitoring:
Drought Severity Index (by IPMA)



http://www.ipma.pt/pt/oclima/observatorio.secas/

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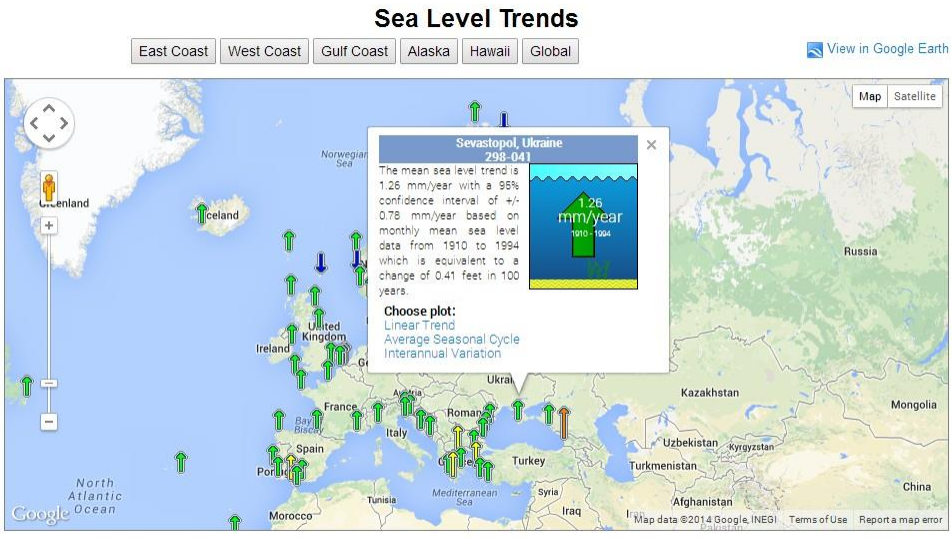
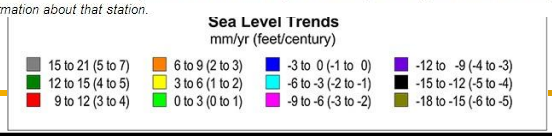


The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.



http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml
https://tidesandcurrents.noaa.gov/sltrends/regionalcomparison.html?region=GNEATL

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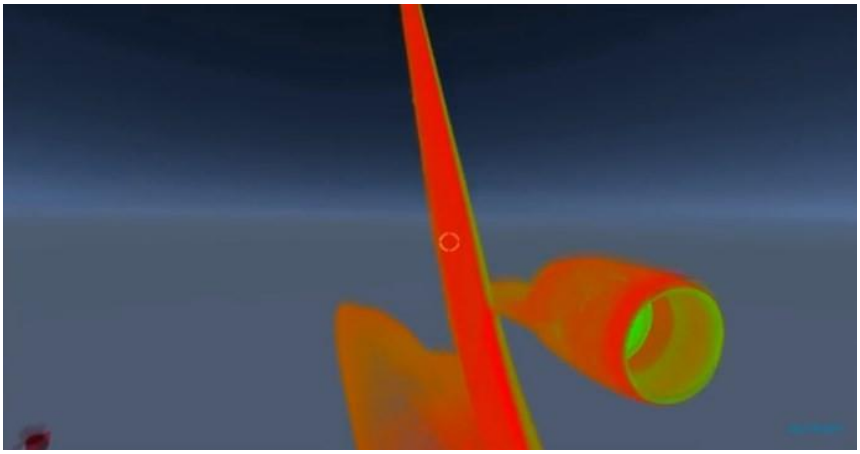
Example of fluid mechanics visualization



https://www.youtube.com/watch?v=3NsKpHftx7c

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The Craft for a Visualization Model

- Although there are **many examples of visualizations and visualization techniques**, we still lack a comprehensive language to describe graphical creations.
- The *art of visualization*, the principles of graphics and their understanding is generally understood.
- However, *as a science* we have yet to define a consistent formalism for visualizations.
- Hence, researchers try to derive good models.
- Through the last decades there has been a craft to formalize the field of information visualization.

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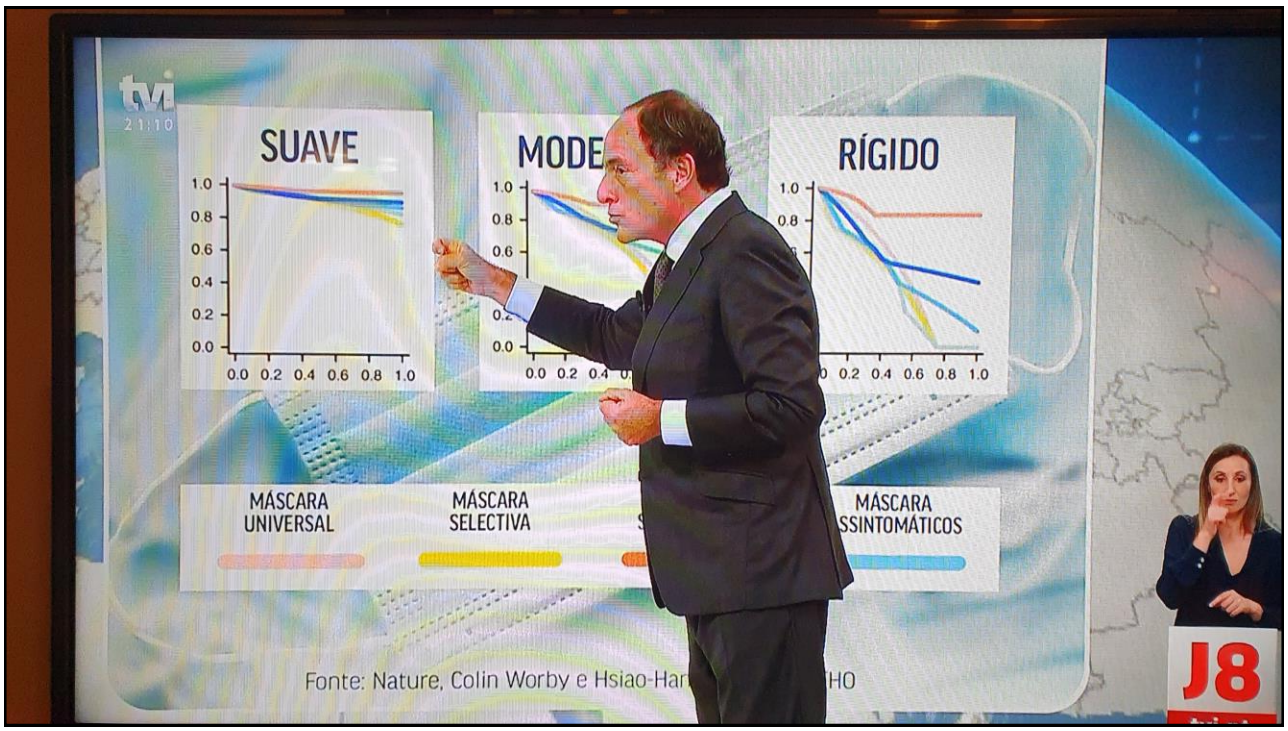

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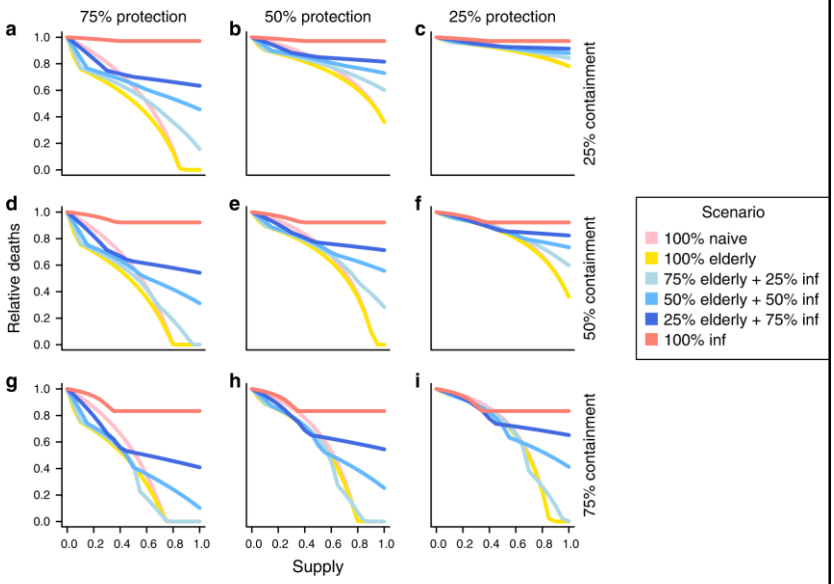
Each panel represents mask effectiveness in terms of relative protection and containment. Containment levels of 25% **a**–**c**, 50% **d**–**f**, and 75% **g**–**i** are shown with varying protection levels; **c** represents the least effective mask and **g** represents the most effective mask. Masks are provided naively (pink), prioritized to the elderly (yellow), saved for detected cases (red), or balanced at different levels between healthy individuals, prioritizing the elderly, and detected cases (blue). Inflection points occur at the point where supplies are exhausted, and the outbreak continues with no new individuals adopting masks. Here, 30% of infections are assumed to be undetected. See "Methods" for further details.



https://www.nature.com/articles/s41467-020-17922-x/figures/2

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History

- Bertin (1967) Semiology of Graphics
  - Marks: points, lines ,areas
  - Positional: 2D
  - Retinal: Size, value, texture, color, orientation, and shape
- Mackinlay (1986) "A Presentation Tool" (APT)
  - Marks: points, lines ,areas
  - Positional: 1D, 2D, and 3D
  - Retinal: Size, value, texture, color, orientation, and shape
  - Temporal: animation
  - **Encoding techniques**
  - Retinal-list: color, shape, size, saturation, texture, orientation
  - Single-position: horizontal axis, vertical axis
  - Apposed-position: line chart, bar chart, plot chart
  - Map: road map, topographic map
  - Connection: tree, acyclic graph, network
  - Misc: pie chart, Venn diagram, …

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History (2)

- Bergeron and Grinstein (1989) Visualization Pipeline
- Wehrend and Lewis (1990) Large Catalog of Encoding Techniques for Visualizations
- Roth (1991) The Visage and SAGE
  - Visage: user-interface for exploring information
  - SAGE: automatic graphic design tool for 2D
- Senay and Inatius (1994) The VISTA (Visualization Tools Assistant) system
  - Pipeline: data manipulation, visualization mapping, and rendering
  - Separate concepts: data characterization, primary visualization techniques, composition rules, visual perception rules
  - Heuristic rules: define visualization effectiveness
- Card, Mackinlay, and Shneiderman (1999) Spatial
  - Primary transf: data transformations, visual mappings, and view transformations
  - Four types of axes: unstructured (no axis), nominal (region divided in sub-regions), ordinal, and quantitative (the region has some metric system)

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History (3)

- Wilkinson (1999) A Grammar of Graphics
  - Data: a set of data operations that creates variables from datasets
  - Trans: data transformations
  - Frame: a set of variables related by operators, that define a space
  - Scale: scale the transformations
  - Coord: a coordinate system
  - Graph: points/lines/bars and their aesthetic attributes
  - Guides: one or more guides

Form	Surface	Motion	Sound	Text
Position: Stack Dodge Jitter Size Shape Polygon Glyph Image Rotation	Color Hue Brightness Saturation Texture Pattern Granularity Orientation Blur Transparency	Direction Speed Acceleration	Tone Volume Rhythm Voice	Label

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Shneiderman's Taxonomy (1996)

- **Shneiderman** proposed a **Data Type by Task Taxonomy**
- Goal to classify visualization techniques based on the type of data being analyzed

(Previously were scalar, nominal, direction, shape, position, region)

Data Types:

- 1D (linear)
- 2D (map)
- 3D (world)
- Temporal
- Multidimensional
- Tree
- Network

Ben Shneiderman contributed to the Flow Chart research, and area of Human Computer Interaction (in design of Interfaces, with the "8 golden rules" and research in the area of Information Visualization.
He was a founding father of the Tree Map representation and precursor of time exploration through sliders.
He also contributed to the development of Node XL

Shneiderman's Taxonomy

- **Tasks types**, focused on the analyst's activities, are

1. **Overview** – get an overview of the data
2. **Zoom** – get a more detailed view of a region
3. **Filter** – filter non-interesting elements (reduce the search size)
4. **Details-on-demand** – select an item or group of items to detail
5. **Relationship** – see relationships between elements (highlight one to show its neighbors)
6. **History** – keep history to allow undo and replay operations
7. **Extract** – extract items or data to facilitate other uses (ex: saving to other formats)

Keim's Taxonomy (2002)

- **Keim** created a classification scheme for visualizations based on three dimensions
  - **Data types**
  - **Interaction/distortion methods**
  - **Visualization techniques**

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Keim's Taxonomy

- **Data types**
  - **Unidimensional** – temporal data, prices, stocks, etc.
  - **Bi-dimensional** – maps, blueprints, etc.
  - **Multidimensional** – spreadsheets, relational tables, etc.
  - **Text and Hypertext** – news, web documents, etc.
  - **Hierarchy and graphs** – network/phone traffic, dynamic systems models, etc.
  - **Algorithms and software** – software, execution traces, memory, etc.

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Keim's Taxonomy

- **Interaction and Distortion** techniques can be classified as
  - **Dynamic projection** –grand tour, XGobi, etc. interactive filters - magic lenses, InfoCrystal, etc. interactive zoom - TableLens, IVEE/Spotfire, etc.
  - **Interactive distortion** – spherical and hyperbolic distortions, bifocal displays, perspective wall, fisheye lens, etc.
  - **Interactive linking and brushing** – multiple scatterplots, parallel coordinates, etc.

Keim's Taxonomy

- **Visualization techniques**
  - **2D/3D displays** – xy/xyz plots, line graphs, etc.
  - **Geometrically transformed displays** – scatterplot matrices, parallel coordinates, etc.
  - **Iconographic displays** – star icons, Chernoff faces, stick figure icons, etc.
  - **Dense pixel displays** – recursive patterns, circle segments, etc.
  - **Stacked displays** – treemaps, dimensional stacking, cone trees, etc.

Keim's Taxonomy