CS 519: Scientific Visualization

Information Visualization: Design

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Slides adapted from:
• Alvitta Otley, Washington University in St Louis
• Mariah Mayer, University of Utah
• Remco Chang, Tufts University
Edward Tufte

- Well-known information visualization researcher/practioner
  - Probably a big understatement
- Evangelist for good design
- Focusses mostly on static visualizations
  - But his principles can often be applied to interactive visualizations
Principles of Graphical Excellence

- Show the data
- Avoid distorting the data
- Present many numbers in a small space
- Make large data sets coherent
- Encourage the eye to compare different pieces of data
- Serve a purpose
  - Description
  - Exploration
  - Tabulation
  - Decoration

From *The Visual Display of Quantitative Information* – Edward Tufte
Graphical Integrity

- Tufte lays out guiding principles...
  - Clear and detailed labelling should be used to defeat graphical distortion and ambiguity.
  - “Above all else show the data”
- So...how can you lie with info visualization?
“...annual report of a company that would just as soon forget about 1970. A careful look at the middle panel reveals a negative income, which is disguised by having the bars begin at the bottom at approximately minus $4,200,000.”
Specifically Ignoring Scale...

- Numbers have magnitude, not just order
Tufte coined the term “lie factor” (LF), defined as

\[
\text{Lie\_factor} = \frac{\text{size of graphic}}{\text{size of data}}
\]

High LF leads to exaggeration of differences or similarities

- Deception
- Misinterpretation

For 0 to indicate not lying, what function could be applied to LF?
Lie Factor Example

- Line representing 18 MPG in 1978 is 0.6 inches long
- Line representing 27.5 MPG in 1985 is 5.3 inches long
Lie Factor Example

- Increase in MPG from 1978 to 1985 is
  \[
  \frac{27.5 - 18.0}{18.0} \times 100 = 53\%
  \]

- Difference in length of lines is
  \[
  \frac{5.3 - 0.6}{0.6} \times 100 = 783\%
  \]

- The Lie Factor is \(\frac{783}{53} = 14.8\)

Ideally Lie Factor should be what?
REQUIRED FUEL ECONOMY STANDARDS:
NEW CARS BUILT FROM 1978 TO 1985

18 19 20 22 24 26 27 27.5
19.1 mpg, expected average for all cars on road, 1985
13.7 mpg, average for all cars on road, 1978

LF of 9.4

The LF is made worse by using a glyph with changing area as a visual representation of a linear change.

Price is keyed to glyph height.

But barrel area appears to change.

Not just height.
Another Way to Lie: Design Variation

- The “3D” effect can be used to distort data
- 5 vertical scales:
  - 1973-1978: 1 inch = $8
  - Jan-Mar 1 inch = $4.73
  - Apr-Jun: 1 inch = $4.37
  - Jul-Sep: 1 inch = $4.16
  - Oct-Dec: 1 inch = $3.92
- Two horizontal scales
  - 1973-1978: 1 inch = 3.8 years
  - 1979: 1 inch = 0.57 years
Another Example of Area Mis-Used

- Both dimensions of the dollars are reduced by the same factor
- This squares the linear difference which the chart should show
- 1978 dollar should be twice as big....
How Does this Chart Distort the Data?

William Playfair 1786

Accompanied by a polemic decrying the financing of colonial wars with debt.

There are two issues...
...Just a Few Pages Later

[Graph showing interest of the National Debt from the Revolution]
Using Visual Elements to Deceive

The graphic wishes to display rising government spending.

The budget, in fact, did not increase in the last 9 years shown.

Some cues the chart provides:

- Horizontal arrows on low values
- Vertical arrows on high values
- Angled 3D-effect lines to provide impression of increase
Removing Statistical Lapses as well

In addition to visual cues:

State population increase neglected in original graphic

Original graphic does not adjust for inflation

Figure at right shows budget accounting for those issues
Removing extra data points leads one to obvious conclusion that stricter speed limit enforcement reduced deaths.

How does the addition of more sample points make that conclusion questionable?
How does the addition of data from other states effect the interpretation of the cause for the decline in Connecticut?
One Last Example...

What’s deceptive here?
Good Design Practice

Tufte suggests a ratio of data ink to total ink be close to 1

Data ink is ink devoted to non-redundant display of data

Observe Playfair’s evolution:
The length of an organism at the time of reproduction in relation to the generation time, plotted on a logarithmic scale.
Less Good...
Improved
Erasing Non-Data Ink

How many times is height encoded?
Erasing Non-Data Ink

Multiple encodings:
1. Height of the left line
2. Height of the right line
3. Height of shading
4. Position of top horizontal line
5. Position (placement) of the number
6. Value of the number
Erasing Non-Data Ink: Example

Results of a study indicating that one type of element always has a higher value under different experimental conditions.
After Removing Non-Data Ink

After removing all non-data ink
Is the Data Easier to Interpret?
Similarly....
Graphical excellence is the well-designed presentation of interesting data – a matter of substance, of statistics, and of design.

Graphical excellence consists of complex ideas communicated with clarity, precision, and efficiency.

Graphical excellence is that which gives the viewer the greatest number of ideas in the shortest time with the least ink in the smallest place.

Graphical excellence is nearly always multivariate.

Graphical excellence requires telling the truth about the data.
Is Tufte Correct?

A User Study of Visualization Effectiveness Using EEG and Cognitive Load

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- Asked participants to choose the box plot with the largest range from a set
- Varied representations
- Measured cognitive load from EEG brain waves
Results

The simplest box plot is the hardest to interpret
Useful Junk? The Effects of Visual Embellishment on Comprehension and Memorability of Charts

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ABSTRACT
Guidelines for designing information charts often state that the presentation should reduce ‘chart junk’ – visual embellishments that are not essential to understanding the data. In contrast, some popular chart designers wrap the presented data in detailed and elaborate imagery, raising the questions of whether this imagery is really as detrimental to understanding as has been proposed, and whether the visual embellishment may have other benefits. To investigate these issues, we conducted an experiment that compared embellished charts with plain ones, and measured both interpretation accuracy and long-term recall. We found that people’s accuracy in describing the embellished charts was no worse than for plain charts, and that their recall after a two-to-three-week gap was significantly better. Although we are cautious about recommending that all charts be produced in this style, our results question some of the premises of the minimalist approach to chart design.

Author Keywords
Charts, information visualization, imagery, memorability.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

data-ink – or the ink in the chart used to represent data.

Despite these minimalist guidelines, many designers include a wide variety of visual embellishments in their charts, from small decorations to large images and visual backgrounds. One well-known proponent of visual embellishment in charts is the graphic artist Nigel Holmes, whose work regularly incorporates strong visual imagery into the fabric of the chart [7] (e.g., Figure 1).

MONSTROUS COSTS
Total House and Senate campaign expenditures, in millions

1972 74 76 78 80 82 84 86 88

11 15 18 20 22 24 26 28 30

15 18 20 22 24 26 28 30 32

15 18 20 22 24 26 28 30 32
Redesigning Holmes Charts
1. No significant difference between **interpretation accuracy**
2. No significant difference in **recall accuracy** after a five-minute gap
3. **Significantly better recall** for Holmes charts of both chart topic and the details (categories and trend) after long-term gap (2-3 weeks).
4. Participants found the Holmes charts **more attractive, more enjoyable**, and were **easiest and fastest to remember**.