CS5346

INFORMATION VISUALIZATION

Improving and Evaluating Effectiveness of Visualizations

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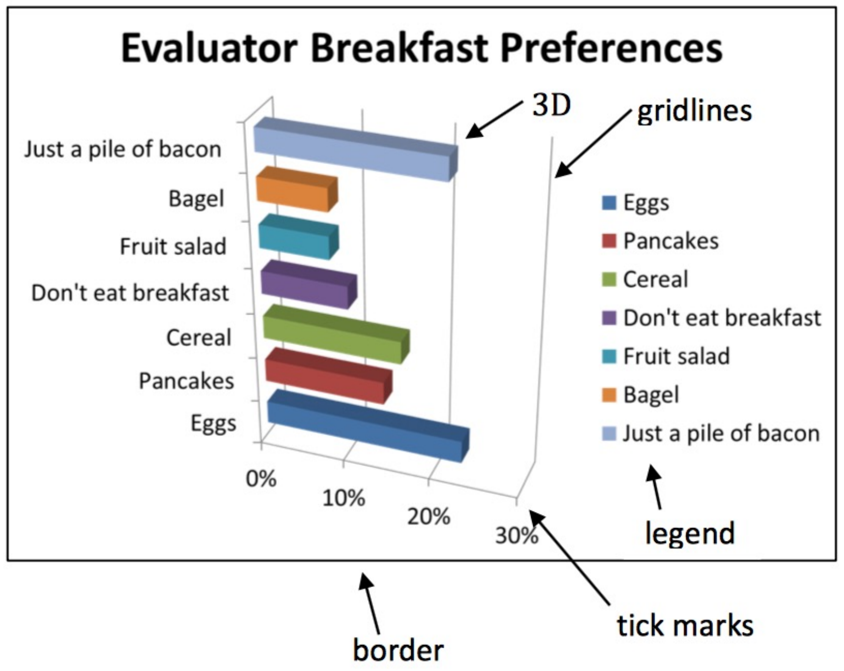
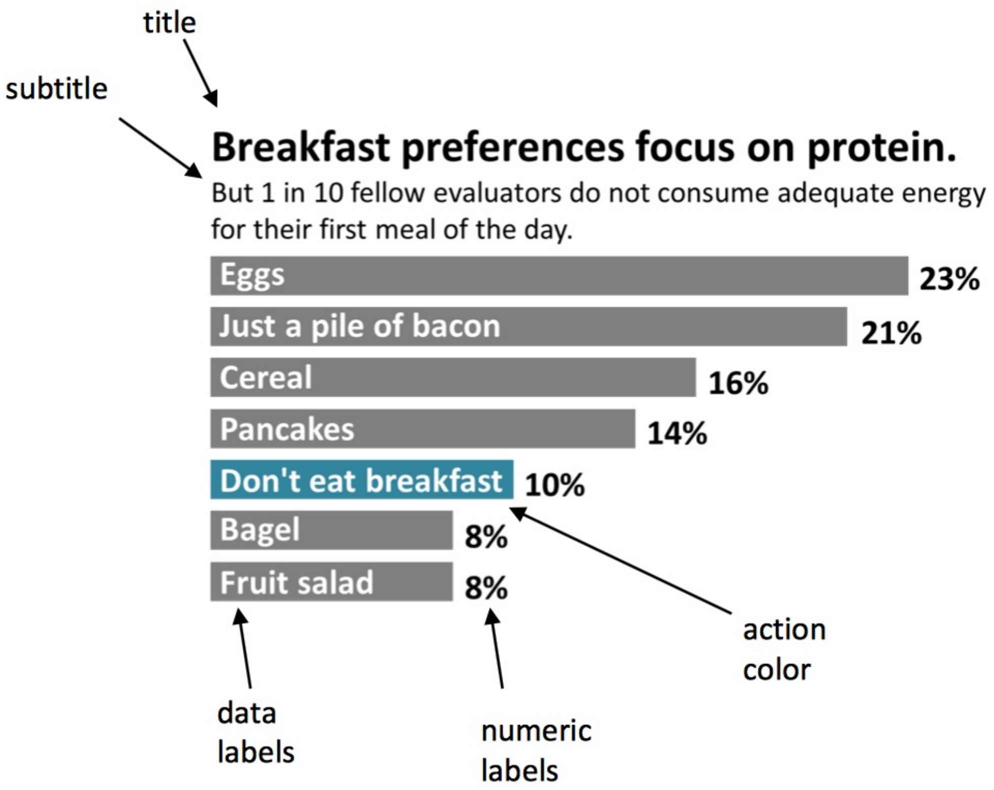
In practice:
Criteria for evaluating effectiveness of Visualizations and of Tools

Data Visualization Anatomy Chart





Title of the visualization

Objective : to inform viewers efficiently about the content they are about to see and to orientate themselves within the hierarchy of its content e.g.

- Aligned with the left side of the chart or centered over the plot
- Sentence case or Title case etc
- Tone: Statement, Descriptive, question, artistic etc.

Reminder : from L10-Annotation in Visualization

Introductions

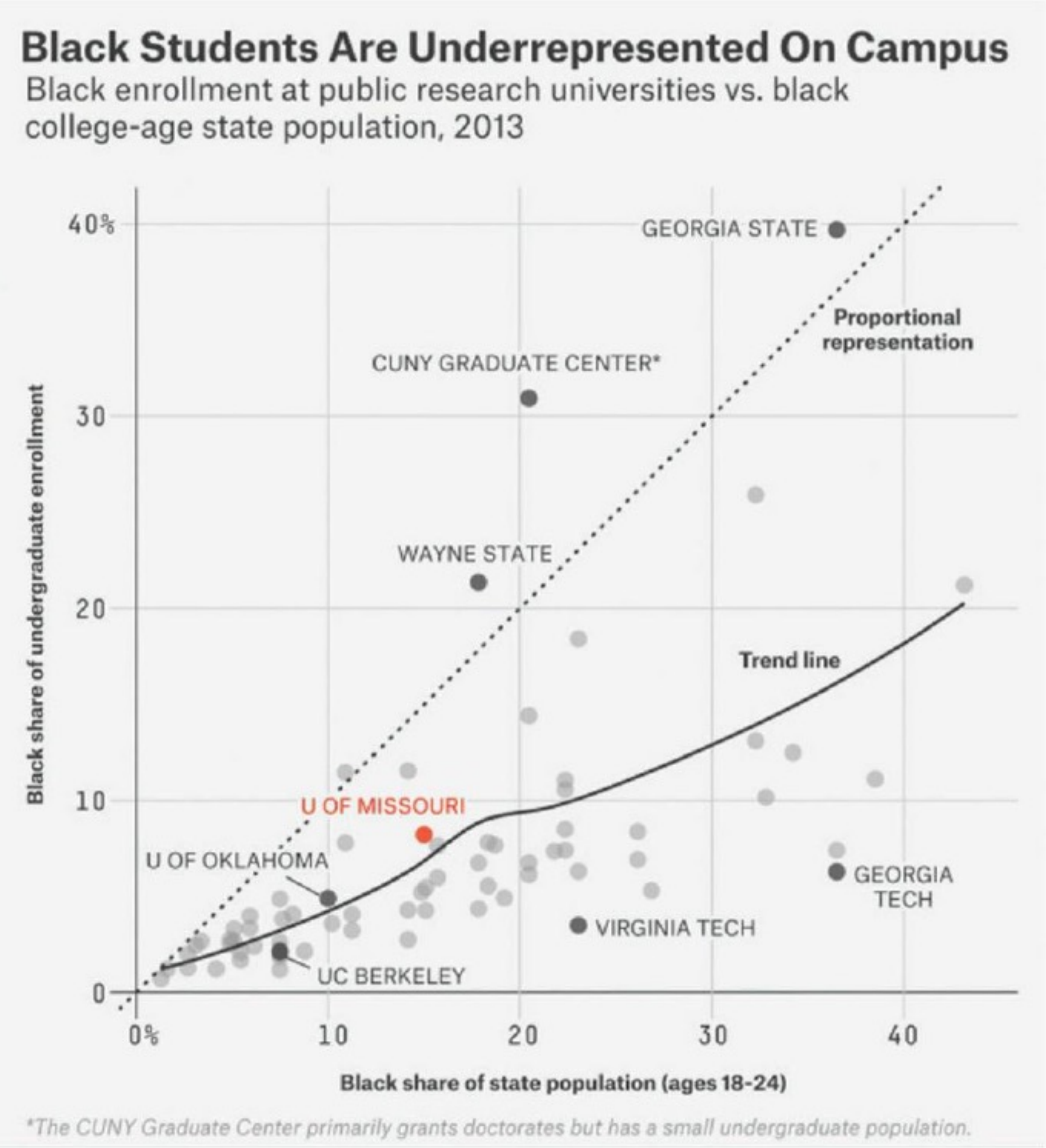
Typically short paragraphs that explain what the project or chart is about than a title can.

Reminder : from L10-Annotation in Visualization

Labels

3 main labelling devices : axis titles, axis labels and value labels

- **Axis titles** describe what values are being referenced by each axis.
- **Axis labels** provide value references along each axis to help identify the categorical value or the date/quantitative value associated with that scale position.
- **Value labels** appear in proximity to specific mark encodings inside the chart.



Reminder : from L10-Annotation in Visualization

Legends

A legend is an annotated feature within or alongside your chart that presents one or several keys to help viewers understand the categorical or quantitative meaning of different attributes.

Reminder : from L10-Annotation in Visualization

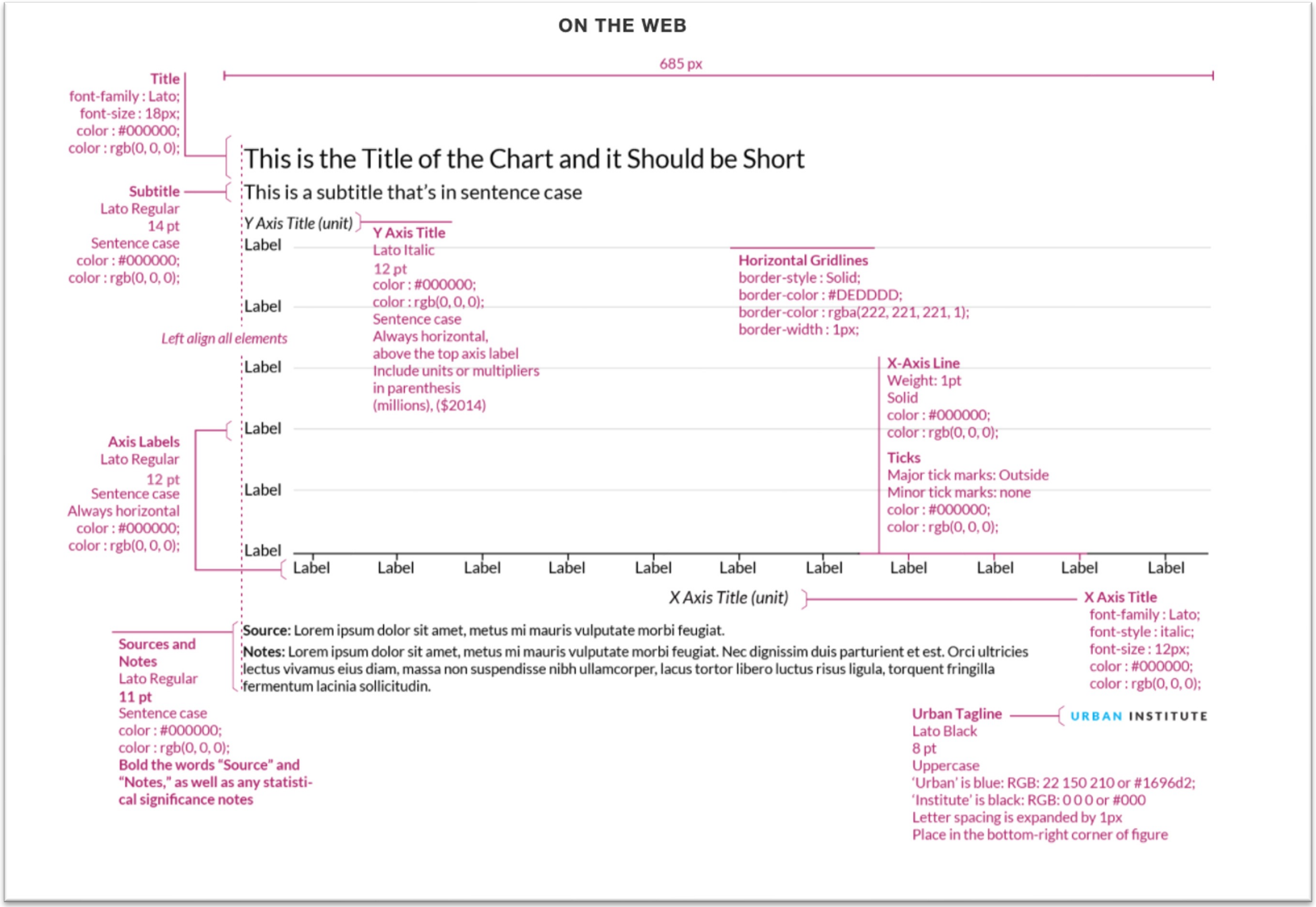
Various Annotations

Annotations may include

- Headings: titles, sub-titles and section headings.
- Introductions: providing background and aims of the project.
- Labels: axis titles, axis labels, value labels.
- Legend: providing detailed keys for colour or size associations.
- Guides: advice or instruction for how to use any interactive features. Detailed instructions advising readers how to perceive and interpret the chart.
- Multimedia: the potential to enhance your project using appropriate imagery, videos or illustrations.
- Footnotes: potentially includes data sources, credits, usage information, and time/date stamps.
- Chart apparatus: axis lines, gridlines, tick marks.
- Captions: drawing out key findings and commentaries.
- Typography: Most of the annotation features are based on text. Consider the legibility of the typeface you choose and the logic behind the font-size hierarchy you display.

Styleguides e.g. Urban institute data visualization style guide

https://urbaninstitute.github.io/graphics-styleguide/



A simple checklist!

Category	Description	Each can be assessed on a scale of 0-3 (NA/No/Somewhat/Yes)
Text	Charts do not contain text….or there is too much text. Titles, annotations, labels or text around and on charts should contain a clear message.	
Arrangement	Arrangement of graph elements should be proper e.g. axis intervals, order , groupings are logical choices	
Ink (Lines)	There should be no extra lines than needed eg just sufficient gridlines.	
Colors	Choice of colors and their display should be justifiable	
Overall	Charts should be truthful, able to get user attention and help him find insights or new hypotheses.	

Data Visualization checklist

[Data Visualization Checklist by Stephanie Evergreen and Ann K Emery]

	Guideline	Rating
Text Graphs don't contain much text, so existing text must encapsulate your message and pack a punch.	**6-12 word descriptive title is left-justified in upper left corner** Short titles enable readers to comprehend takeaway messages even while quickly skimming the graph. Rather than a generic phrase, use a descriptive sentence that encapsulates the graph's finding or "so what?" Western cultures start reading in the upper left, so locate the title there.	2 1 0 n/a
	Subtitle and/or annotations provide additional information Subtitles and annotations (call-out text within the graph) can add explanatory and interpretive power to a graph. Use them to answer questions a viewer might have or to highlight one or two data points.	2 1 0 n/a
	Text size is hierarchical and readable Titles are in a larger size than subtitles or annotations, which are larger than labels, which are larger than axis labels, which are larger than source information. The smallest text - axis labels - are at least 9 point font size on paper, at least 20 on screen.	2 1 0 n/a
	Text is horizontal Titles, subtitles, annotations, and data labels are horizontal (not vertical or diagonal). Line labels and axis labels can deviate from this rule and still receive full points.	2 1 0 n/a
	Data are labeled directly Position data labels near the data rather than in a separate legend (e.g., on top of or next to bars or pie slices, and next to lines in line charts). Eliminate/embed legends when possible because eye movement back and forth between the legend and the data can interrupt the brain's attempts to interpret the graph.	2 1 0 n/a
	Labels are used sparingly Focus attention by removing the redundancy. For example, in line charts, label every other year on an axis.	2 1 0 n/a

Arrangement

Improper arrangement of graph elements can confuse readers at best and mislead viewer at worst. Thoughtful arrangement makes a data visualization easier for a viewer to interpret.

Proportions are accurate 2 1 0 n/a

A viewer should be able to take a ruler to measure the length or area of the graph and find that it matches the relationship in the underlying data.

Data are intentionally ordered 2 1 0 n/a

Data should be displayed in an order that makes logical sense to the viewer. Data may be ordered by frequency counts (e.g., from greatest to least for nominal categories), by groupings or bins (e.g., histograms), by time period (e.g., line charts), alphabetically, etc.

Axis intervals are equidistant 2 1 0 n/a

The spaces between axis intervals should be the same unit, even if every axis interval isn't labeled.

Graph is two-dimensional 2 1 0 n/a

Avoid three-dimensional displays, bevels, and other distortions.

Display is free from decoration 2 1 0 n/a

Graph is free from clipart or other illustrations used solely for decoration. Some graphics, like icons, can support interpretation.

Color

Keep culture-laden color connotations in mind. For example, pink is highly associated with feminine qualities in the USA.

Use sites like Color Brewer to find color schemes suitable for reprinting in black-and-white and for colorblindness.

Color scheme is intentional 2 1 0 n/a

Colors should represent brand or other intentional choice, not default color schemes. A safe bet for consultants is to use your client's colors. Use online tools to identify brand colors and others that are compatible.

Color is used to highlight key patterns 2 1 0 n/a

Action colors should guide the viewer to key parts of the display. Less important or supporting data should be a muted color.

Color is legible when printed in black and white 2 1 0 n/a

When printed or photocopied in black and white, the viewer should still be able to see patterns in the data.

Color is legible for people with colorblindness 2 1 0 n/a

Avoid red-green and yellow-blue combinations when those colors touch one another.

Text sufficiently contrasts background 2 1 0 n/a

Black/very dark text against a white/transparent background is easiest to read.

Lines

Excessive lines—gridlines, borders, tick marks, and axes—can add clutter or noise to a graph, so eliminate them whenever they aren't useful for interpreting the data.

Gridlines, if present, are muted Color should be faint gray, not black. Full points if no gridlines are used.	2 1 0 n/a
Graph does not have border line Graph should bleed into the surrounding page or slide rather than being contained by a border.	2 1 0 n/a
Axes do not have unnecessary tick marks Tick marks are useful in line graphs (to demarcate each point in time along the y-axis) but unnecessary in bar charts.	2 1 0 n/a
Graph has one horizontal and one vertical axis Viewers can best interpret one x- and one y-axis, even if one is hidden. Don't add a second y-axis.	2 1 0 n/a

Overall

Graphs will catch a viewer's attention so only visualize the data that needs attention. Too many graphics of unimportant information dilute the power of visualization.

Graph highlights significant finding or conclusion Graphs should have a "so what?" – either a practical or statistical significance (or both) to warrant their presence.	2 1 0 n/a
The type of graph is appropriate for data Data are displayed using a graph type appropriate for the relationship within the data. For example, change over time is displayed as a line graph, area chart, slope graph, or dot plot.	2 1 0 n/a
Graph has appropriate level of precision Few numeric labels need decimal places. When precision is important, choose a type of graph type that displays differences through length or points along a line (e.g., bar charts, dot plots). When precision is less important, you can use a graph that displays differences through angles or area (e.g., pie charts, circle charts).	2 1 0 n/a
Contextualized or comparison data are present Comparisons—over time, across programs or subgroups of participants, etc.—help the viewer understand the significance of the data.	2 1 0 n/a
Individual chart elements work together to reinforce the overarching takeaway message Choices about graph type, text, arrangement, color, and lines should reinforce the same takeaway message.	2 1 0 n/a

Score: _________ / _____ = ______ %

Well-formatted data visualizations score between 90-100% of available points. At this level, viewers are better able to read, interpret, and retain content.

Slide 15 onwards in this deck are optional from Test(Exam) point of view

Topic of Information Visualization Evaluation

- BoK(The body of knowledge) on Info Viz evaluation is evolving
- We can find in literature works about :
  - evaluating **process** of designing a visualization system
  - evaluating specific **systems** and visualization **techniques**
  - comparing alternative **visualizations**.

- Help from several disciplines : Human-Computer Interaction , Ethnography, Graphic Design, Visual design

Example - Criteria for evaluating Visualization Tools

http://becomingvisual.com
Data Visualization Made Simple: Insights Into Becoming Visual   by Kristen Sosulski

Sharing – Can others view and edit your visualization and analysis?

Output – Can you publish visualizations to the web, create PDF documents, and embed them into other applications?

Interoperability – How easily can you connect to data sources?

Display types – What types of visualizations do you intend on building?

Data exploration – Do you need a tool to explore and present your data visually ?

Simplicity – Are you looking to create charts and graphs quickly?

Persistence – Do you think that you will have to go back and revise the visualizations you create?

An excellent visualization

A excellent visualization is used by many people, who use it routinely to obtain highly valuable knowledge, without having to spend a lot of time and money on hardware, software, and effort.

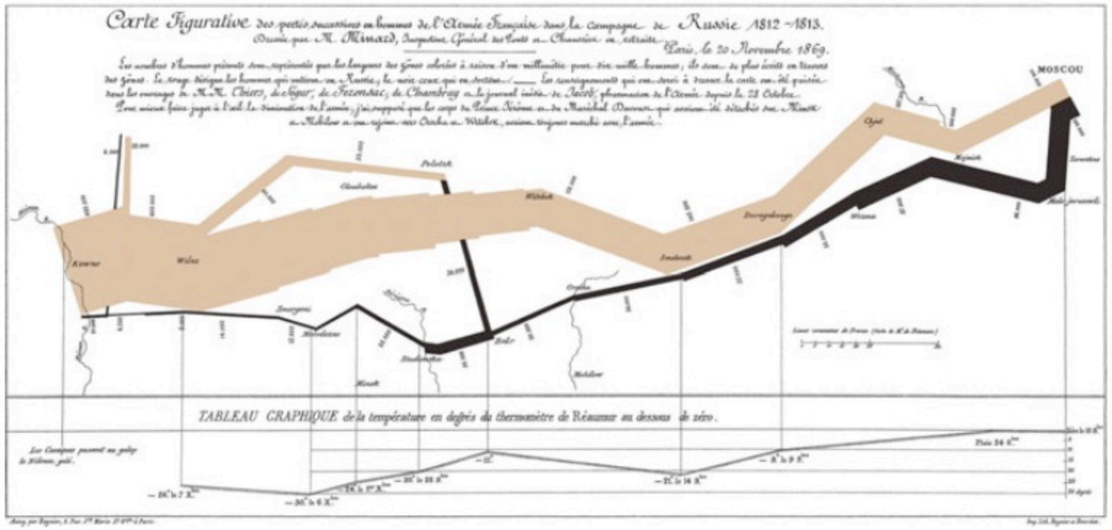


Fig. 1.10 Minard's map showing the march of Napoleon's army towards Moscow, and its retreat

FYI :

Van Wijk, Jarke J. "The value of visualization." *Visualization, 2005. VIS 05. IEEE*. IEEE, 2005.

$F = nm(W(\Delta K) - C_s - kC_e) - C_i - nC_u$

Profit : F

Return on investment : nm(W(ΔK)

costs : various C factors

A simple model of Visualization

Van Wijk, Jarke J. "The value of visualization." *Visualization, 2005. VIS 05. IEEE*. IEEE, 2005.

Basic assumption :

- a homogeneous user community,

- consisting of *n* users which use a certain visualization *V* to visualize

- a data set *m* times each,

- where each session takes *k* explorative steps

- and time *T* .

users: n

visualization: *V*

Visualizes : *m* times

makes: *k* explorative steps in each session

takes: time T for each session

Continued..

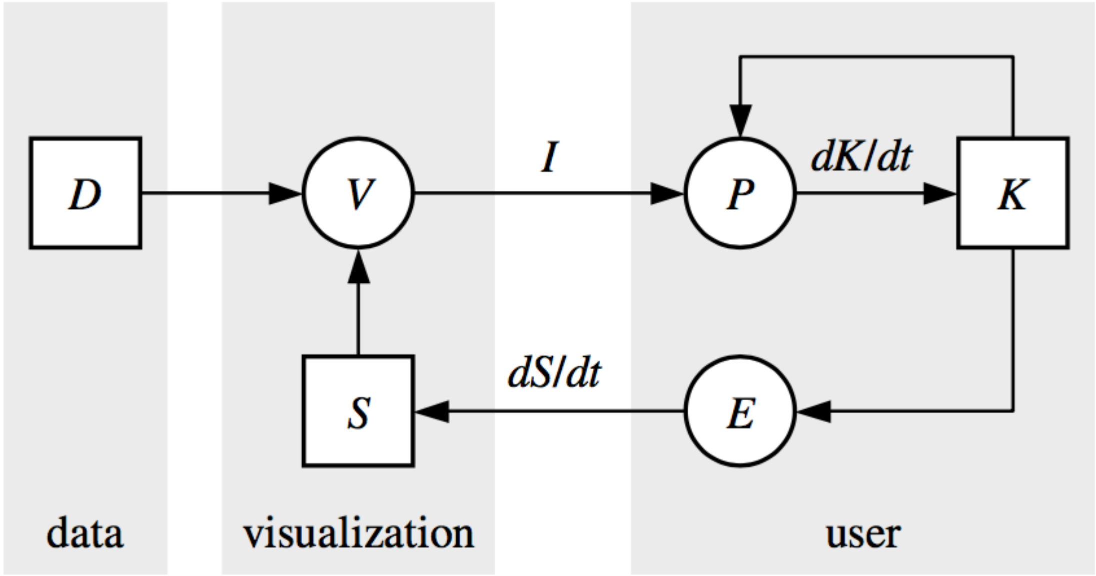
Visualization ~ Transformation of Data according to a Specification into an Image (a time varying image).

$$(D, S) \rightarrow I$$

$$I(t) = V(D, S, t)$$

In broadest sense:
The specification *S* includes a specification of the hardware used, the algorithms to be applied, and the specific parameters to be used;

The image *I* will often be an image in the usual sense, but it can also be an animation, or auditory or haptic feedback.



Continued..

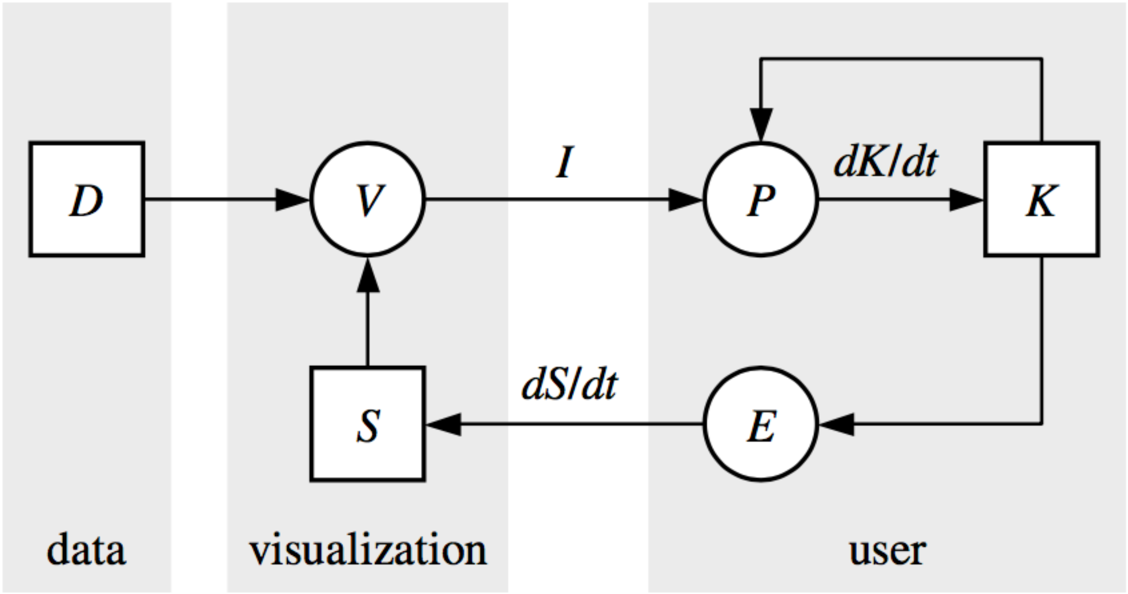
The image *I* is perceived by a user, with an increase in knowledge *K* as a result:

$$\frac{dK}{dt} = P(I, K)$$

The amount of knowledge gained depends on

-the image,
-the current knowledge of the user, and

-the particular properties of the perception and cognition *P* of the user.



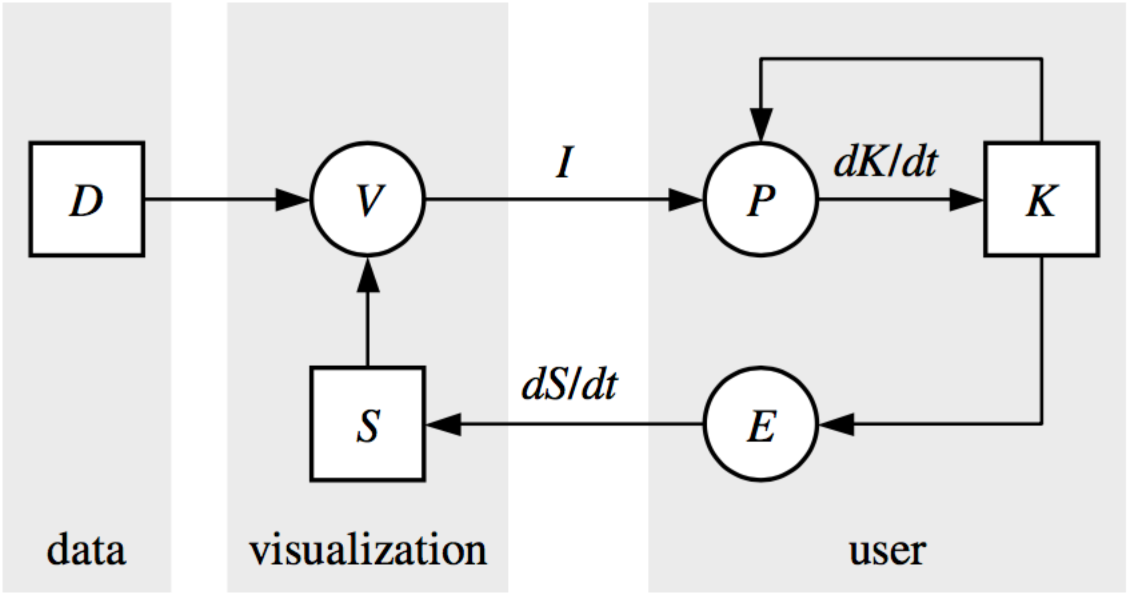
Continued..

The current knowledge $K(t)$ follows from integration over time

$$K(t)=K_0+\int_0^t P(I,K,t)dt$$

where K_0 is the initial knowledge.

Based on his current knowledge, K, the user may decide to explore(E) the data further.



Continued..

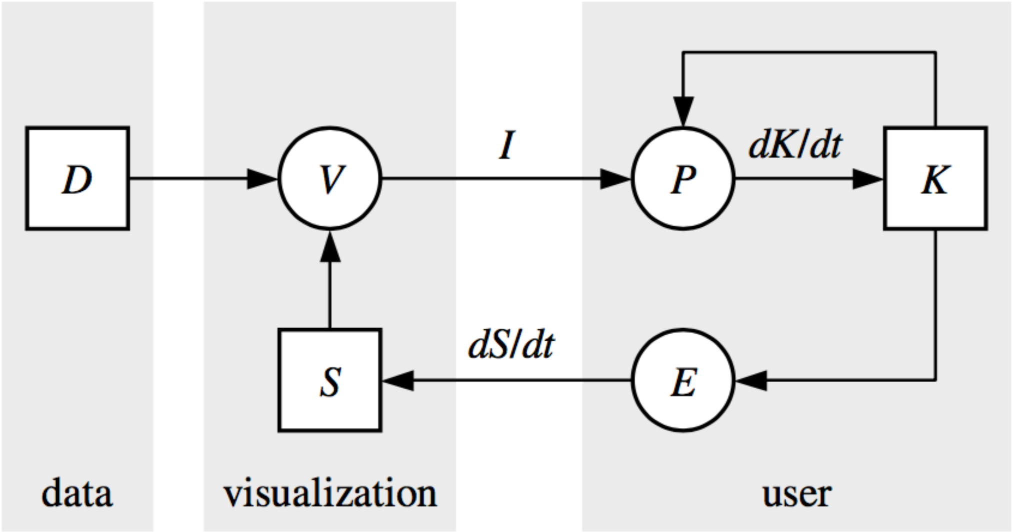
The user may decide to adapt the specification of the visualization, based on his current knowledge, in order to explore the data further

$$\frac{dS}{dt} = E(K)$$

The current specification $S(t)$ follows from integration over time

$$S(t) = S_0 + \int_0^t E(K)\,dt$$

where S_0 is the initial specification.



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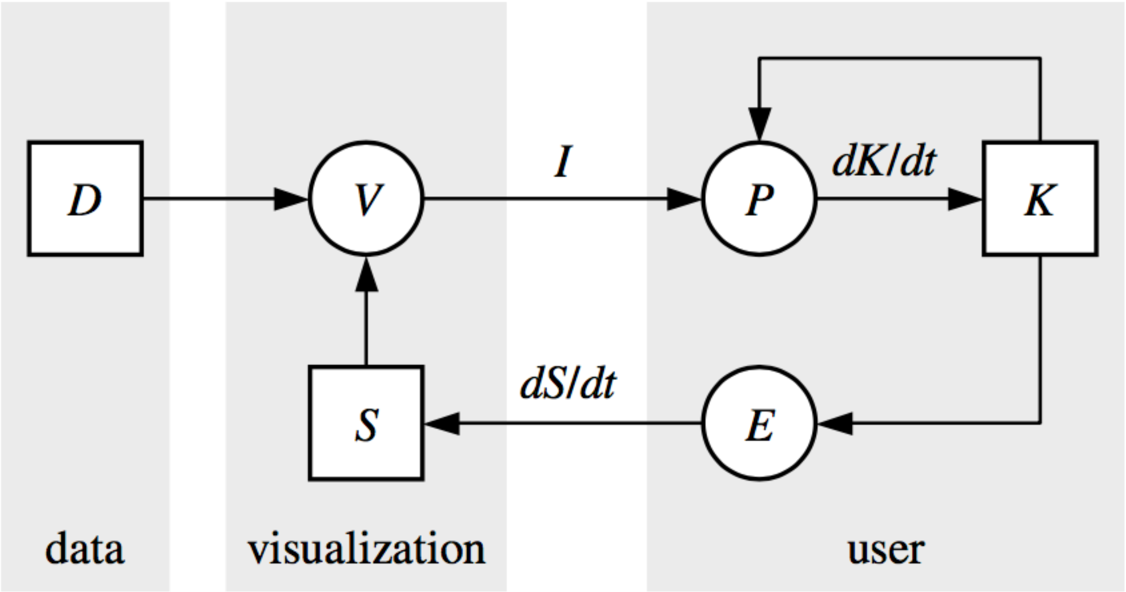
The costs associated with using *V* come at four different levels:

Initial development costs

Initial costs per session.

Initial costs per user.

Perception and exploration costs.



Recall the assumption:

users: n

visualization: *V*

Visualizes : *m* times

makes: *k* explorative steps in each session

takes: time T for each session

The costs associated with using *V* come at four different levels:

• $C_i(S_0)$*: Initial development costs*. The visualization method has to be developed and implemented, possibly new hardware has to be acquired.

• $C_s(S_0)$*: Initial costs per session*. Data have to be converted, and an initial specification of the visualization has to be made.

- $C_u(S_0)$*: Initial costs per user*. The user has to spend time on selection and acquisition of *V* , understanding how to use it, and tailoring it to his particular needs.

• C_e*: Perception and exploration costs*. The user has to spend time to watch the visualization and understand it, as well as in modification and tuning of the specification, thereby exploring the data set.

Continued..

The total costs is

$C = C_i + nC_u + nmC_s + nmkC_e$

The return on these investments consists of the value $W(\Delta K)$ of the acquired knowledge $\Delta K = K(T) - K(0)$ per session, multiplied by the total number of sessions:

$G = nmW(\Delta K)$

and hence for the total profit $F = G - C$ we find

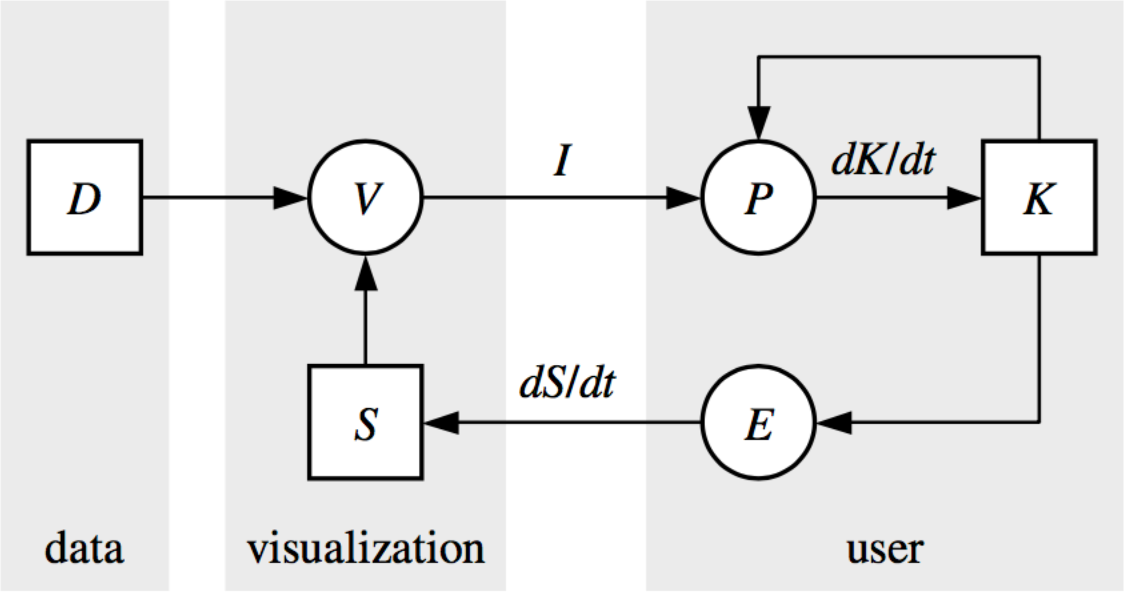
$F = nm(W(\Delta K) - C_s - kC_e) - C_i - nC_u$

This gives us a recipe to decide on the value of a visualization method.
Positive are high values for n, m, $W(\Delta K)$, and low values for Cs, Ce, Ci, Cu, and k.

Or, in other words, **a great visualization method is used by many people, who use it routinely to obtain highly valuable knowledge, without having to spend time and money on hardware, software, and effort.**

Issues implied by the model

1. Insights and Knowledge
2. Visualization is subjective
3. Negative knowledge
4. Interaction



1. Insight and Knowledge :

Insights : an aim of visualization.

Users are enabled to see things they were not aware of, and this **insight helps them to define new questions, hypotheses, and models of their data.**

However, one problem is that **we cannot directly observe or measure how much insight is acquired,** and also, it is **difficult to assess what the value of that insight is.**

Continued..

- **Knowledge** -- **the same limitation**

  -- We cannot directly observe or measure how much knowledge is acquired

- **A strange paradox -**
  - We don’t know what information is contained in the data, therefore we make pictures to get insight.
  - But if we do not know which specific aspects or features should be visible, we cannot assess if we are successful or not.

- **We should try to measure or estimate Value of Visualization *W* (Δ*K*) as in the given model**

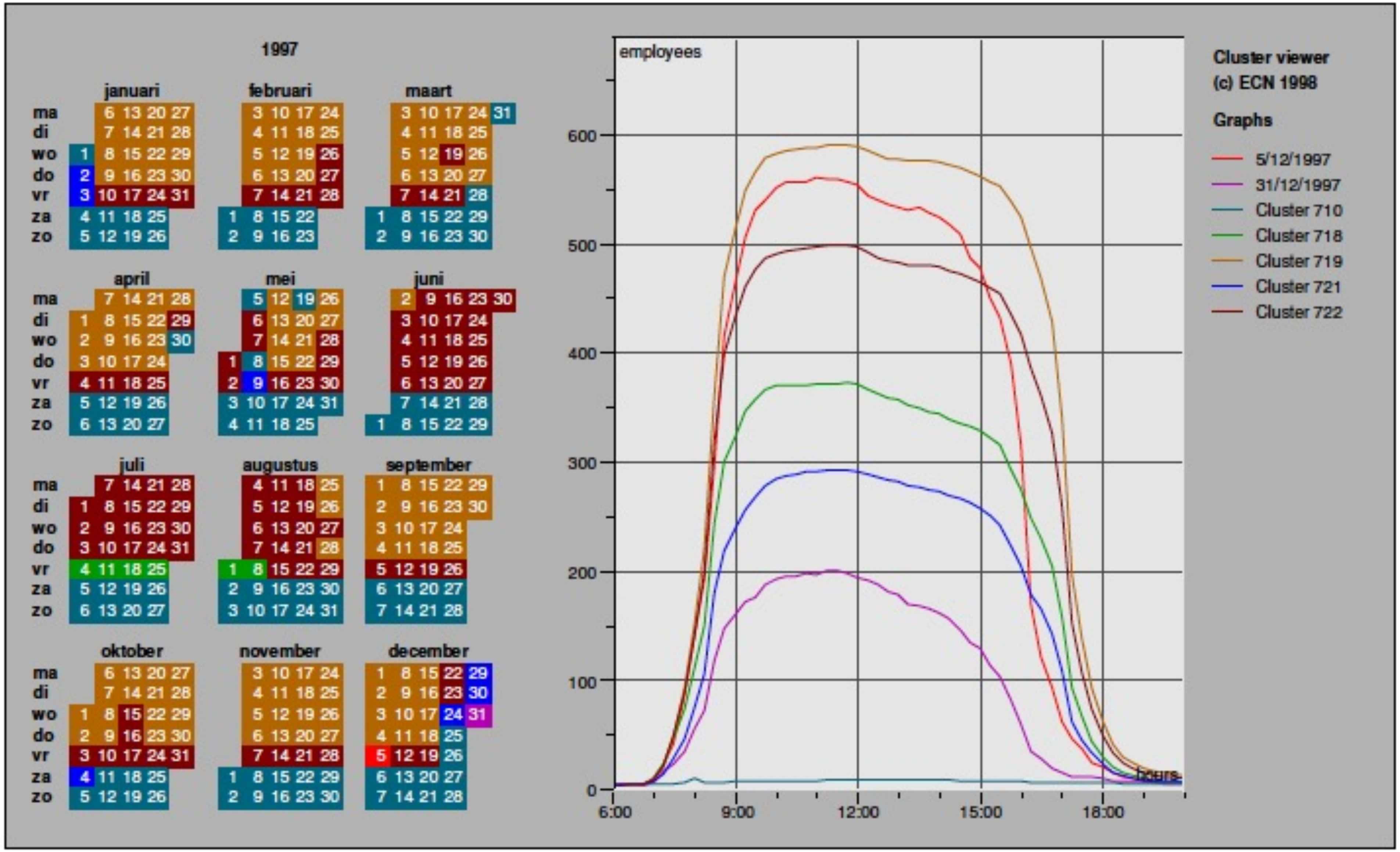
$$F = nm(W(\Delta K) - C_s - kC_e) - C_i - nC_u$$

Continued..

- **Decisions are typically about actions to be taken or not.**
  - To decide which **action to take , user needs information.**
  - The visualization should **enable him to extract the relevant information from the data.**
  - **If such actions cannot be found or defined, the value of visualization is doubtful.**

- **Just claiming that a visualization gives insight is not enough**, if we want to offer additional value.
  - **Assess whether the knowledge derived from the visualization does indeed support the decision**, and also, to assess the **economic value of this decision**.
  - Not easy, but one can **try for instance to estimate how much time is saved, or try to quantify the consequences of a wrong decision**.

Continued..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Cluster 722

2. Visualization is subjective

Ideally, **extraction of knowledge from data is expected to be an objective process,**
-- the **outcome should not depend on who performs it,** and

-- the analysis should be repeatable with the same outcome.

$\frac{dK}{dt}$ $=P(I,K) = (V(D,S,t),K)$.

→ **the increase in knowledge depends on D, S, P and K**

→ visualization shows that a certain phenomenon occurs is **subjective**.

Continued..

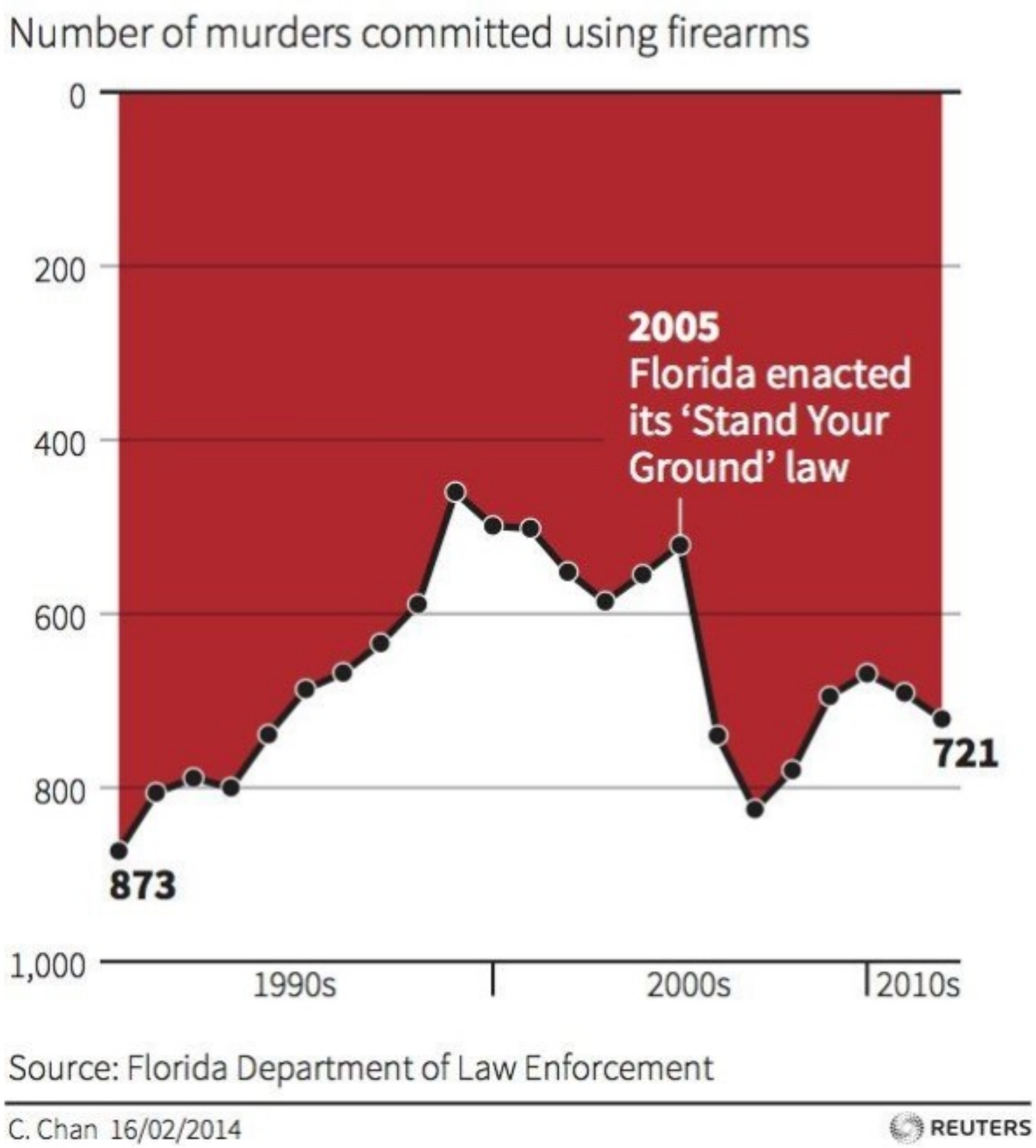
- How about when visualization does not show clear patterns
  - limitation of the visualization OR data simply does not contain significant patterns.

- Useless visualization?
  - Not reall, unless there are better alternatives to inspect complex data
  - Visualization is not always used to verify the final truth, but also to inspire to new hypotheses.

3. Negative knowledge

- Visualizations can be wrong and misleading.
- Negative knowledge ($|\Delta K| < 0$) can be produced.

Tufte's *lie-factor* = the ratio of the size of an effect shown in the graphic to the size of the effect in the data.



4. Interaction

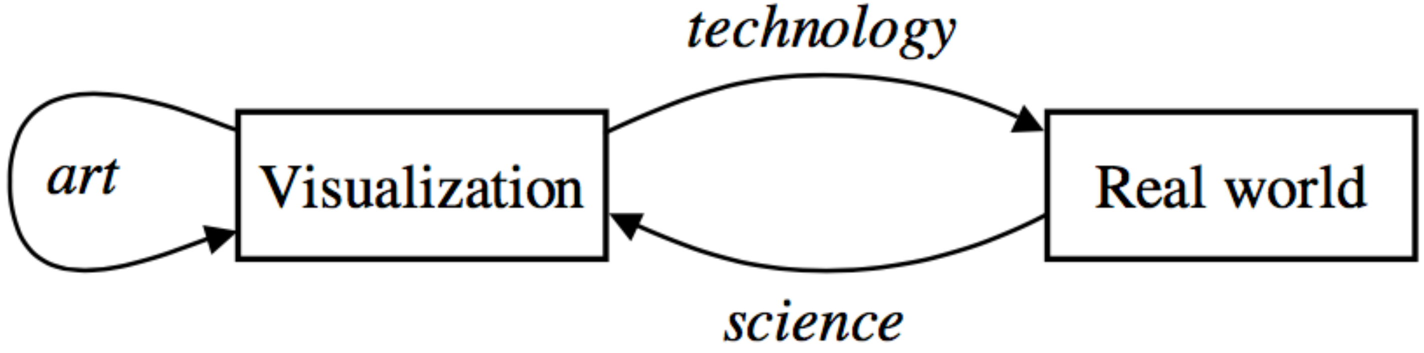
- Interaction strongly enhances the understanding of the data
- When the amount of data to be shown does not fit on the screen, or is too large to be understood from a single image.
  - Navigation and selection of the data has to be supported.

Continued..

- Two reasons to avoid it
  - **Allowing the user to modify *S* freely will leads to subjectiveness**.
    - High customization can make it hard to compare different visualizations.
  - **Interaction - > high C_e**.
    - Re-rendering the image after a change of the mapping or the point of view taken requires often a few seconds, viewing it again also.
    - If many options are available to modify the visualization, trying them all out can take hours.
      - Therefore , think carefully about good defaults

Summary: No single point of view

A **technological point of view** : aiming for effectiveness and efficiency; assessing costs and benefits
Visualization as an art i.e., something that is interesting enough for its own sake
Visualization as an empirical science: a coherent set of theories, laws, and models that describe a range of phenomena, have predictive power, are grounded in observations, and that can be falsified



References

The value of visualization by Jarke J Van Wijk
Seven Guiding Scenarios for Information Visualization Evaluation by Heidi Lam, Enrico Bertini, Pera Isenberg, Catherine Plaisant, Sheelagh Carpendale
Chapter 8 of Book : Data Visualization by Andy Kirk, 2nd Edition