Interactive Data Visualization

01 Course Overview



IDV 2020/2021

Notice

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Bibliography

Many examples are extracted and adapted from:



Visualization Analysis & Design Tamara Munzner 2015, ISBN: 9781466508910 ISBN (e-Book): 9781498707763



Interactive Data Visualization: Foundations, Techniques, and Applications Matthew O. Ward, Georges Grinstein, Daniel Keim

2015, 2nd Edition ISBN: 9781482257373 ISBN (e-Book): 9781482257397



Table of Contents

- Landmarks of (Data) Visualization
- What is (Data) Visualization?
- Why (data) visualization is important?
- What is the core idea of Data Visualization?
- (Data) Visualization today
- (Data) Visualization and other fields

- Course Organization and Overview
 - Syllabus; Bibliography; Evaluation rules; important dates, etc.



Interactive Data Visualization

Ask google for Data Vis (images)



















Landmarks of (Data) Visualization



Charles Minard's map of Napoleon's disastrous Russian campaign of 1812.





Charles Minard's map of Napoleon's disastrous Russian campaign of 1812

Carte Figurative des pertes successives en hommes de l'Armée Française dans la campagne de Russie 1812-1813. Dressée par M. Minard, Inspecteur Général des Lonts en Chaussiea en retraite. Daris, le 20 Novembre 1869. Les nombres d'hommes présents som-représentés par les largeurs des zones colorées à raison d'un millimêtre pour dix mille hommes; ils som- de plus écrits en travers des zones. Le rouge désigne les hommes qui entrem en Russie, le noir ceux qui en sortem. dans les ouvrages de M.M. Chiers, de l'égur, de Fezensac, de Chambray en le journal inédin de Iacob, pharmacien de l'Armée depuis le 28 Octobre. Iour mieux faire juger à l'œil la diminution de l'armée, j'ai supposé que les corps du Lince Iérôme en du Maréchal Davous- qui avaiem- été détachés sur Minsk en Mobilow en om-rejoim-vers Orscha en Witebsk, avaiem-tónjours marché avec l'armée.

- Carte Figurative des pertes successives en hommes de l'armée Française dans la campagne de Russie 1812-1813
- Le nombre d'hommes présents sont représentés par les largeurs des zones colorés à raison d'un millimètre pour dix mille hommes au travers des zones.
- Le "rouge" désignent des hommes qui entrem en Russie, le noir ceux qui en sorte
- Les renseignements qui on servit [References]



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- Figurative map of the successive losses of men of the French army in the Russian campaign 1812-1813
- The number of men present is represented by the widths of the colored areas at the rate of one millimeter for every ten thousand men across the areas.
- The "red" designate men who enter Russia, the black those who come out.
- The information we served.... [References]





Charles Minard's map of Napoleon's disastrous Russian campaign of 1812.



Six different sets of data: geography, the army's course, the army's direction; the number of soldiers remaining; temperature; time.





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Broad Street cholera outbreak, (John Snow, 1854)







Early visualizations

- Recommended readings:
 - Matthew O. Ward et all, 2010) pages 6 15.
 - See the suggested links at the end.

- Some "Landmarks":
 - Broad Street cholera outbreak, by John Snow, 1854.
 - Charles Minard's map of Napoleon's disastrous Russian campaign of 1812.
 - William Playfair founder of graphical methods of statistics.



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



The Bottom line is divided into Years, the Right hand line into L10,000 each. Published as the Act directs, 14t May 1766, by W. Playfair Neele sculpt 352, Strand, London.

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 - Periodic Table: Dmitri Mendeleev (1869); Julius Lothar Meyer (1870).



Interactive Data Visualization

What is (Data) Visualization?



Interactive Visualization

- Used for discovery
- Intended for a single investigator or collaborators
- Rerenders based on input
- Prototype quality



John C. Hart

Modes of Visualization

John C. Hart

Presentation Visualization

- Used for communication
- Intended for large group or mass audience
- Does not support user input
- Highly polished



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Interactive Storytelling

Presentations via interative webpages



	Modes o	zation	John C. Hart		
Visualization Mode	User Interaction	Graphics Rendering	Target	Medium	



	zation	John C. Hart			
Visualization Mode	User Interaction	Graphics Rendering	Target	Medium	
Presentation Visualization	User only observes	Precomputed rendering	Colleagues, mass	Slide shows, video	
			audience		



	John C. Hart				
Visualization Mode	User Interaction	Graphics Rendering	Target	Medium	
Interactive Visualization	User controls everything, including dataset	Real-time rendering	Individual or collaborators	Software or internet	



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Visualization Mode	User Interaction	Graphics Rendering	Target	Medium		
Interactive Storytelling	User can filter or inspect details of preset datasets	Real-time rendering	Mass audience	Internet or kiosk		



Modes of Visualization John C. Hart

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Presentation Visualization	User only observes	Precomputed rendering	Colleagues, mass audience	Slide shows, video	



What is the Goal of Data Visualization?



and being able to make decisions based on the data"

by John C. Hart



What is the Goal of Data Visualization?

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What is the Goal of Data Visualization?

"Data visualization is not just about seeing data !




What is the Goal of Data Visualization?

"Data visualization is not just about seeing data !

Is about UNDERSTANDING data,

and being able to make decisions based on the data"

by John C. Hart



The concerns of Data Visualization field

- Visualization provides an alternative or a supplement for textual or verbal information
- (in many situations) Visualization provides a richer description of information than the word-based counterpart !

Why?

- In what kinds of situations are visualizations effective?
- What type of information can and cannot be visualized?
- How many different ways are there to show the same data? Which ones are best for

particular circumstances?

Why should we study visualization?





Course Overview - 39

1		2		3	3	4		
Х	Υ	Х	Y	Х	Υ	Х	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	

Anscombe's Quartet: Raw Data



	1		2		3		4	
	Х	Υ	Х	Y	Х	Υ	Х	Υ
	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
Mean	9.0	7.5	9.0	7.5	9.0	7.5	9.0	7.5
Variance	10.0	3.75	10.0	3.75	10.0	3.75	10.0	3.75
Correlation	0.816		0.816		0.816		0.816	

Anscombe's Quartet: Raw Data

4 datasets 2 variables, 11 rows

Property	Value
Mean of X	9
Variance of X	11
Mean of Y	7.5
Variance of Y	4.1
Correlation	0.816
Linear Regression	y = 3.0 + 0.5x

F. J. Anscombe (1973)



4 datasets 2 variables, 11 rows

Property	Value
Mean of X	9
Variance of X	11
Mean of Y	7.5
Variance of Y	4.1
Correlation	0.816
Linear Regression	y = 3.0 + 0.5x

F. J. Anscombe (1973)

Statistic is not enough !

Data Vis is not enough



- What is the effect of the presentation of the data on the decision making process?
- Can the presentation of data impact the decision?
- Can we say which presentations are better or more influential than others?





- What is the effect of the presentation of the data on the decision making process?
- Can the presentation of data impact the decision?
- Can we say which presentations are better or more influential than others?





What is the the role of human preferences and training in the visualization?

Linda S. Elting, James M. Walker, Charles G. Martin, Scott B. Cantor, and Edward B. Rubenstein.
"Influence of Data Display Formats on Decisions to Stop Clinical Trials." British Medical Journal 318 (1999)

Hypothetical clinical trial:

- Two treatments: 50 patients with conventional and 60 with investigational
- Two populations: 65 with good prognosis and 45 with bad prognosis
- Two outcomes for each treatment: Response (positive) vs Fail
- 34 clinicians
- If a clinician sees that one treatment is better than the other, then he should stop the clinical treatment



What is the the role of human preferences and training in the visualization?

4 visualizations: Table Pie Chart

Bar Graph Icon

Green - Response Red - Fail







Copyright © 1999, British Medical Journal





Table

	Conventional	treatment	Investigational treatment		
	Total no	% Fail	Total no	% Fail	
Good prognosis	30	30	35	11	
Poor prognosis	20	45	25	12	
Total	50	38	60	12	

(Negatively framed tables displayed failure rates in red. Positively framed tables displayed response rates in green)



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Conv	entiona	Itreatm	ent					
							N	
Inves	tigation	al treatr	ment					
	Good p	prognos	is		Poor p	rognosi	\$	
-	Respo	nse		Fail				

Bar graph



Pie chart

- What is the the role of human preferences and training in the visualization?
 - PARTICIPANTS were shown tables, pie charts, bar graphs, and icon displays containing hypothetical data from a clinical trial and were asked to decide whether to continue the trial or stop for an unplanned statistical analysis.
 - MAIN MEASURE : Percentage of accurate decisions with each type of display
 - RESULTS:
 - More correct decisions were made with icon displays (82%) than with tables (68%), pie charts (56%), and bar graphs (43%).
 - Most (21) clinicians preferred the table; Several were contemptuous of the icon display.

The visualization is key in presenting data but the user preferences are very involved



Nowadays

- Generating a lot of data and information
- Need to process such information
- Need to communicate increasing levels of information

Visualization is a cornerstone of modern knowledge discovery tools. Applications often include one or more visualizations to provide different views of data to describe some patterns or structures.

We need to communicate information to people in an efficient and effective manner.











Introduction to Data Visualization - 51





Introduction to Data Visualization - 52

- Why have a human in the decision-making loop?
- Why have a computer in the loop?
- Why use an external representation?
- Why depend on vision?
- Why show the data in detail?
- Why use interactivity?



- Why is the vis idiom design space huge?
- Why focus on tasks?
- Why are most designs ineffective?
- Why care about effectiveness?
- Why is validation difficult?
- Why are there resource limitations?
- Why analyze vis?



Why the **study** of data visualization is important?

Tamara Munzner, 2015

1.11 Why Are Most Designs Ineffective?

The most fundamental reason that vis design is a difficult enterprise is that the vast majority of the possibilities in the design space will be ineffective for any specific usage context. In some cases, a possible design is a poor match with the properties of the human perceptual and cognitive systems. In other cases, the design would be comprehensible by a human in some other setting, but it's a bad match with the intended task. Only a very small number of possibilities are in the set of reasonable choices, and of those only an even smaller fraction are excellent choices. Randomly choosing possibilities is a bad idea because the odds of finding a very good solution are very low.



Why the **study** of data visualization is important?

Tamara Munzner, 2015



Figure 1.5. A search space metaphor for vis design.



What is the core idea of Data Visualization?



Course Overview - 57

What is the core idea of Interactive Data Visualization?





What is the core idea of Interactive Data Visualization?





Introduction to Data Visualization - 59

What is the core idea of Interactive Data Visualization?

- eight visual variables:
 - position,
 - shape,
 - size,
 - brightness,
 - color,
 - orientation,
 - texture,
 - motion





Eight visual variables



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Introduction to Data Visualization - 61



Interactive Data Visualization

The Visual Variables



Course Overview - 63

Eight visual variables

- eight visual variables:
 - position,
 - shape,
 - size,
 - brightness,
 - color,
 - orientation,
 - texture,
 - motion

It is important to remember that the result will **be an image** that is to be interpreted by the human visual system



Eight visual variables

- eight visual variables:
 - position,
 - shape,
 - size,
 - brightness,
 - color,
 - orientation,
 - texture,
 - motion

The first and and **most important**

visual variable is that of position



Eight visual variables: Position

- Spatial arrangement of graphics is the first step in reading a visualization:
 - The maximization of the spread of representational graphics throughout the display space maximizes the amount of information communicated, to some degree.
 - Worst case positioning scheme maps all graphics to the exact same position
 - Best positioning scheme maps each graphic to unique positions, such that all the graphics can be seen with no overlaps.



Eight visual variables: Position - Scales





Introduction to Data Visualization - 67









X - Linear; Y - Linear

X - Log; Y - Log





Eight visual variables: When Log is appropriate



Log Scale

Linear Scale



Introduction to Data Visualization - 70



Eight visual variables: Position - Scales

Y - Count of Cars

X - Class (excluding "Normal") Equally spaced; Sorted alphabetically

Marks - Bars




Eight visual variables: Position - Scales

Y - Count of Cars

X - Class (excluding "Normal")





Eight visual variables: Position - Scales

Y - Count of Cars

X - Class (excluding "Normal")





Eight visual variables: Position - Scales

Y - Count of Cars

X - Class (excluding "Normal")





Eight visual variables: Position - Splitting the views



X - Average of Retail Price

Y - Average of HP

Decorate with a trend line

X - Split views by Class



Eight visual variables: Position - Splitting the views





Eight visual variables: Position - Splitting the views



X - Average of Retail Price

Y - Average of HP

X - Split views by Drive Train

Y - Split views by Class

Decorate with a trend line





Y - Average of HP

X - Split views by Drive Train

Y - Split views by Class

Decorate with a trend line

- The second visual variable is the mark or shape: points, lines, areas, volumes, and their compositions.
- Marks are graphic primitives that represent data:



Several examples of different marks or glyphs that can be used.

When using marks, it is important to consider

how well one mark can be differentiated from

other marks





- Y Count of Cars
- X Class (excluding "Normal") Equally spaced; Sorted alphabetically

Marks - Bars





X - Class (excluding "Normal")





X - Class (excluding "Normal")





X - Class (excluding "Normal")





X - Class (excluding "Normal")





X - Class (excluding "Normal")





X - Class (excluding "Normal")













Eight visual variables

The position and marks, are required to define a visualization. Without these two variables there would not be much to see !

The remaining visual variables affect the way individual representations are displayed;

These are the graphical properties of marks other than their shape.



Eight visual variables

- eight visual variables:
 - position,
 - shape,
 - size,
 - brightness,
 - color,
 - orientation,
 - texture,
 - motion





Interactive Data Visualization

(Data) Visualization today



Course Overview - 92

Single visualization versus Multiple visualization



Heart 3D Model Additional parameters

Linked parallel coordinates presentation



D. L. Gresh, B. E. Rogowitz, R. L. Winslow, D. F. Scollan, and C. K. Yung. "WEAVE: A System for Visually Linking 3D and Statistical Visualizations, Applied to Cardiac Simulation and Measurement Data."



Static versus Interactive



In an **interactive** visualization the user can query the display and thus interact with the application display directly rather than menus

Linked parallel coordinates presentation



D. L. Gresh, B. E. Rogowitz, R. L. Winslow, D. F. Scollan, and C. K. Yung. "WEAVE: A System for Visually Linking 3D and Statistical Visualizations, Applied to Cardiac Simulation and Measurement Data."



Abstraction versus "real images"



Blood vessel configuration of the head and Brain (http://www.bodyworlds.com/)



Simulation visualization of the air generated by a Harriet Jet (<u>http://quest.nasa.gov/aero/</u><u>background/tools/</u>)



Abstraction versus "real images"



x-coordinate: number of atoms; *y*-coordinate: heat information; y = mx + b; m = -12.5 and b = 50

Color of each point: Gibs energy

Visualization provides **visual representation of objects** that may include data, algorithms, results of computations, process and many other components of the application

The ability to provide rich descriptions of data is one of the strengths of visualization

Mechanism of action for yeast (image generated by UMass Lowell UVP Software)



(Data) Visualization and other fields



Course Overview - 97

Visualization and other fields

- Visualization emerges as a sub-field of Computer Graphics, and is now a new field that encompasses aspects from *human-computer interaction*, *perceptual psychology*, *databases*, *statistics*, *data mining*, and *computer graphics*, and others.
- Computer graphics focus on graphical objects and the organization (and implementation) of graphical primitives.
- Visualization is the application of graphics to display data by mapping data to graphical primitives and rendering the display.
- In Computer Graphics the visual realism is often one major concern. In Visualization the focus is on finding an effective communication of information.



Visualization Process

- What is involved in the Visualization process?
 - Type of data available for display
 - Type of the information the Viewer hopes to extract from (exploration; confirm hypotheses) or convey with the display (present results)





Visualization Process: computer graphics pipeline

- For computer graphics the stages are:
 - Modeling: 3D model
 - Viewing: virtual camera
 - Clipping: bounds of the desired image
 - Hidden surface removal & Projection: mapping to a 2D system
 - Rendering: color, illumination, etc.





Visualization Process: the knowledge discovery pipeline

- For knowledge discovery the stages are:
 - Data
 - Data integration, cleaning, warehousing and selection
 - Data mining
 - Pattern evaluation
 - Rendering or visualization:



(*) Interactive visualization can be used at every step of KD pipeline



Visualization Process: Visualization pipeline

- For visualization the stages are:
 - Modeling: the data to be visualized
 - Data Selection: similar to clipping
 - Data to visual mappings: the heart of the visualization is mapping data values to graphical entities or their attributes; may involve scaling, shifting, filtering, interpolating, or subsampling.
 - Scene parameter setting: (ex: color mapping)
 - Rendering or generation of the visualization





Visualization Process: visualization pipeline

- What is involved in the Visualization process?
 - Type of data available for display
 - Type of the information the Viewer hopes to extract from (exploration; confirm hypotheses) or convey with the display (present results)





Interactive Data Visualization

Further Reading and Summary







Course Overview - 104

Further Reading

Recommend Readings

 Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward et all, 2015, pages 1 - 38.

Supplemental readings:

- Cholera map's John Snow:
 - <u>https://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak</u>
- Napoleon
 - https://en.wikipedia.org/wiki/Charles_Joseph_Minard
- William Playfair:
 - https://en.wikipedia.org/wiki/William_Playfair
- Florence Nightingale:
 - https://pt.wikipedia.org/wiki/Florence_Nightingale
- Periodic table:
 - <u>https://en.wikipedia.org/wiki/Periodic_table</u>

Check - vis25timeline

What you should know

What is Visualization.

grocking the data => take decisions

Data Visualization can be extremely powerful

Uncover new patterns; confirm hypothesis;

Why Visualization is important.

Stats not enough; communication needs; exploratory needs

Key aspects of today Visualizations.

- Interactions; visual abstractions; multiple (linked) visualizations.
- The general steps of a Visualization Process
 - Raw data -> data -> viz structures -> images -> perception + feedback

The role of Perception.

The role and the importance of the user.



Further Reading and Summary







Course Organization and Overview



Course Overview - 108
Syllabus

Introduction to Data Visualization

What Is Visualization? Relationship between Visualization and Other Fields. The Visualization Process. Data Foundations. Human Perception and Information Processing. Semiology of Graphical Symbols. The Visual Variables.

Visualization Techniques

Visualization Techniques for Spatial Data Visualization Techniques for Geospatial Data Visualization Techniques for Time-Oriented Data Visualization Techniques for Multivariate Data Visualization Techniques for Trees, Graphs, and Networks Text and Document Visualization

Interaction Concepts and Techniques

Interaction Operators, Operands and Spaces (screen, object, data, attributes) Visualization Structure Space (Components of the Data Visualization) Animating Transformations Interaction Control Designing Effective Visualizations Comparing and Evaluating Visualization Techniques

Visualization Systems

Systems Based on Data Type Systems Based on Analysis Type Text Analysis and Visualization Modern Integrated Visualization Systems Toolkits

Research Directions in Visualization



Bibliography



Visualization Analysis & Design Tamara Munzner 2015, ISBN: 9781466508910 ISBN (e-Book): 9781498707763



Interactive Data Visualization: Foundations, Techniques, and Applications Matthew O. Ward, Georges Grinstein, Daniel Keim 2015, 2nd Edition ISBN: 9781482257373 ISBN (e-Book): 9781482257397



Bibliography



How Charts Lie

Getting Smarter about Visual Information

Alberto Cairo



How Charts Lie: Getting Smarter about Visual Information Alberto Cairo 2019

The Truthful Art: Data, Charts, and Maps for Communication (Voices That Matter) Alberto Cairo 2016





https://www.tableau.com/learn



Weekly routine

Lectures - 1 x 2 h

- The lab sessions 1 x 2 h
 - Demoing and Training
 - Project support

The recommended readings

The recommended actions

Meetings for student support if required



Evaluation rules

- Two mid-term written individual tests (25% each)
- One project (for team of two students), with several phases:
 - Specification
 - Paper
 - Code/implementation
 - (*) an oral discussion will be required to validate the project components
- Course approval requires the following minimal grades:
 - (mean (Test1; Test2) >= 10)
 - Project >= 10
- Final exam may replace mean (Test1; Test2) if project is approved.
- Tests and Exam presencial if possible; Without consultation.

Summaries

[T01]: Course overview

06 Mar 2020, 04:10 PM Filed in: Lectures

What we mean by "Interactive Data Visualization"? What is Visualization? Why Visualization is important? Early Visualizations; Visualization today; Visualization and other fields. Visualization Process; The role of Perception.

Course Organization and Overview: Syllabus; Bibliography; Evaluation rules; important dates, etc..

Recommended Readings: (i) Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew 0. Ward et all, 2010, pages 1 - 33.

Recommended Activities: (ii) Visit the various sections of this site; **(iii)** instal Tableau software of your computer. Follow the link <u>http://www.tableau.com/academic/students</u>.

To Know:

- What is Visualization.
- The main "applications" of Visualization.
- Why Visualization is important.
- Key aspects of today Visualizations.
- Some important landmarks of early visualizations. For each one why is a landmark.
- The relation between Visualization and computer graphics. The differences between them.
- The relation of Visualization with other fields.
- The general steps of a Visualization Process
- The role of Perception.
- The role and the importance of the user.



Important Dates

Week	Subjects	Event
1	Overview	
2	Introduction to Data Visualization	DATES WILL BE PUBLISHED
3		
4		
5		
6		
7		
8	Visualization Techniques	
9		Working in progress
10		
11	Advanced Topics: Evaluation; Research directions	
12		
13		
14	Students Support	
15	Oral Sessions	



Interactive Data Visualization

Further Reading and Summary



Course Overview - 117

Further Reading

Recommend Readings

- Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward et all, 2015, pages 1 - 38.
- Visualization Analysis & Design, from Tamara Munzner, Chapter 1

Supplemental readings:

- Cholera map's John Snow:
 - https://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak
- Napoleon
 - https://en.wikipedia.org/wiki/Charles_Joseph_Minard
- William Playfair: (<u>https://en.wikipedia.org/wiki/William_Playfair</u>)
- Florence Nightingale: (<u>https://pt.wikipedia.org/wiki/Florence_Nightingale</u>)
- Periodic table: (<u>https://en.wikipedia.org/wiki/Periodic_table</u>)

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Uncover new patterns; confirm hypothesis;

Why Visualization is important.

Stats not enough; communication needs; exploratory needs

Key aspects of today Visualizations.

- Interactions; visual abstractions; multiple (linked) visualizations.
- The general steps of a Visualization Process
 - Raw data -> data -> viz structures -> images -> perception + feedback

The role of Perception.

The role and the importance of the user.



Recommended Activities

- See the video of Hans Rosling, "Debunking third-world myths"
 - http://www.gapminder.org/videos/ted-talks/hans-rosling-ted-2006-debunking-mythsabout-the-third-world/
 - https://www.youtube.com/watch?v=RUwS1uAdUcl



Play with Gapminder

- https://www.gapminder.org/tools/
 - Bubble Charts
 - Income





Recommended Actions

- Check the Summaries and follow its recommendations
- Install Tableau software
 - https://www.tableau.com/products/desktop/download
 - Get the academic license
 - <u>http://www.tableau.com/academic/students</u>

