

Visualization
Design

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Graphical
Excellence

Graphical
Integrity

Design
Principles

Chartjunks —
How Not To
Design a
Chart

Redesigning
Statistical
Charts

References

Visualization Design

Design Principles and Main Visual Forms

S. Santoni¹

¹Bayes Business School

MSc in Business Analytics, 2024/25

Outline

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What is Good Data Viz?

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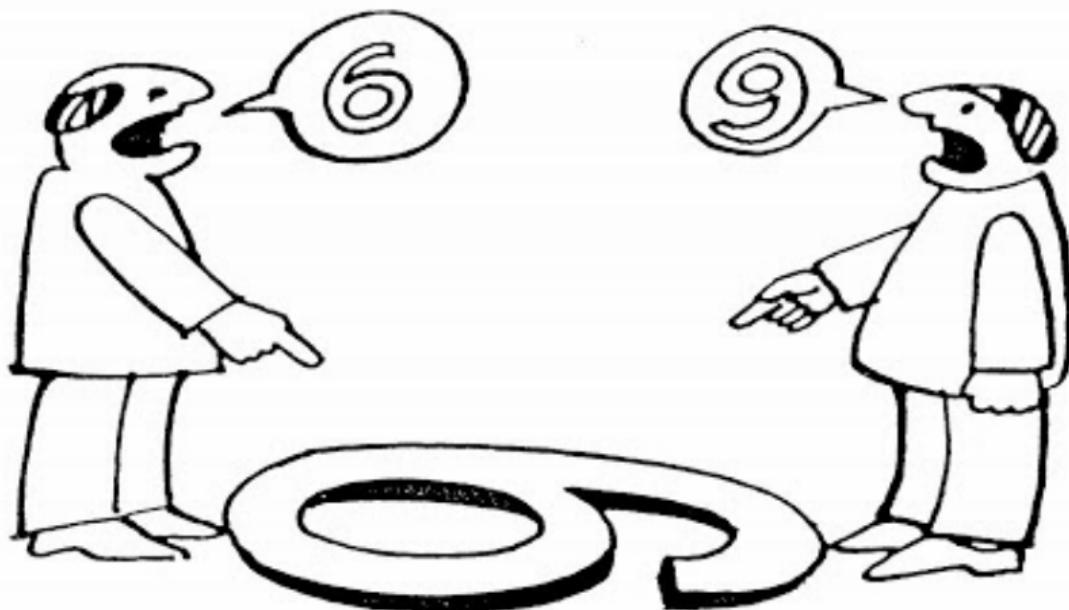
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Example A: A Plot from the a Towards Data Science Post

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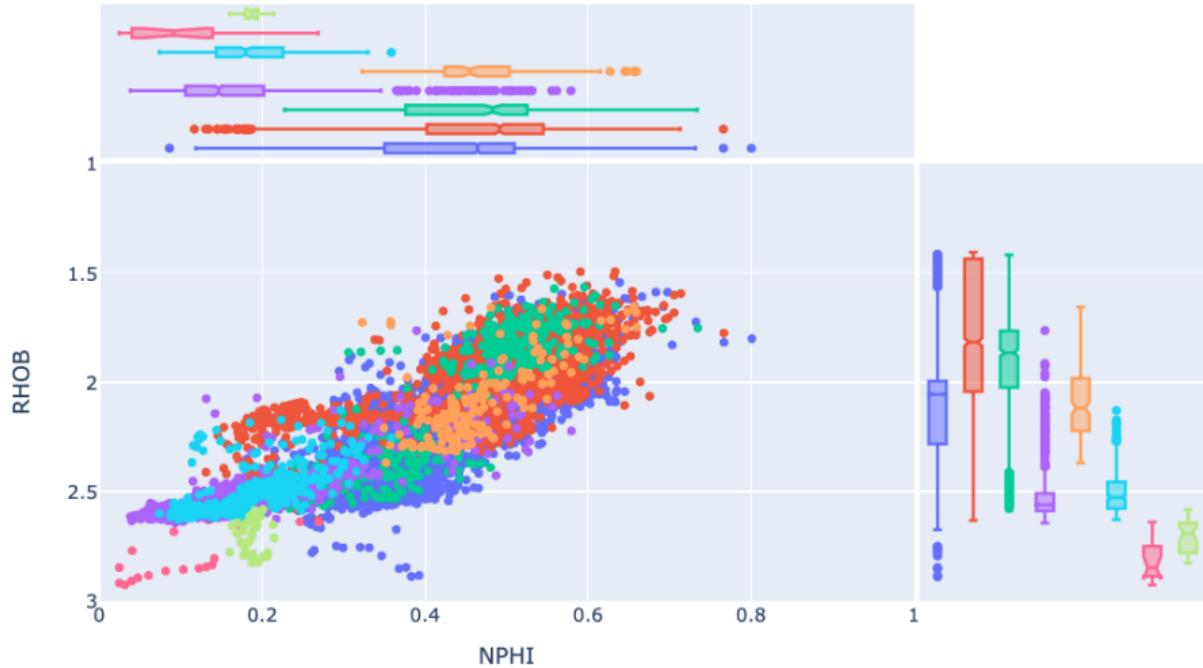
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Source: <https://towardsdatascience.com/enhance-your-plotly...>

Example B: A Chart from an Article in The Economist

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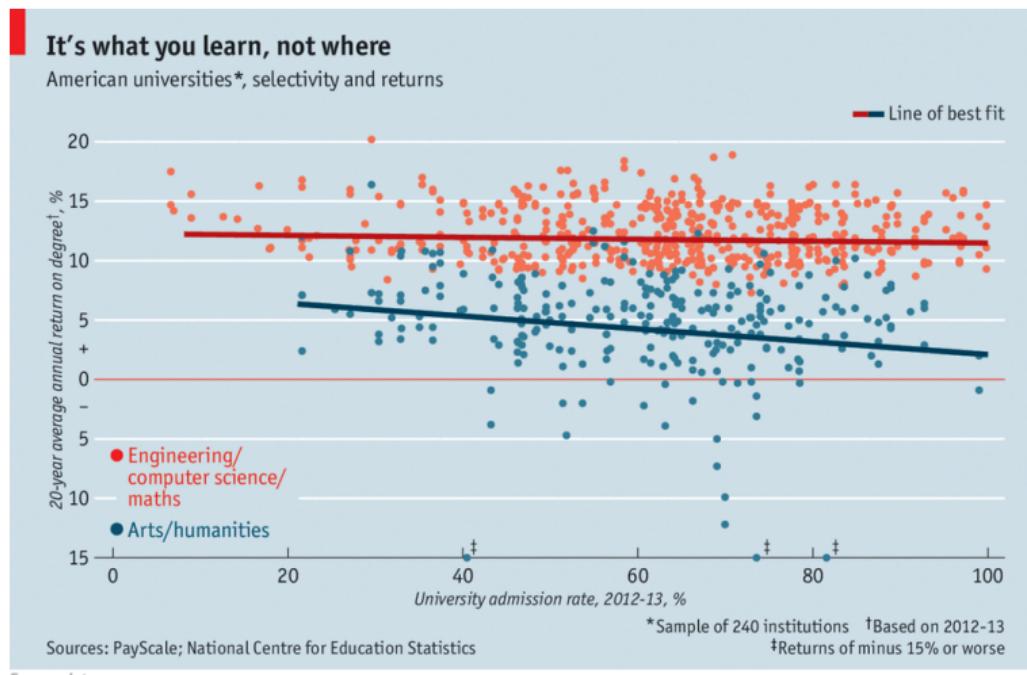
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Source: <https://www.economist.com/...it-depends-what-you-study-not-where>

Graphical Excellence according to Tufte

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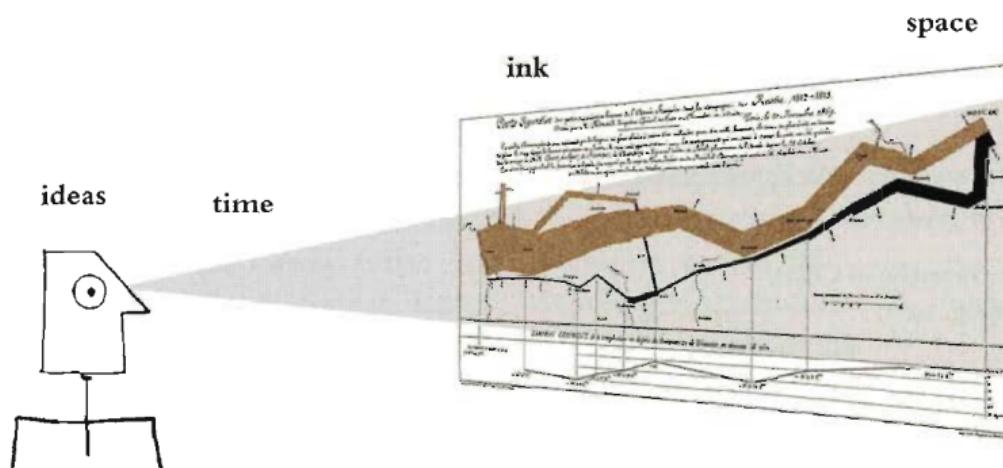
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Per Tufte's work [3], excellence in statistical graphs consists of complex “*ideas communicated with clarity, precision, and efficiency.*”

Graphical displays pursuing clarity, precision, and efficiency “*give to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space.*”



How to Reach Clarity, Efficiency, and Precision?

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Tufte points out graphical displays should

- Show the data
- Induce the viewer to think about the substance rather than about the methodology, graphical design, the technology of graphic production, or something else
- Avoid distorting what the data have to say
- Present many numbers in a small space
- Make large datasets coherent
- Encourage the eye to compare different pieces of data
- Reveal the data at several levels of detail, from a broad overview to the fine structure
- Serve a reasonably clear purpose: description, exploration, tabulation, or decoration
- Be closely integrated with the statistical and verbal description of a data set

Show the Data!

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Here is a classic example on the importance of showing the data, the case of Anscombe's quartet [2].

	I		II		III		IV	
	X	Y	X	Y	X	Y	X	Y
Anscombe's Quartet	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

$$N = 11$$

$$\text{mean of } X\text{'s} = 9.0$$

$$\text{mean of } Y\text{'s} = 7.5$$

$$\text{equation of regression line: } Y = 3 + 0.5X$$

$$\text{standard error of estimate of slope} = 0.118$$

$$t = 4.24$$

$$\text{sum of squares } X - \bar{X} = 110.0$$

$$\text{regression sum of squares} = 27.50$$

$$\text{residual sum of squares of } Y = 13.75$$

$$\text{correlation coefficient} = .82$$

$$r^2 = .67$$

Show the Data! (cont'd)

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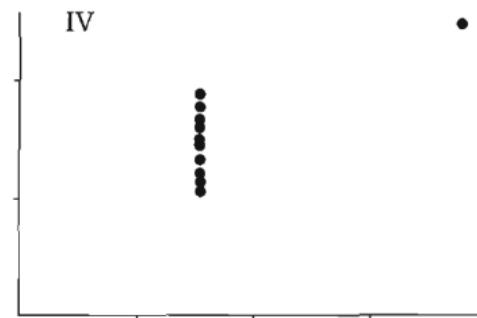
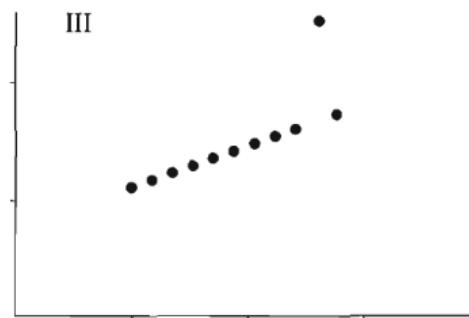
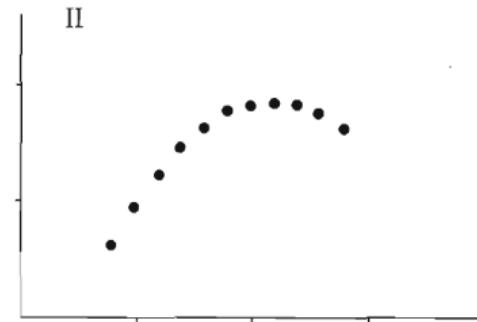
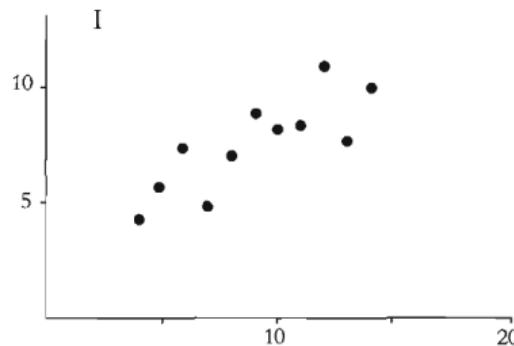
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Excellent Graphical Displays Tell the Truth!

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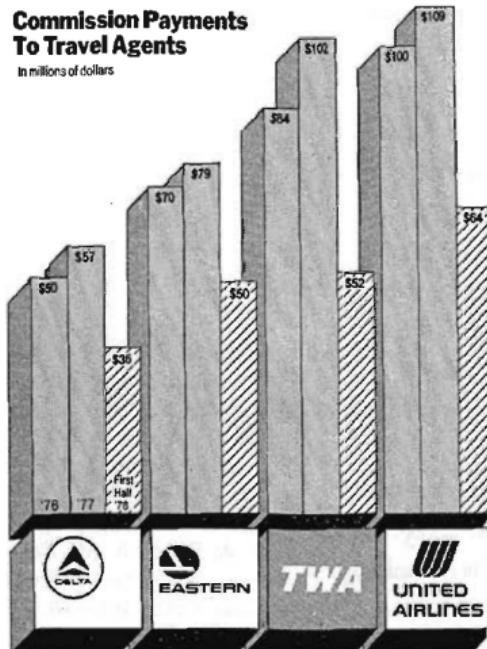
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Source: New York Times, August 8, 1978, page D-1.

Tufte [3, page 54] observes that '*the pseudo-decline was created by comparing six months' worth of payments in 1978 to a full year's worth in 1976 and 1977, with the lie repeated four times.*'

Excellent Graphical Displays Tell the Truth!

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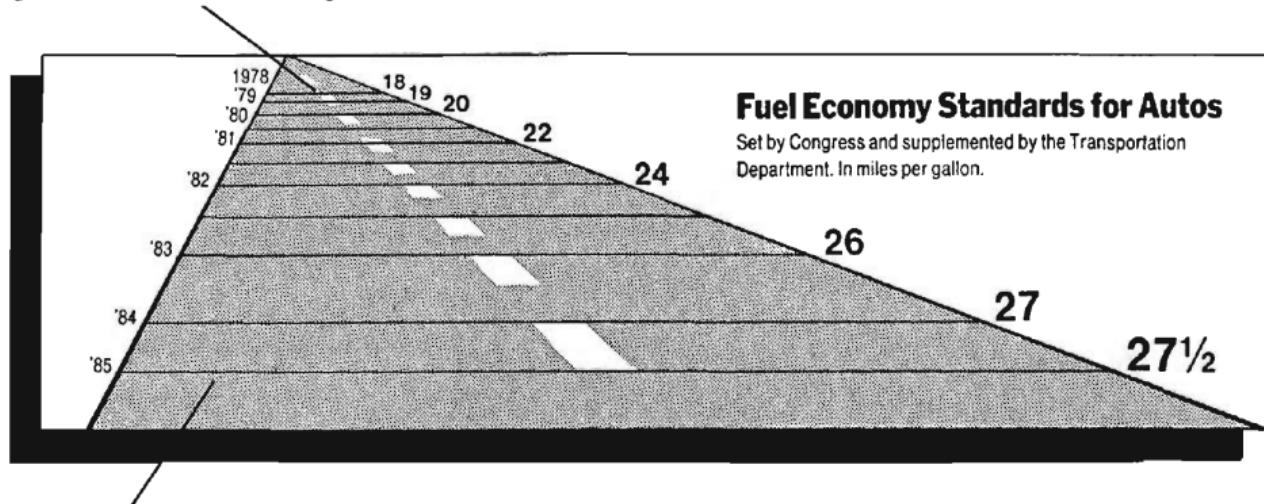
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This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



Source: New York Times, August 9, 1978, page D-2.

The Lie Factor

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$$\text{Lie Factor} = \frac{\text{Size of the effect shown in graphic}}{\text{Size of effect in data}} \quad (1)$$

I think I see that area B
is 3.14 times bigger than
area A. Is that correct?



The Lie Factor

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Effect size in data

$$\frac{27.5 - 18.0}{18.0} = 5.3 \quad (2)$$

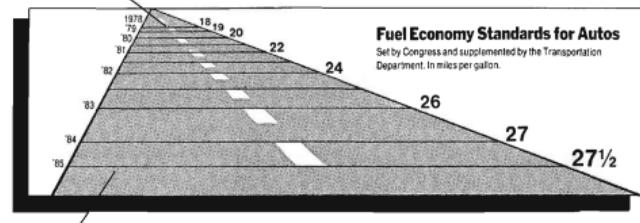
Effect shown in graphic

$$\frac{5.3 - 0.6}{0.6} = 78.3 \quad (3)$$

Lie factor

$$\frac{78.3}{5.3} = 14.8 \quad (4)$$

This line, representing 18 miles per gallon in 1978, is 0.6 inches long.



This line, representing 27.5 miles per gallon in 1985, is 5.3 inches long.

Let Us Redesign the ‘Fuel Economy Standards’ Graph

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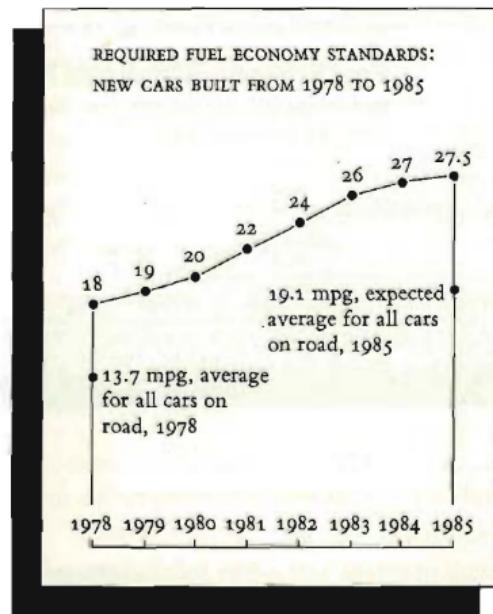
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Tufte points out “*it is easy enough to decorate the data without lying*”



Another Time Series that Lies

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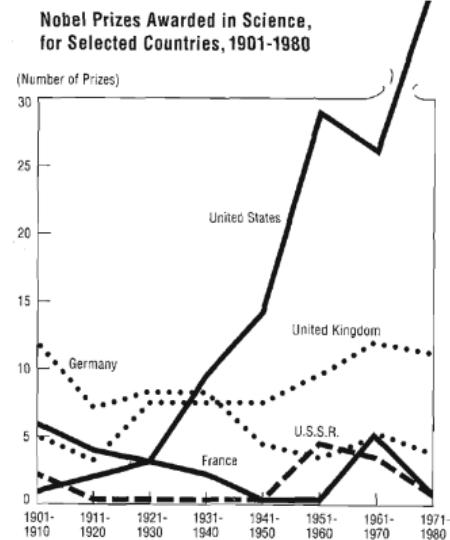
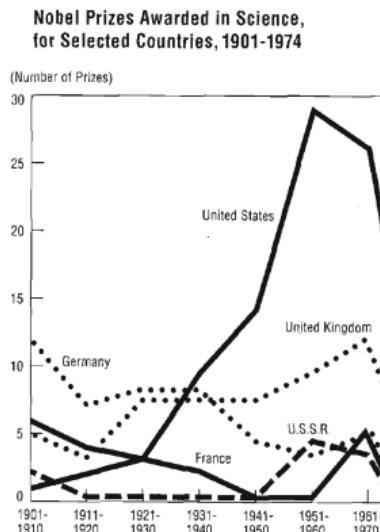
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Source: National Science Foundation, Science Indicators, 1974.

Yet another Time Series that Lies

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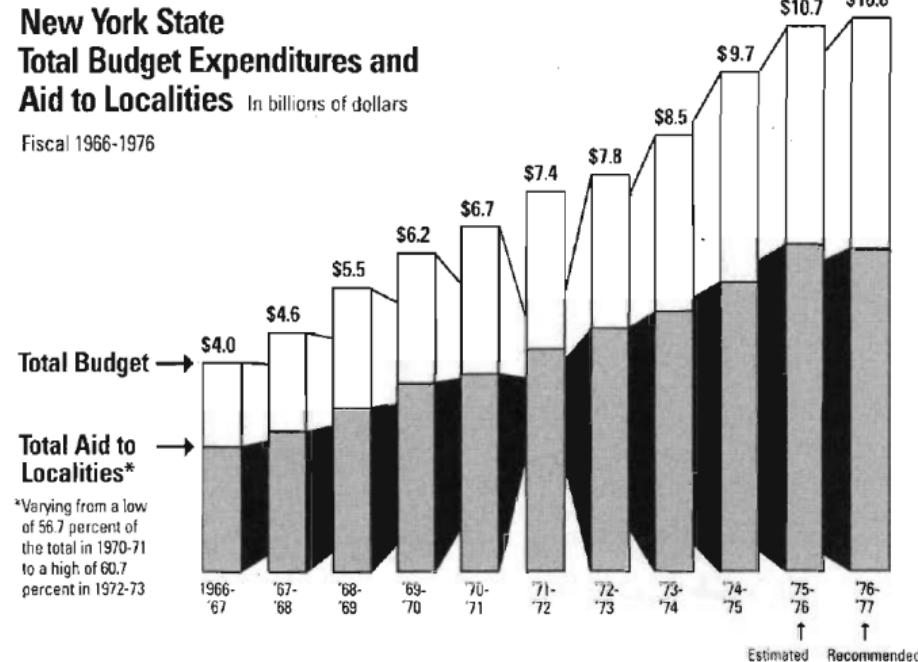
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Source: New York Times, February 1, 1976, page IV-6.

Yet another Time Series that Lies

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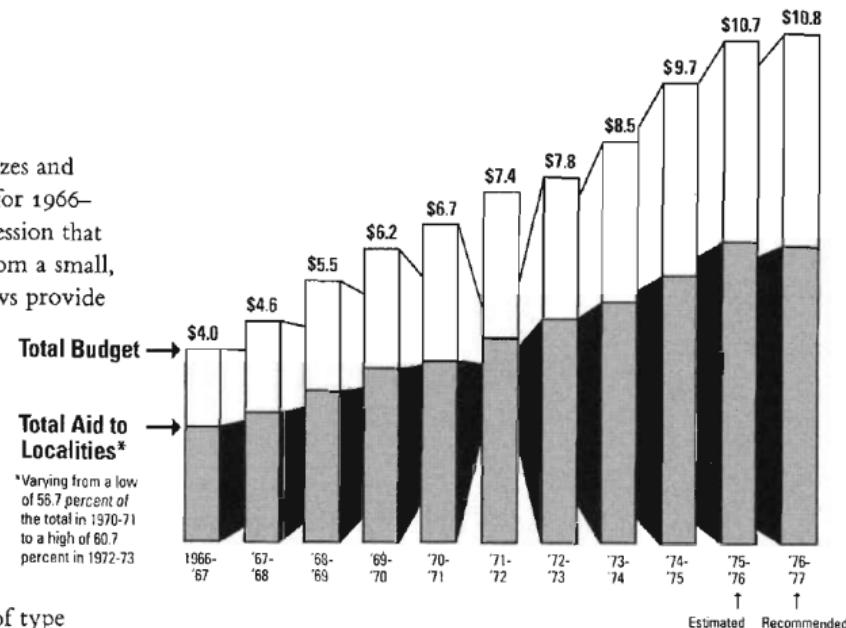
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This cluster of type emphasizes and stretches out the low value for 1966–1967, encouraging the impression that recent years have shot up from a small, stable base. Horizontal arrows provide similar emphasis.



This squeezed-down block of type contributes to an image of small, squeezed-down budgets back in the good old days.

Arrows pointing straight up emphasize recent growth. Compare with horizontal arrows at left.

Chartjunks Distort the Data!

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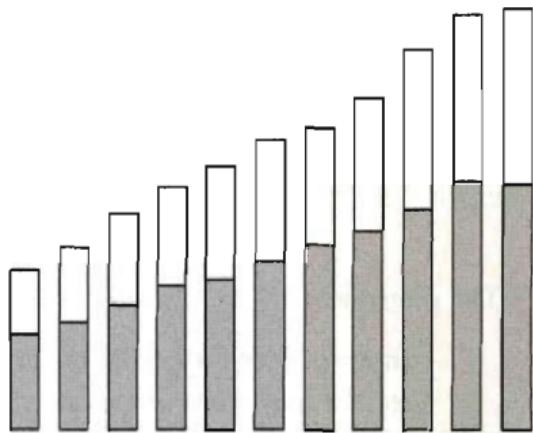
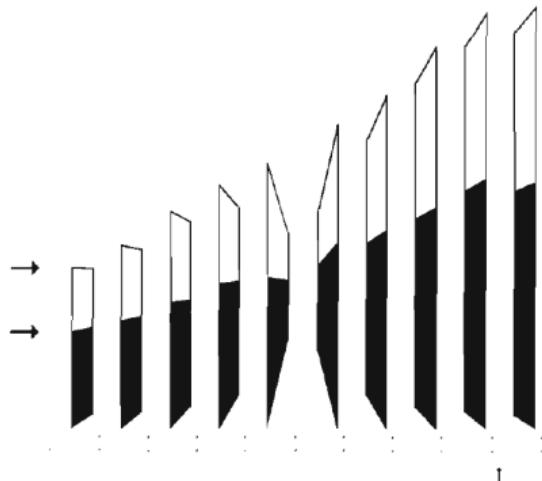
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Let Us Redesign the 'NYS Total Budget Expenditures' Graph

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Per capita
budget expenditures,
in constant dollars



How Can Graphic Mediocrity Be Remedied?

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Graphical competence demands three different skills

- Substantive skills
- Statistical skills
- Design skills

Let Us Redesign the 'NYS Total Budget Expenditures' Graph

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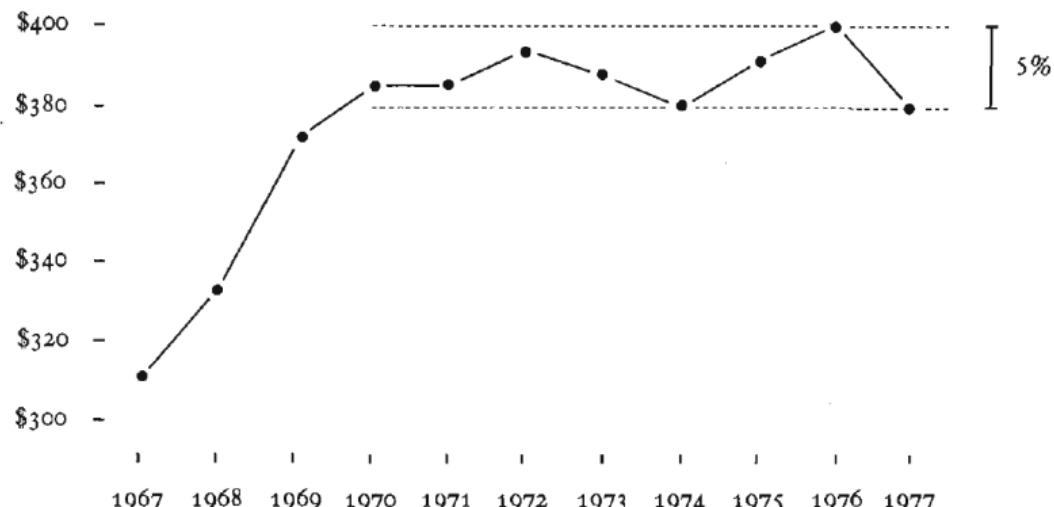
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Per capita
budget expenditures,
in constant dollars



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The Data Visualization Process according to Cairo

Data, information, knowledge, wisdom

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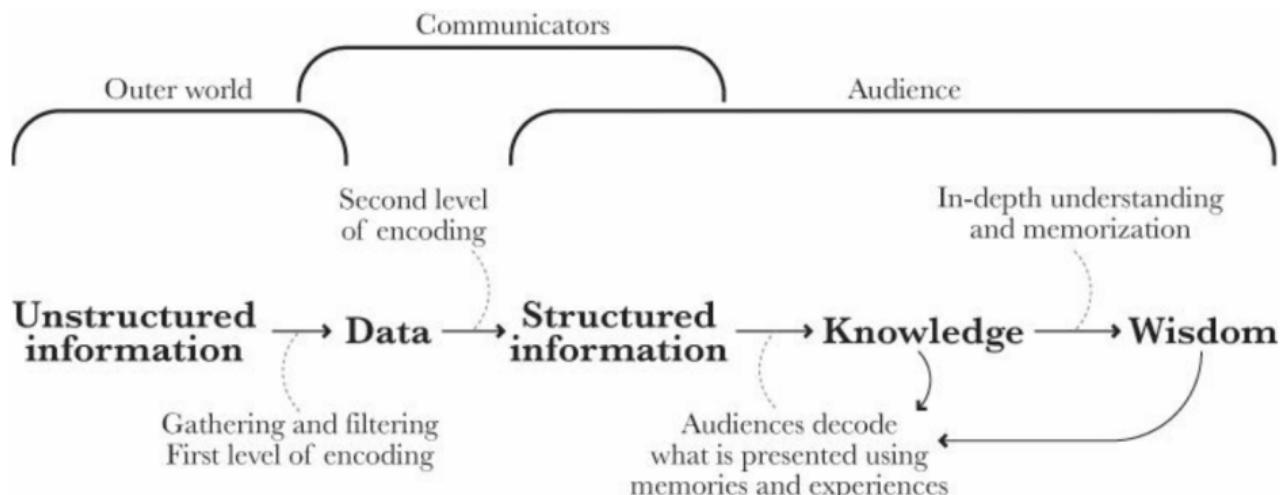


Figure 1.8. From reality to people's brains.

Source is [1, page 29]

How to Navigate the Data Visualization Process?

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Tufte [3, page 92] suggests to adhere to a basic design principle:

Show the data.

The principle is the basis for a theory for a theory of data graphics.

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Fine — So What?!

Maximize the Data-Ink Ratio!!

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$$\text{Data-Ink ratio} = \frac{\text{data-ink}}{\text{total ink used to print the graphic design}}$$

Data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented.

Theee Versions of the Same Scatter Diagram

Low data-ink ratio

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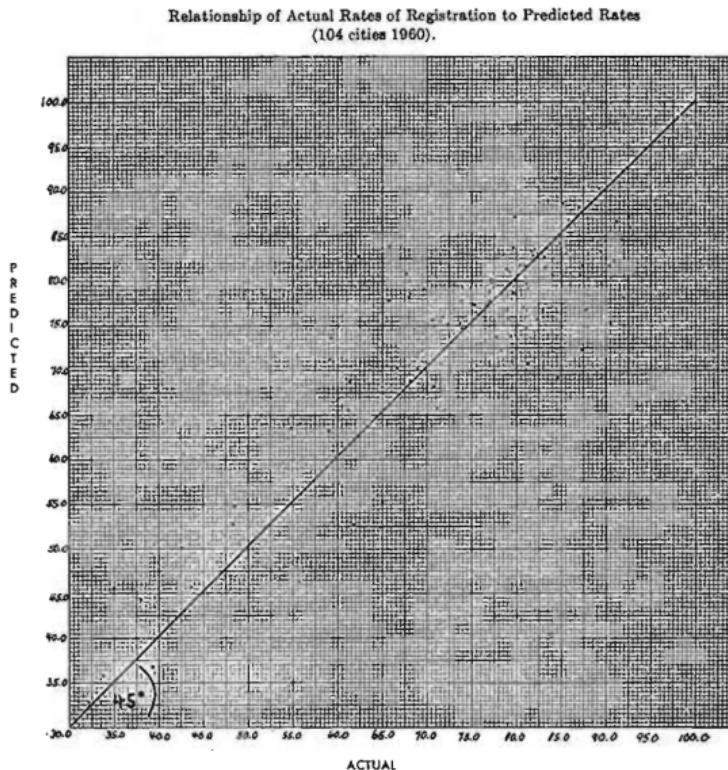
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Theee Versions of the Same Scatter Diagram

Substantial data-ink ratio

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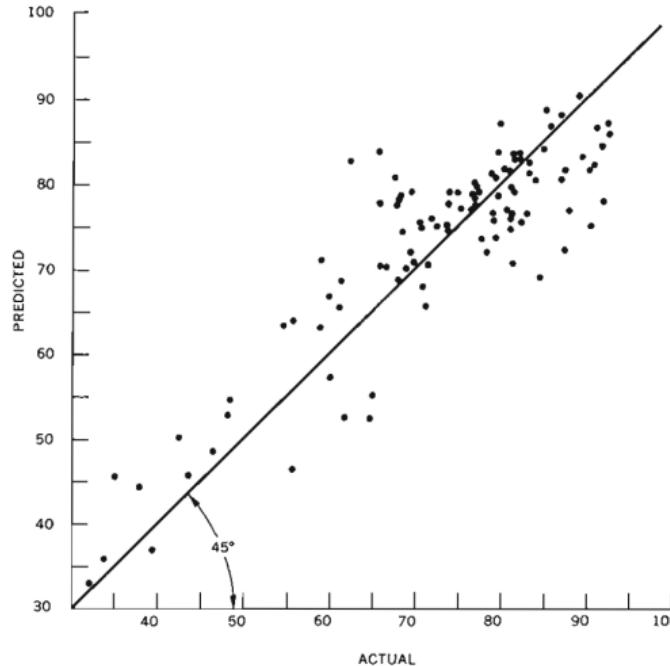
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Relationship of Actual Rates of Registration to Predicted Rates (104 cities 1960).

Theee Versions of the Same Scatter Diagram

Null data-ink ratio

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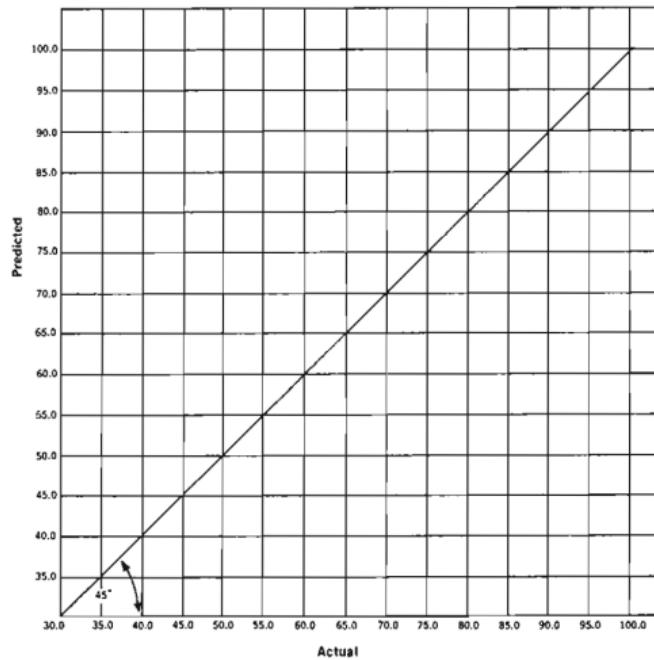
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Figure 19.1 Relationship of Actual Rates of Registration to Predicted Rates
(104 cities, 1960)



How to Improve the Data-Ink Ratio?

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**Pre-chart execution:
careful scoping**

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Pre-chart execution: careful scoping

!! Maximize the data-ink ratio !!

Every bit of ink on a graphic requires
a reason — and the reason should be
that the ink presents new information.

How to Improve the Data-Ink Ratio?

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Pre-chart execution: careful scoping

!! Maximize the data-ink ratio !!

Every bit of ink on a graphic requires
a reason — and the reason should be
that the ink presents new information.

Post-chart execution: critical assessment

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Pre-chart execution: careful scoping

!! Maximize the data-ink ratio !!

Every bit of ink on a graphic requires a reason — and the reason should be that the ink presents new information.

Post-chart execution: critical assessment

!! Erase the non data-ink !!

Non data-ink data clutters up the data, as is the case of a thick mesh of grid lines, or gratuitous decorations.

How to Improve the Data-Ink Ratio?

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Pre-chart execution: careful scoping

!! Maximize the data-ink ratio !!

Every bit of ink on a graphic requires a reason — and the reason should be that the ink presents new information.

Post-chart execution: critical assessment

!! Erase the non data-ink !!

Non data-ink data clutters up the data, as is the case of a thick mesh of grid lines, or gratuitous decorations.

!! Erase redundant data-ink !!

Bilateral symmetry of data measures also creates redundancy as in the box plot and the open bar.

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Chartjunk? Give me a Break!!

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“The interior decoration of graphics generates a lot of ink that not thell the viewer anything new. The purpose of decoration varies — to make the graphic appear more scientific and precise, to enliven the display, to give the designer an opportunity to exercise artistics skills. Regardless of its cause, it is all non data-data-ink or redundant data-ink, and it is often chartjunk.”

— Source is [3, page 107]

Moiré Effects

...geometric shapes creating a sense of movement

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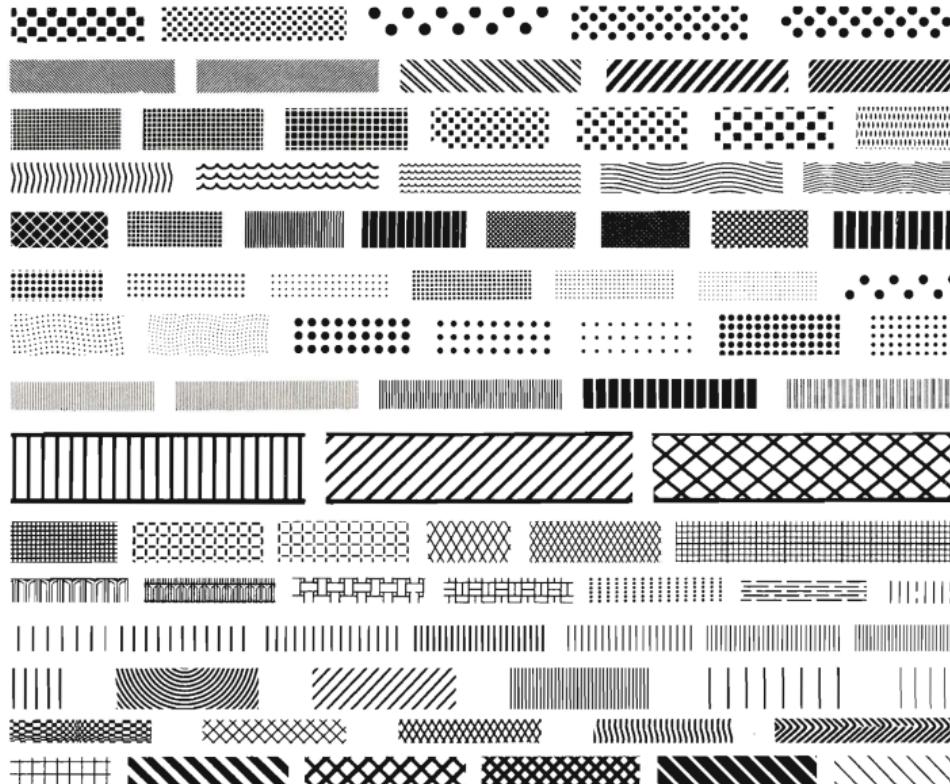
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Get Rid of Moiré Effects

Example 1 — Source is “Instituto de Expansao Commercial (1929)”

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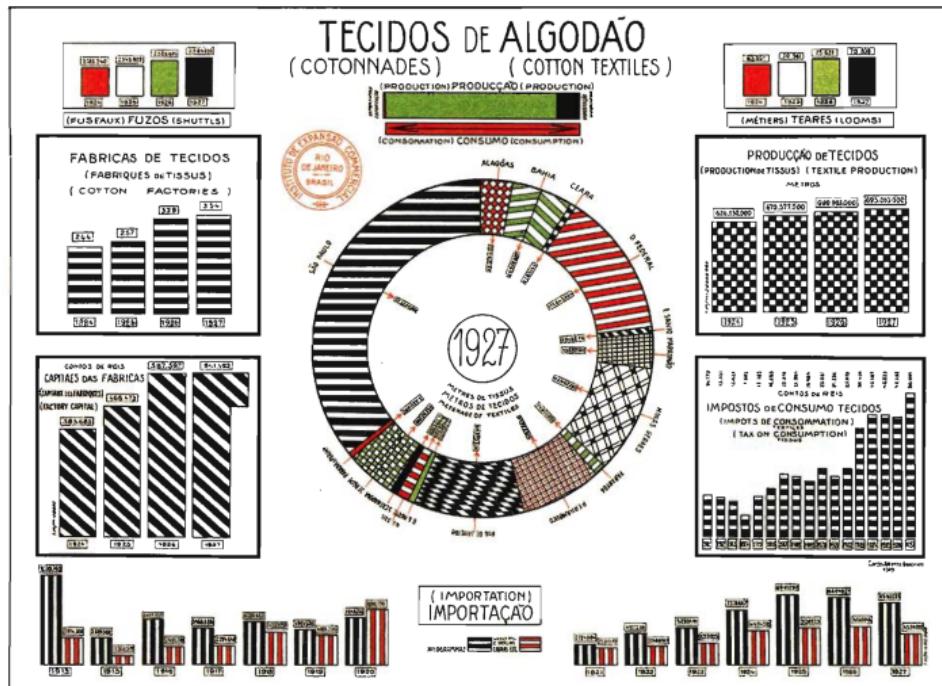
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Get Rid of Moiré Effects

Example 2 — Source is "Kouchoukos et al. (1994), New England Journal of Medicine"

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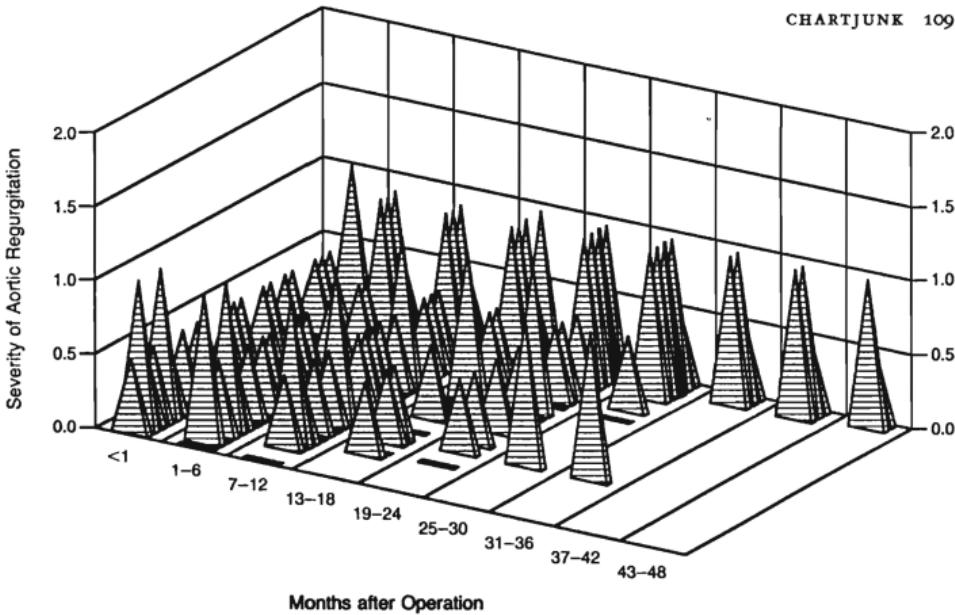


Figure 2. Serial Echocardiographic Assessments of the Severity of Regurgitation in the Pulmonary Autograft in 31 Patients.
The numerical grades were assigned according to the severity of regurgitation, as follows: 0, none; 0.5, trivial; 1.0 to 1.5, mild; 2.0, moderate; and 3.0, severe.

Get Rid of Moiré Effects

Example 3 — Source is “JASA style sheet (1976), Journal of the American Statistical Association”

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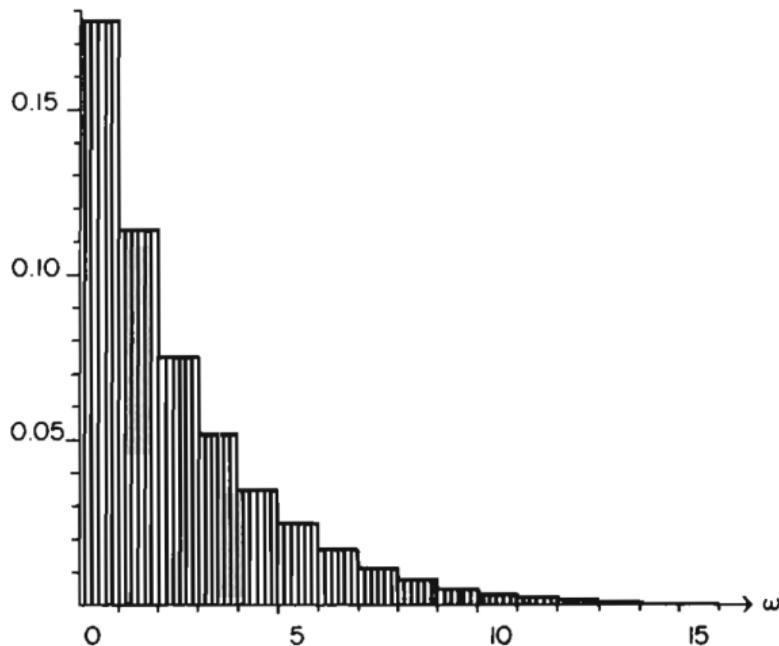
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A. Average Probabilities of W from $N(1,1)$
with $n = 10$

AVERAGE PROBABILITY



Use Grids Conscientiously

Example — Source is “Institut National de la Statistique et des Études Économiques”

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Excellence

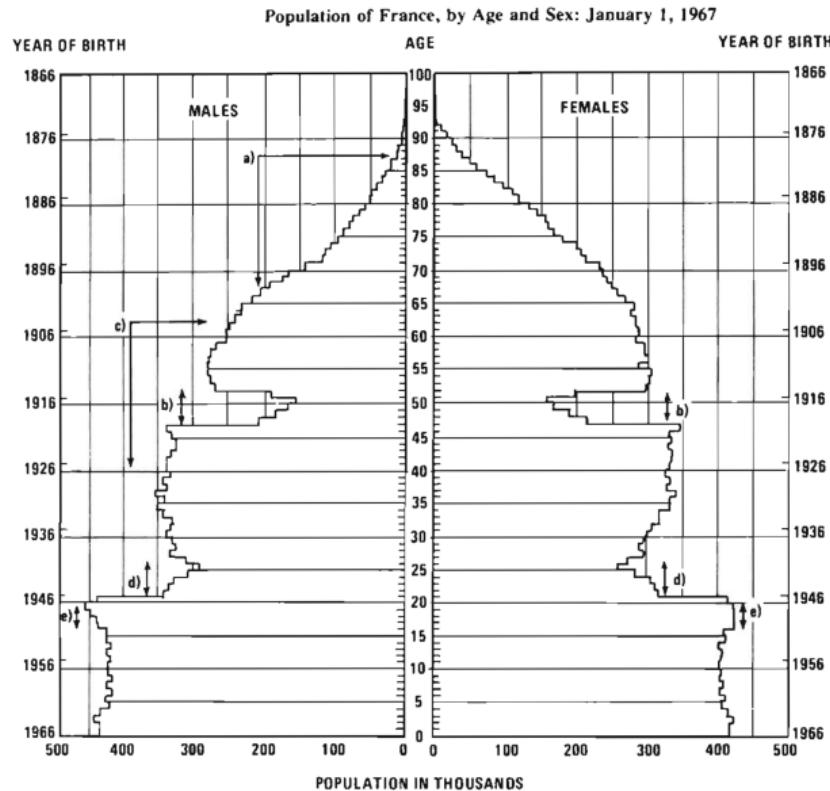
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Use Grids Conscientiously

Redesigning the previous example

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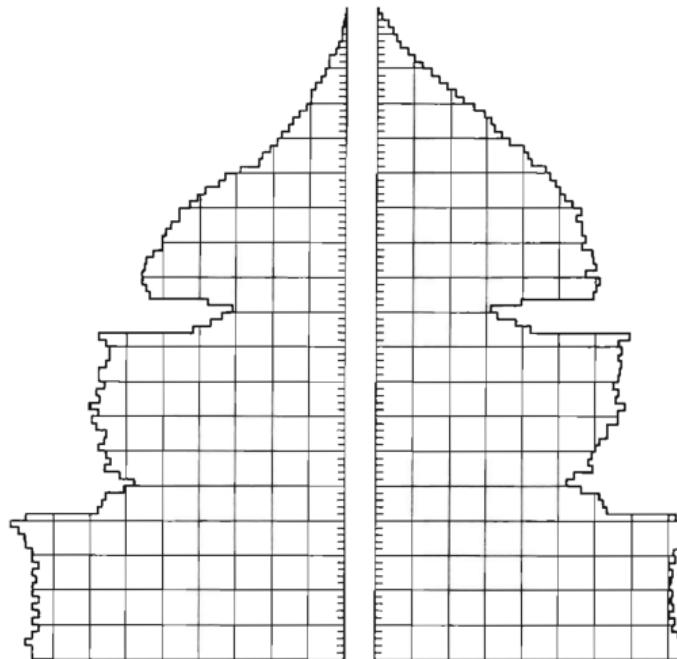
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Have You Created a 'Duck Chart'?

Big Duck, Flanders, New York, photograph by Edward Tufte, July 2000.

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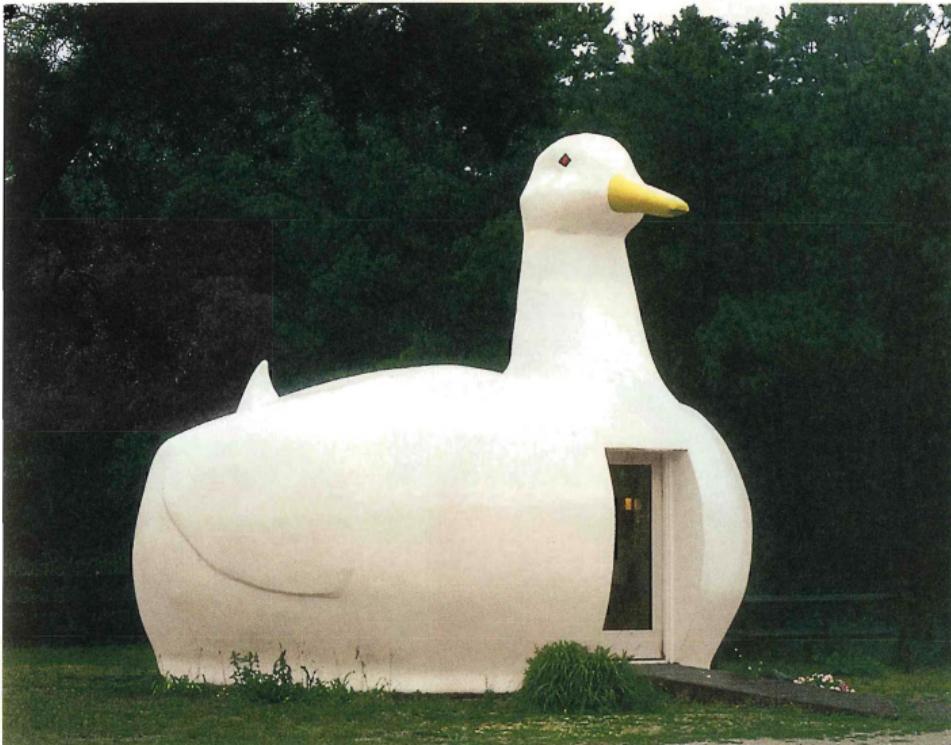
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An Example of 'Duck Chart'

Source is [3, page 118]

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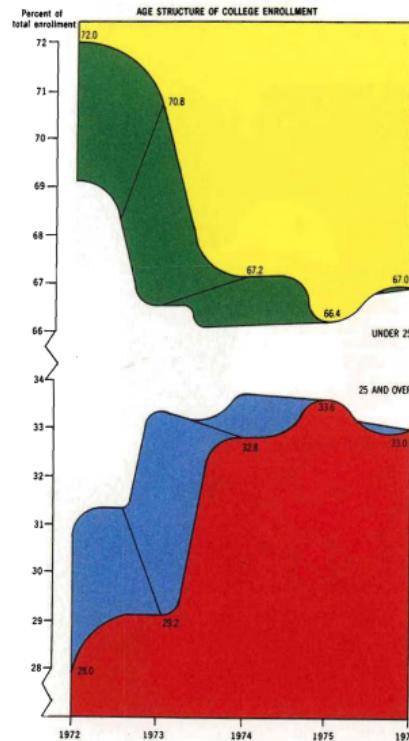
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Outline

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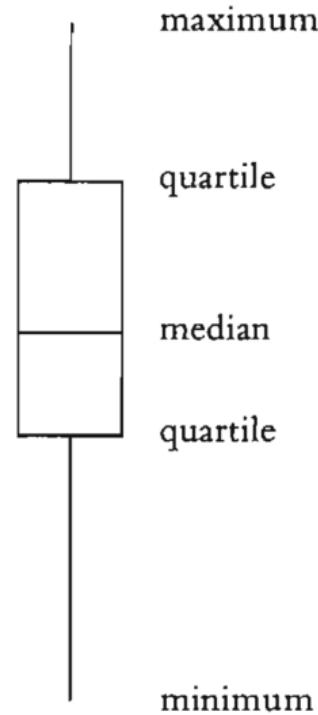
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5 Redesigning Statistical Charts

John Tukey's Box Plot



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A Box Plot with a Limited Data-Ink Ratio

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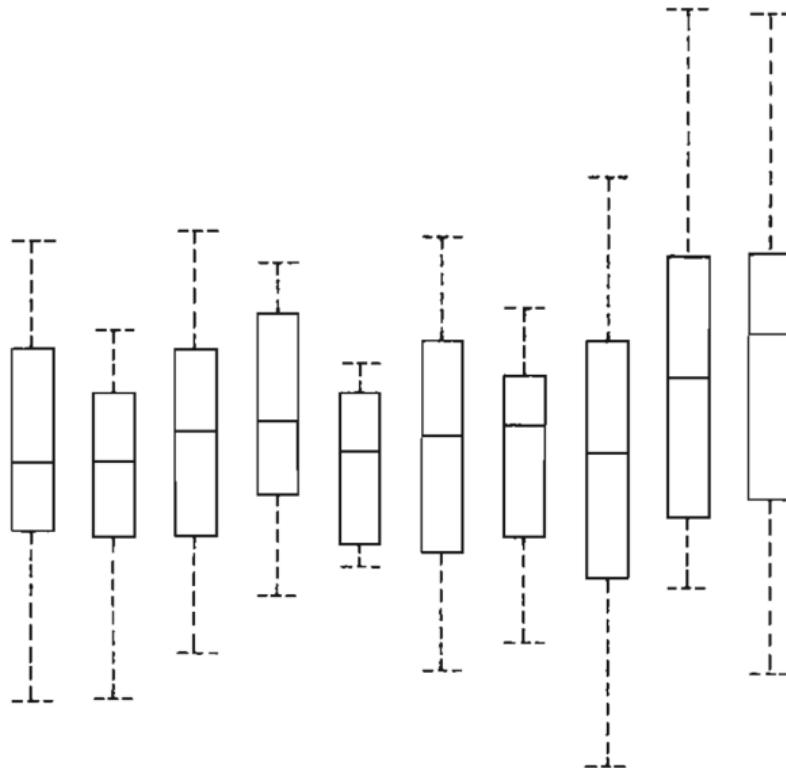
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Tufte-Alike Box Plot

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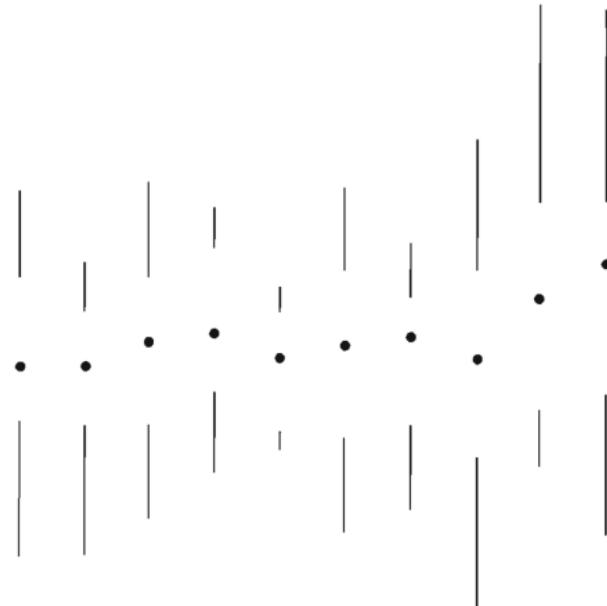
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A Bar Chart with a Limited Data-Ink Ratio

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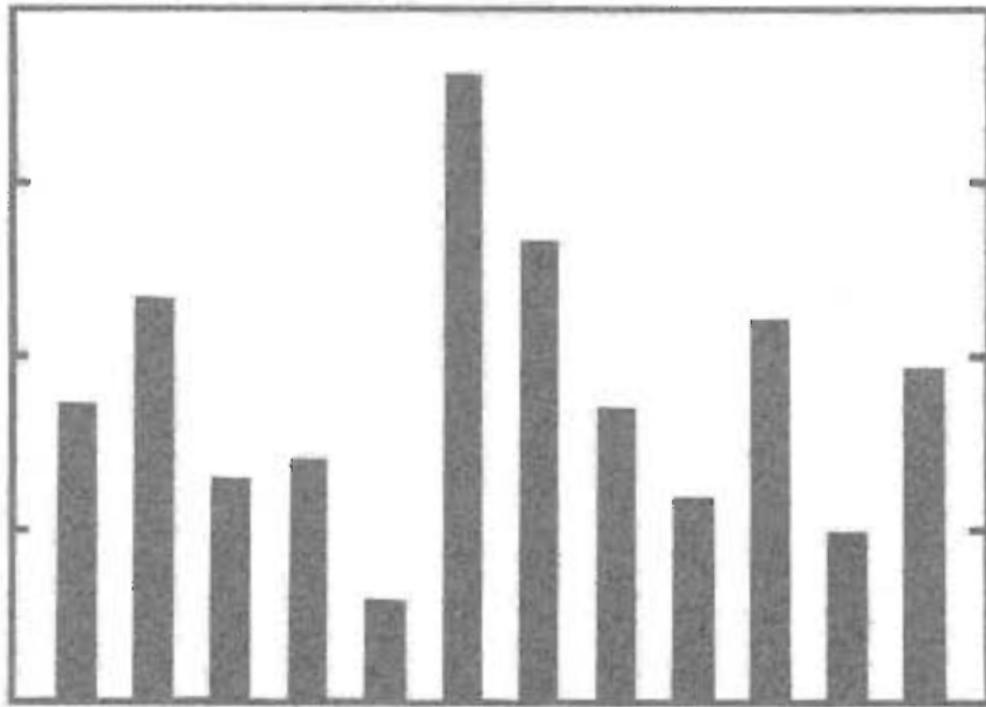
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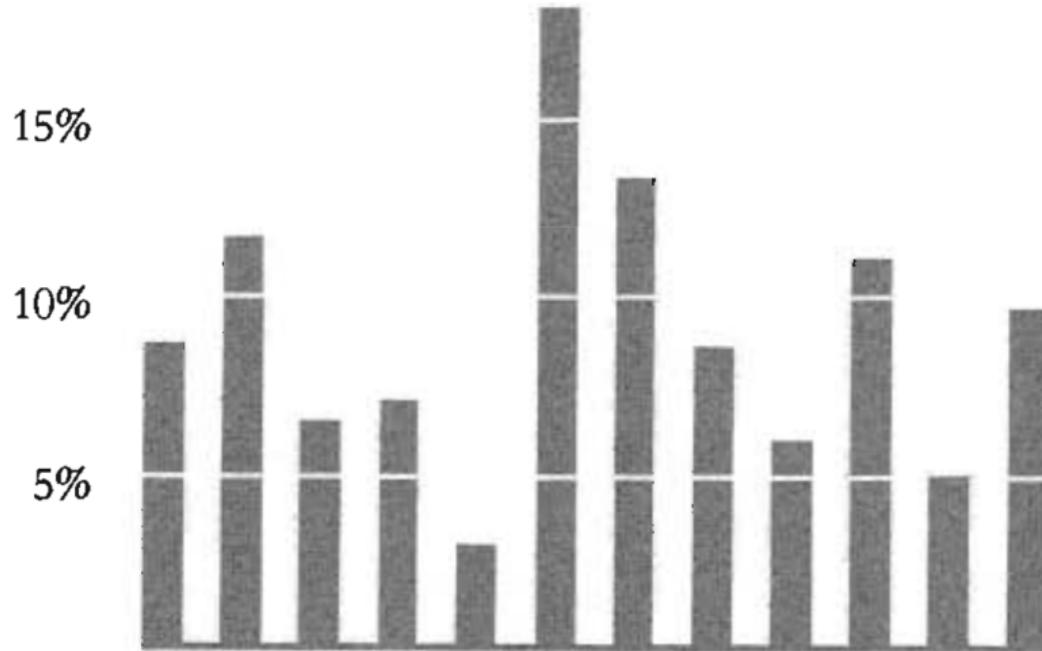
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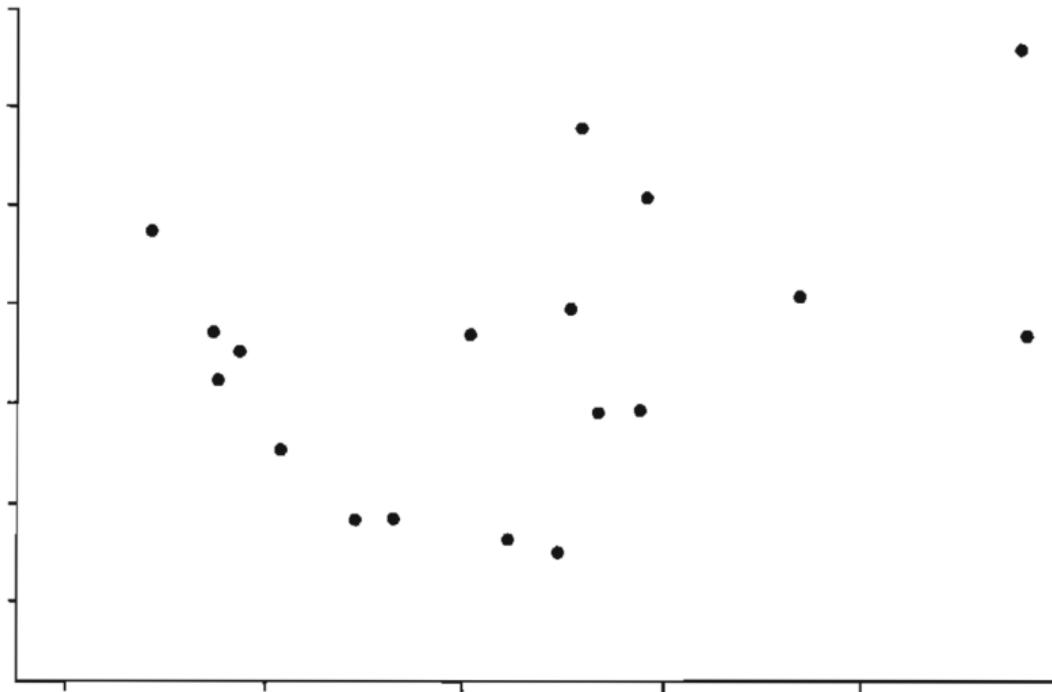
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A Bare-Bone Scatter Diagram

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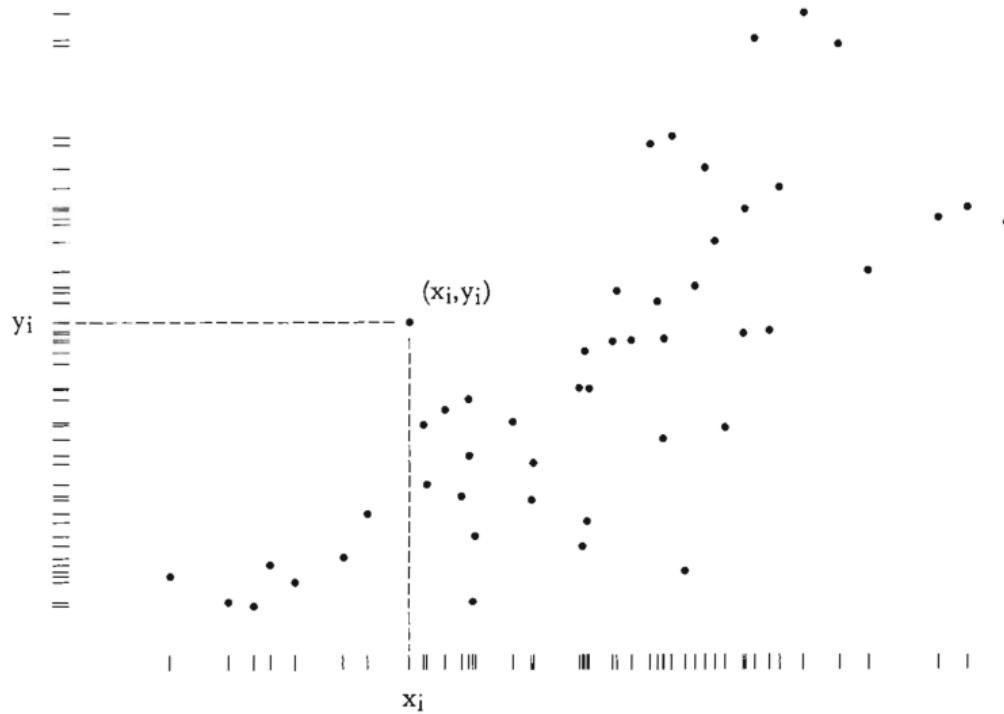
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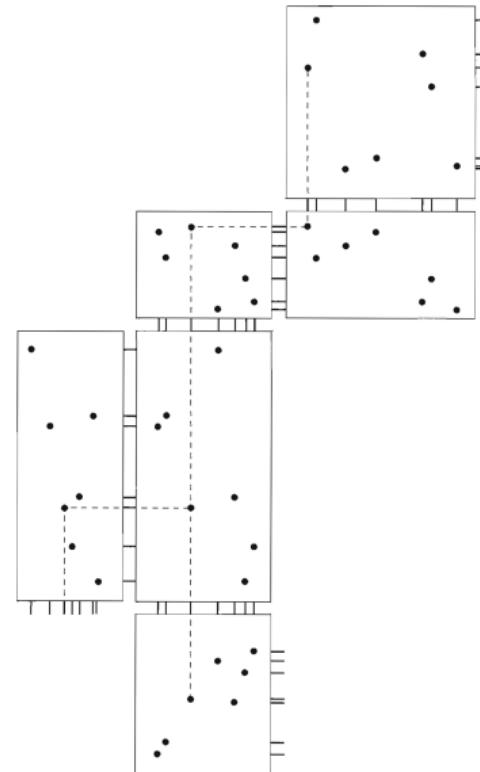
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Tufte-Alike Scatter Diagram



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- [2] “Graphs in Statistical Analysis”. In: *American Statistician* 27 (February 1973), pp. 17–21.
- [3] *The Visual Display of Quantitative Information*. Second edition. Graphics Press LLC, 2001.