Elective in Software and Services
(Complementi di software e servizi per la società dell'informazione)

Section **Information Visualization**

Numbers of credit : 3

Giuseppe Santucci

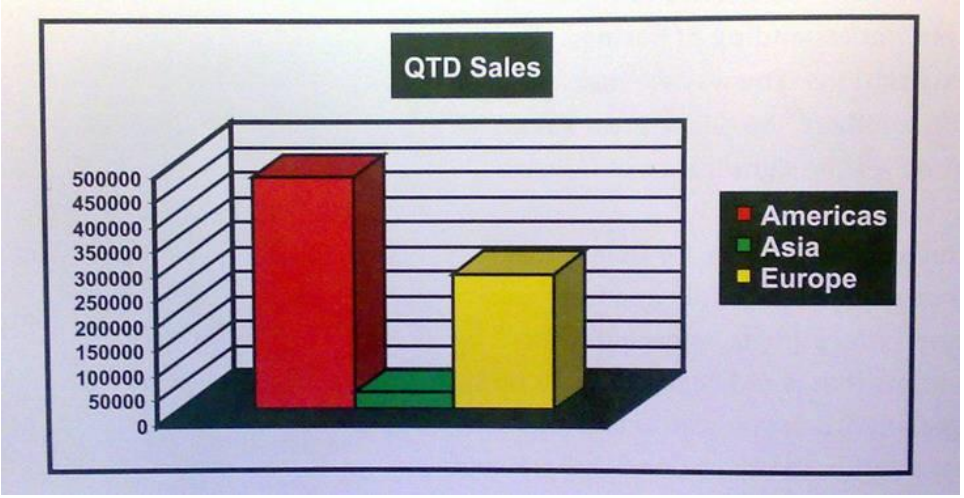
3 – Visualizing quantitative Information

Outline

- New ideas about good and bad graphs
- Meaning of numbers
- Tables and graphs
- Basic table variations
- Basic graph variations

An example

- You are a manager of a big company
- You need to control and to report, every Monday, the current state of quarterly sales in the Americas, Asia, and Europe, with the goal of verifying your forecast
- Someone presents you with this graph



- Are you happy with it?
- Think how to design something that is more informative for your job

All the needed information

2003 Q1-to-Date Regional Sales

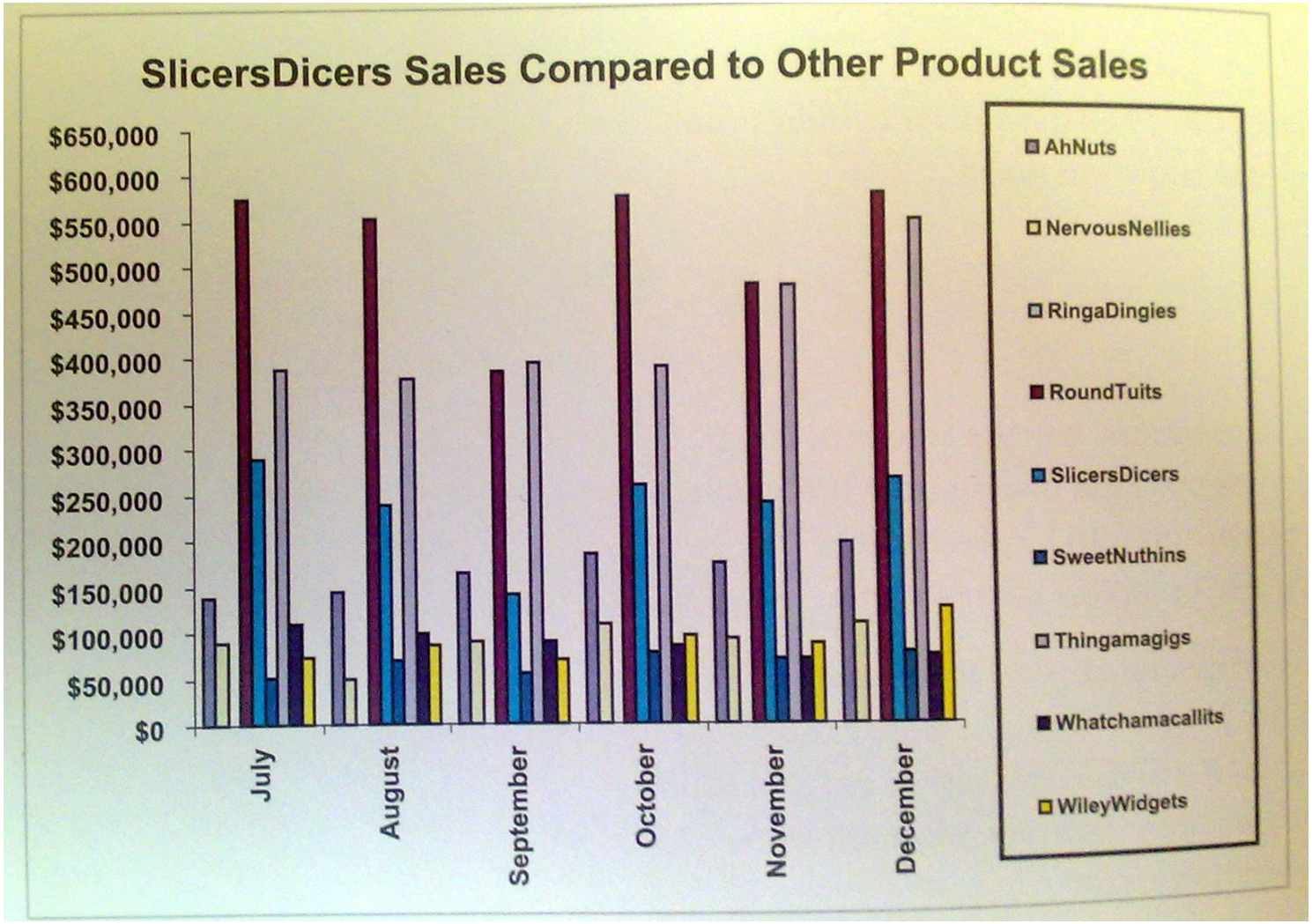
March 15, 2003

	Sales (U.S. $)	Percent of Total Sales	Current Percent of Qtr Plan	Projected Sales (U.S. $)	Qtr End Projected Percent of Qtr Plan
Americas	469,384	60%	85%	586,730	107%
Europe	273,854	35%	91%	353,272	118%
Asia	34,847	5%	50%	43,210	62%
	$778,085	100%	85%	$983,212	107%

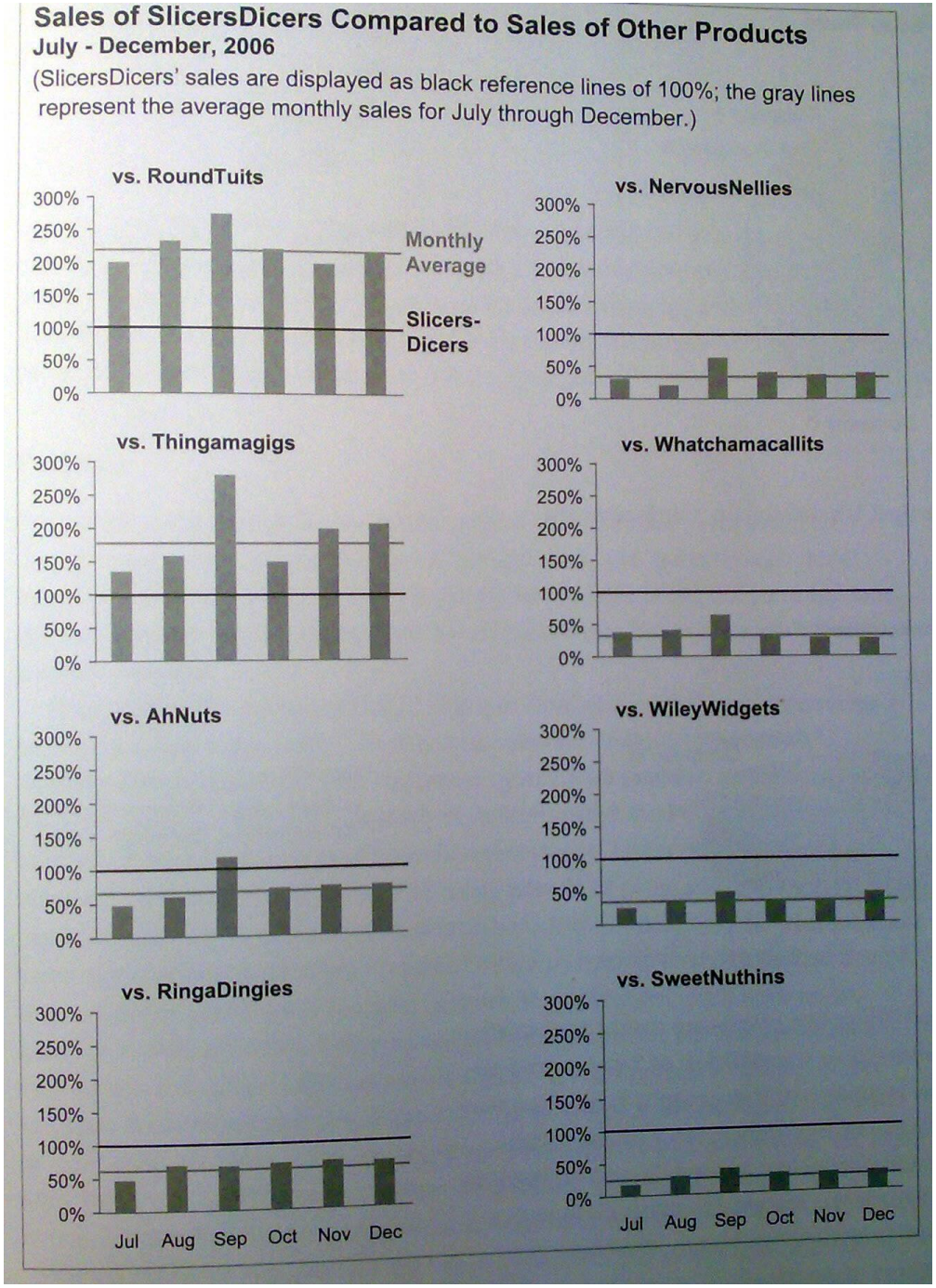
Note: To date, 83% of the quarter has elapsed.

- Units !
- The actual date !
- Some additional summarizing information (percentage)
- Planned sales vs actual sales

Another example



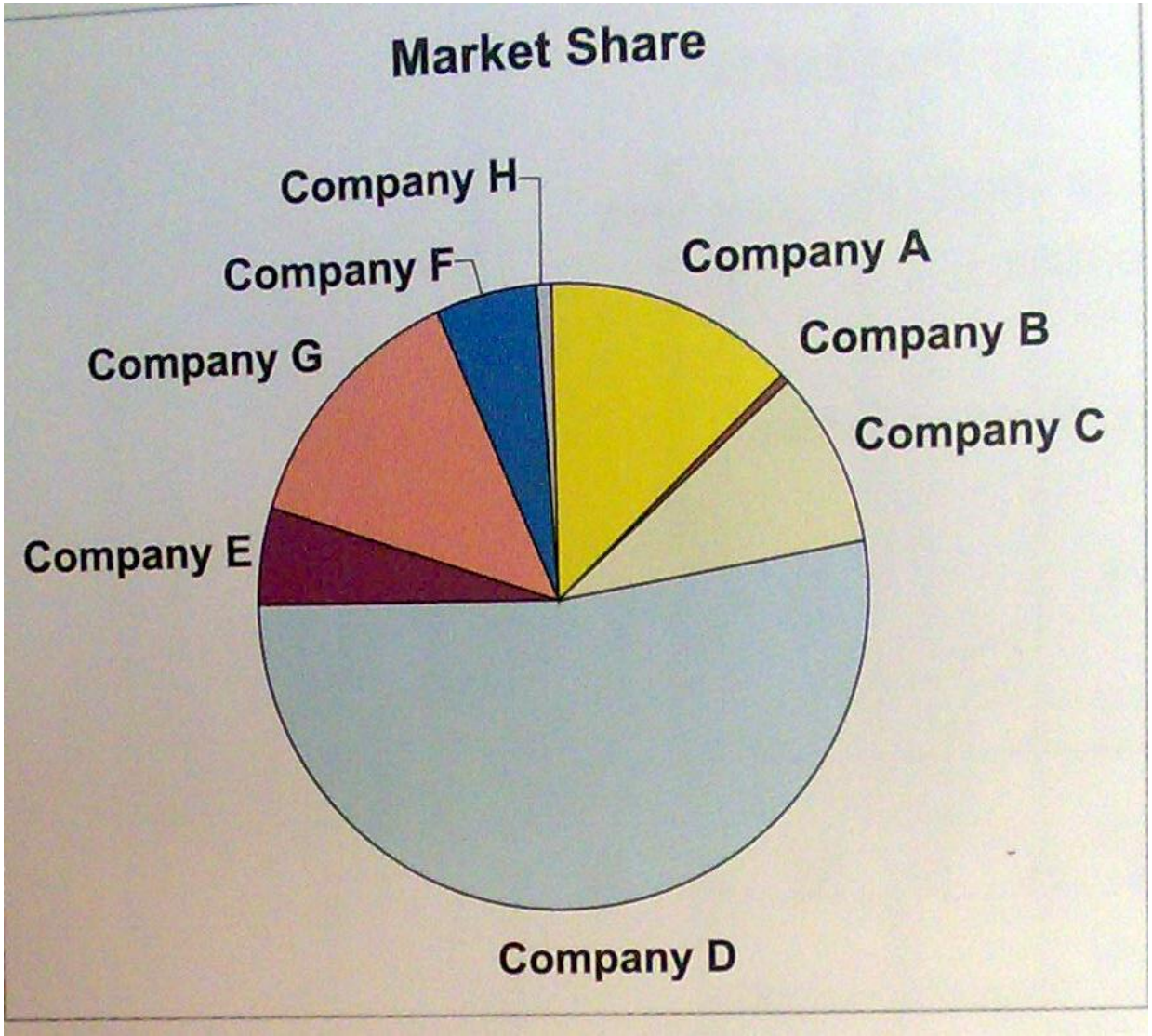
- Is it ok?
- Try to design a better bar chart
- The focus is the comparison



Comparison !

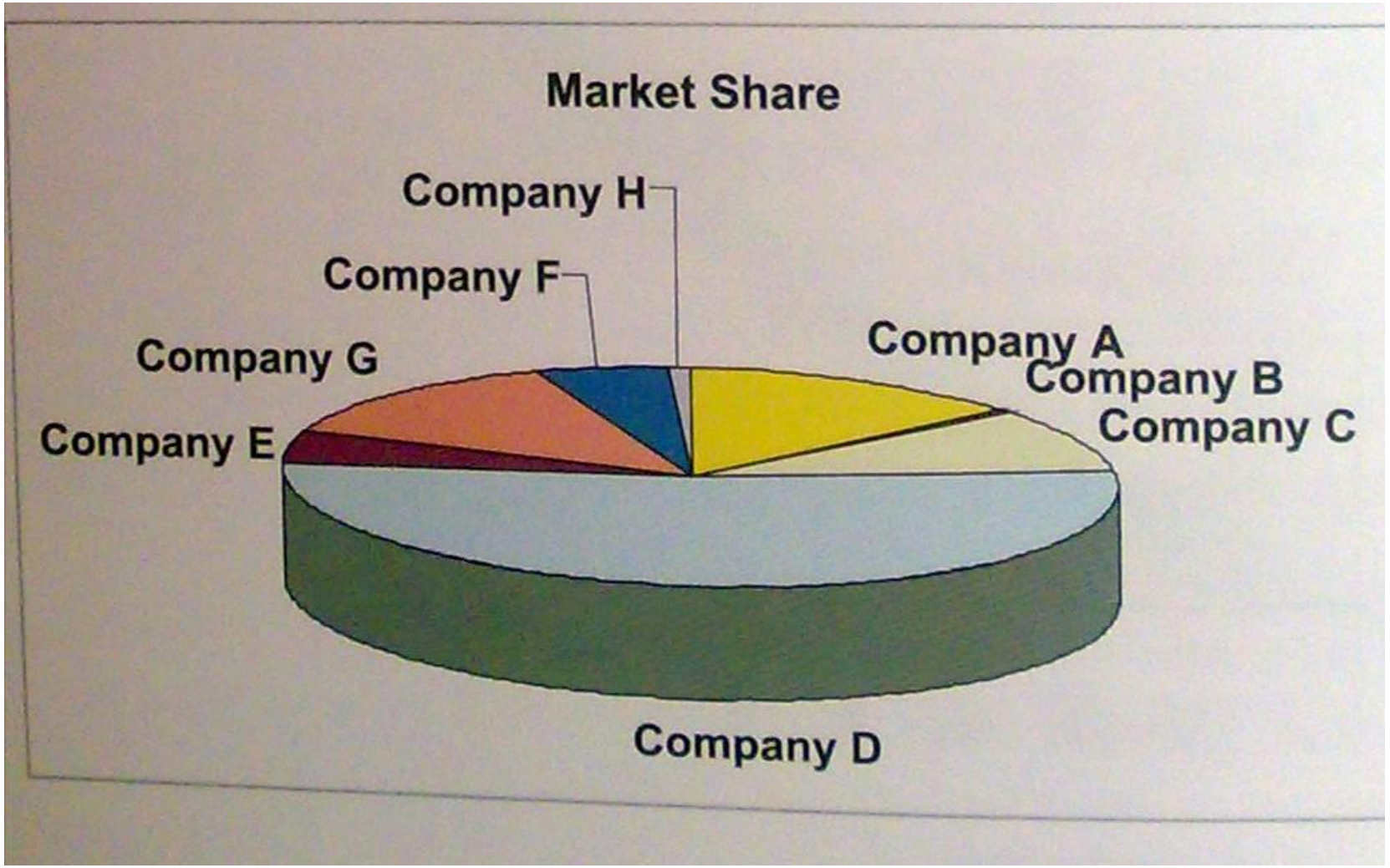
- A possible solution using percentages

The last example: our company against the world!

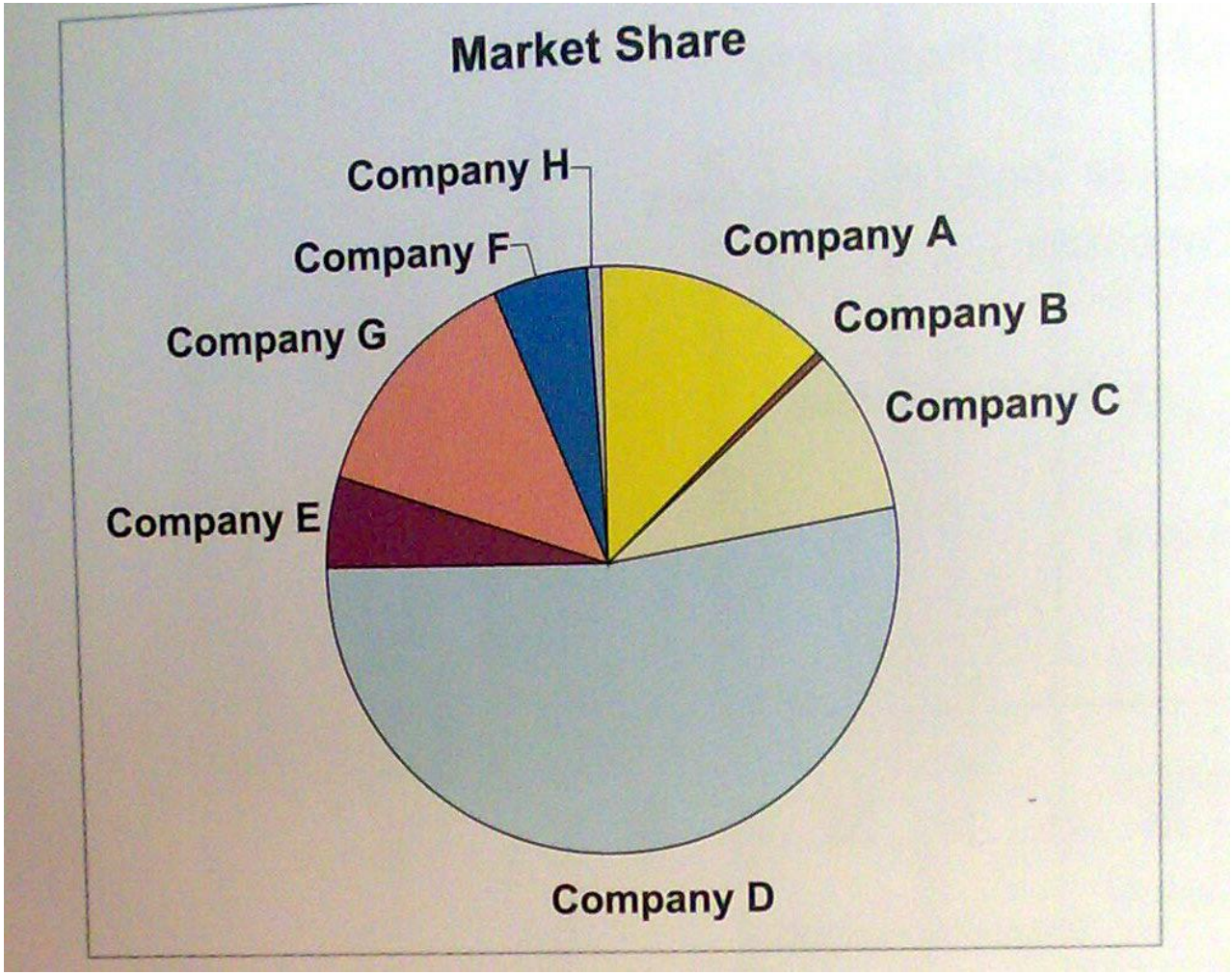


- What is the purpose of this chart?
- Comparison !
- What is wrong whit it?

Even worst : 3D!!!

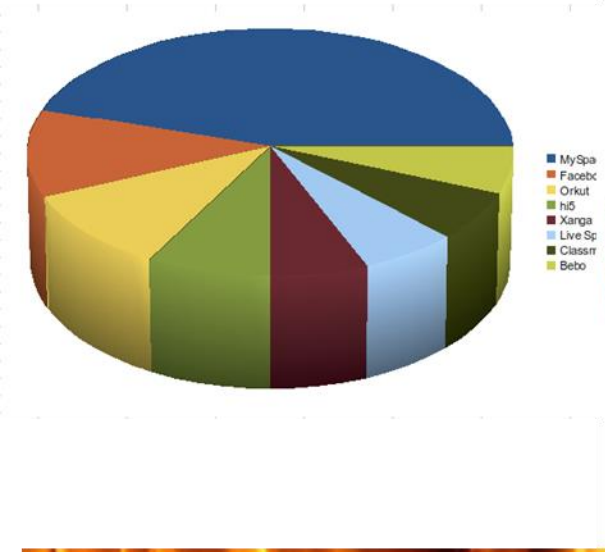


The last example



- Is the order clear?
- Which is my company?
- Who is bigger G or A?

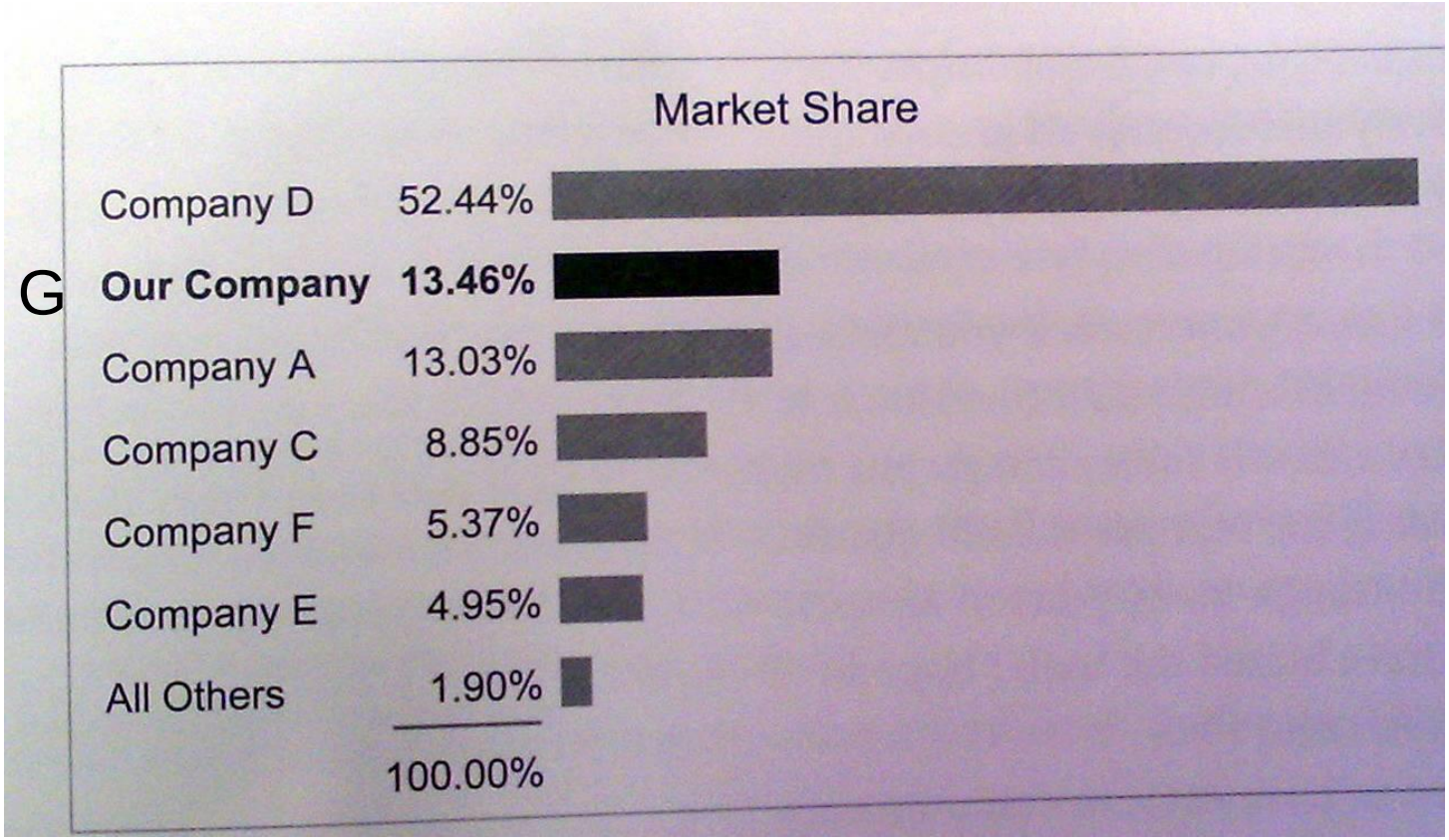
I 
HATE
pie charts!


MySpa
Faceb
Orkut
hi5
Xanga
Live Sp
Classm
Bebo


Product Y
$12,000
$30,000
$23,000
17,000
$21,000
$30,000

At least most of them...

A better solution

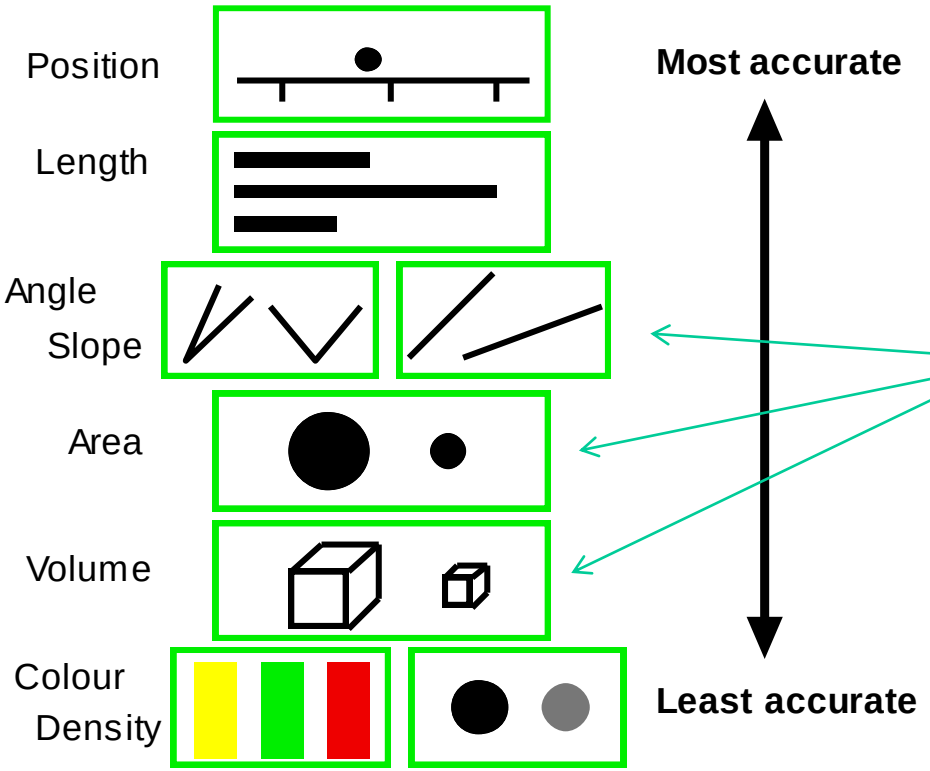


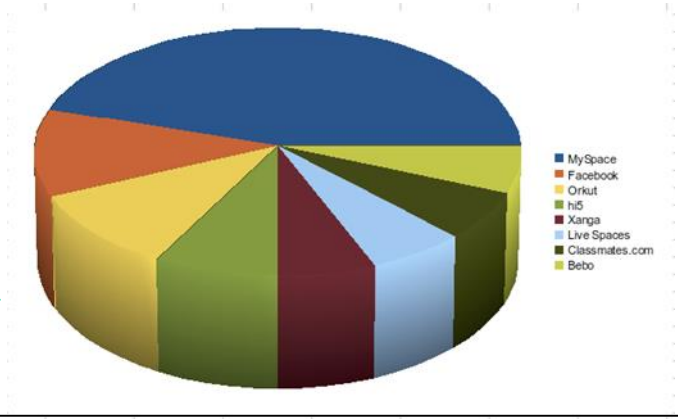
If you have ordering (ranking) alternatives think about that!

Why do I 

pie-charts?

The relative difficulty of assessing **quantitative** value as a function of visual encoding mechanism, as established by Cleveland and McGill

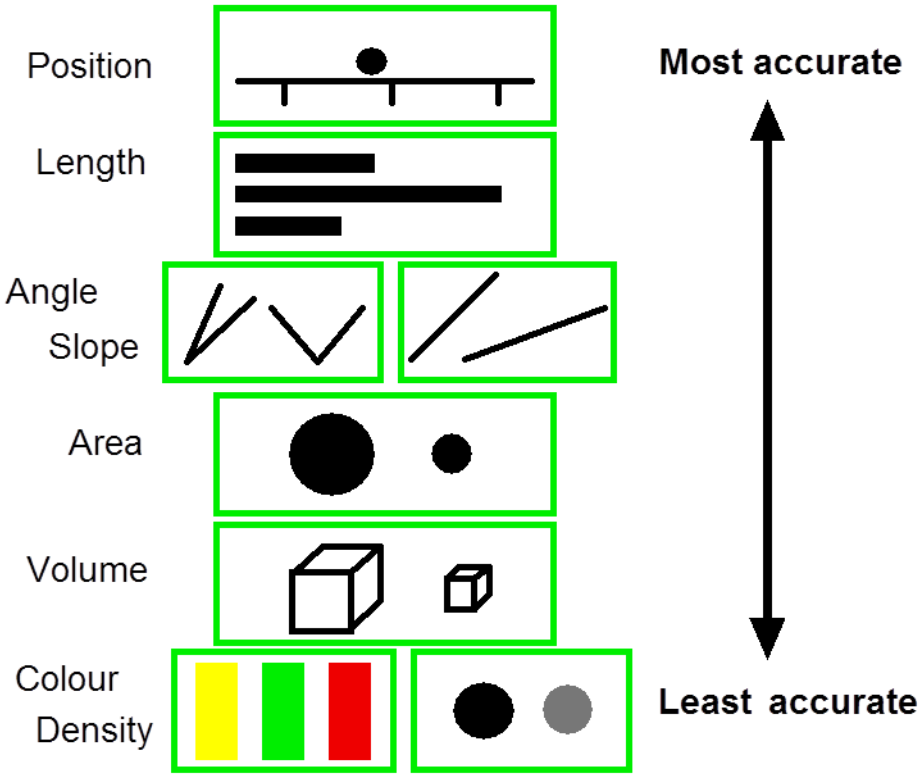




Pie-charts discards the two first choices

I do NOT see ANY reason to use them

What about quantitative comparison?

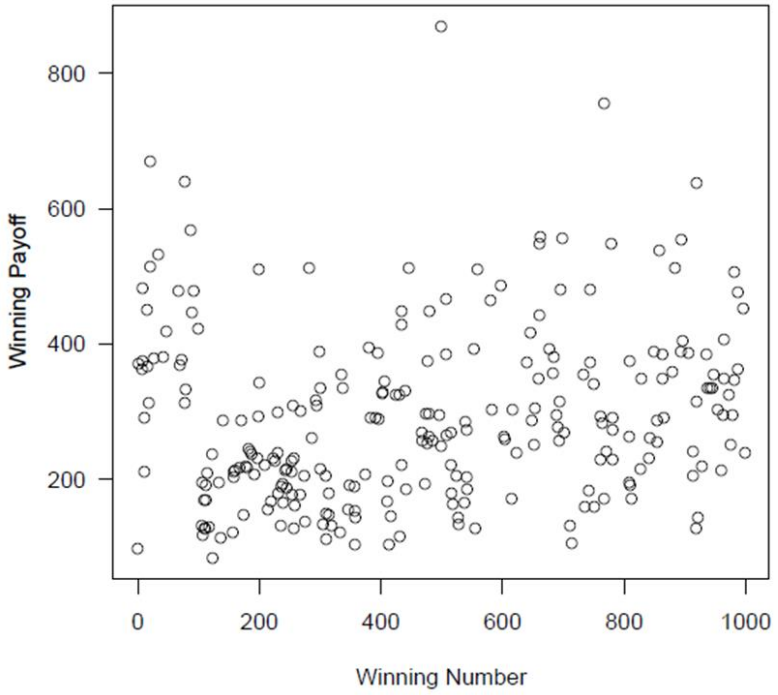


Use position and length
Avoid angles
Avoid areas
Avoid volumes

Use colors carefully

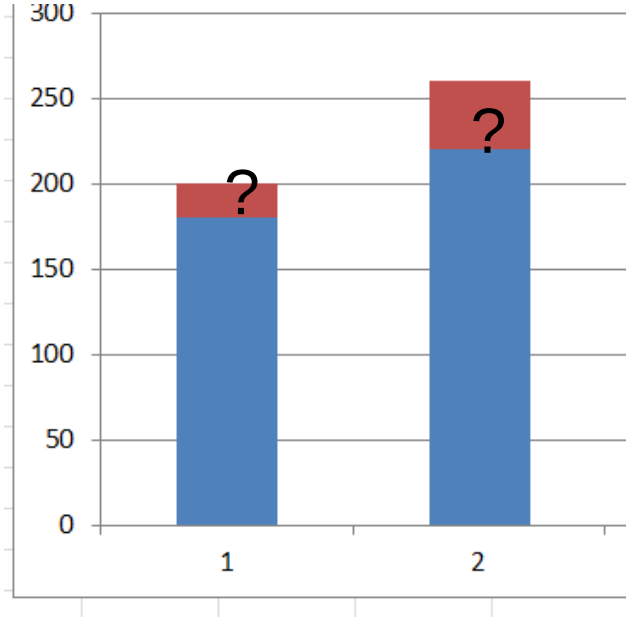
Position

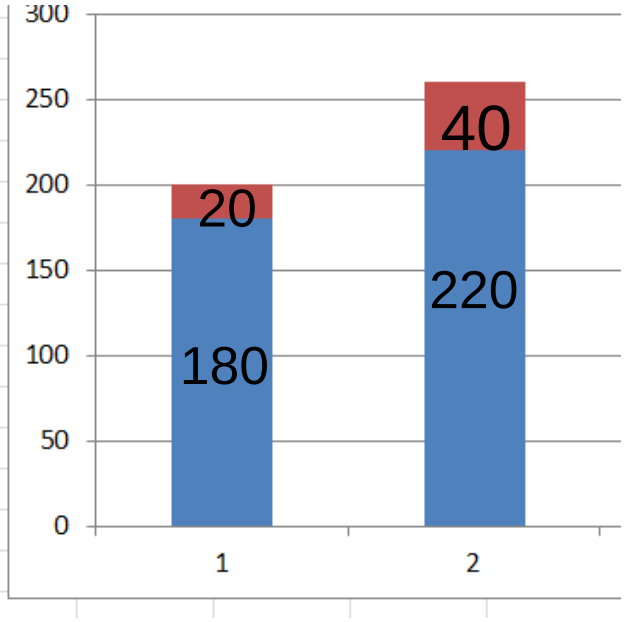
- It works fine



Length?

- The lookup of precise number might be difficult if the position is not evident (e.g., stacked bar chart)

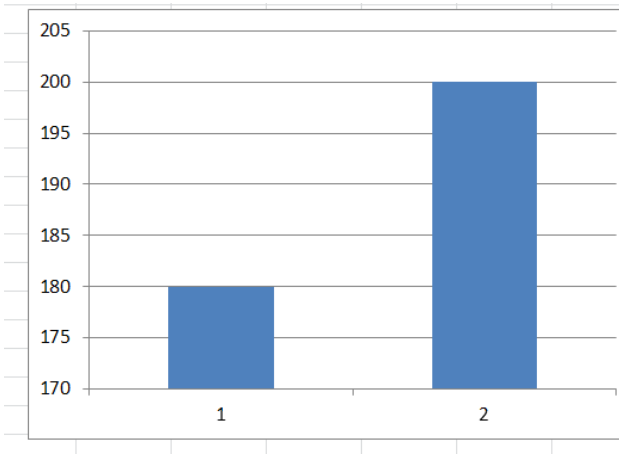




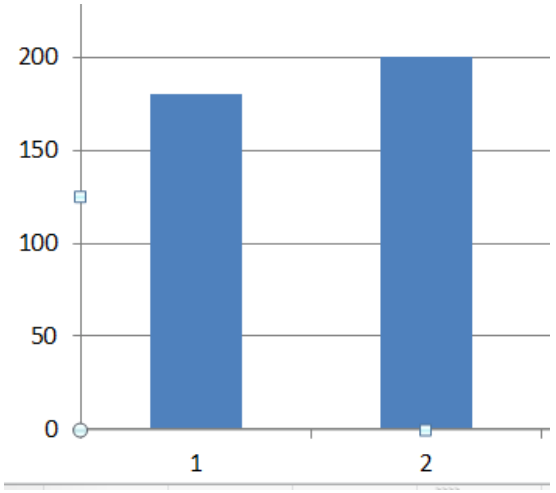
It makes sense to explicitly add figures

Length?

- Length is fine as well , but use the right scale!



Automatically produced by Excel



The reality

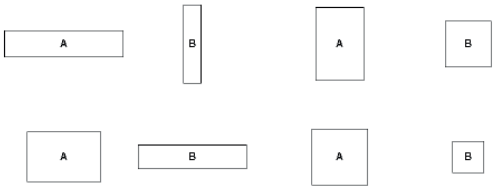
Areas: some new surprising issues

- Human being are very bad in estimating area ratios

- What is the ratio between this two circles?

  35% 40% 45% 50% 55% 60% ?

- What is the shape that produces the biggest error?



- The square!
- Perceptual Guidelines for Creating Rectangular Treemaps (Nicholas Kong et al., Infovis 2010)

Colors / Numerical data

- Someone already thought how to associate quantitative values to colors and different choices are available
- Do not reinvent the wheel
- (The rainbow scale does not work)

rainbow scale

HSI color model
(Keim and Kriegel) - Issues in visualizing large databases. Proc. of the IFIP working conference on Visual database Systems, 1995

Other choices (Colin Ware)

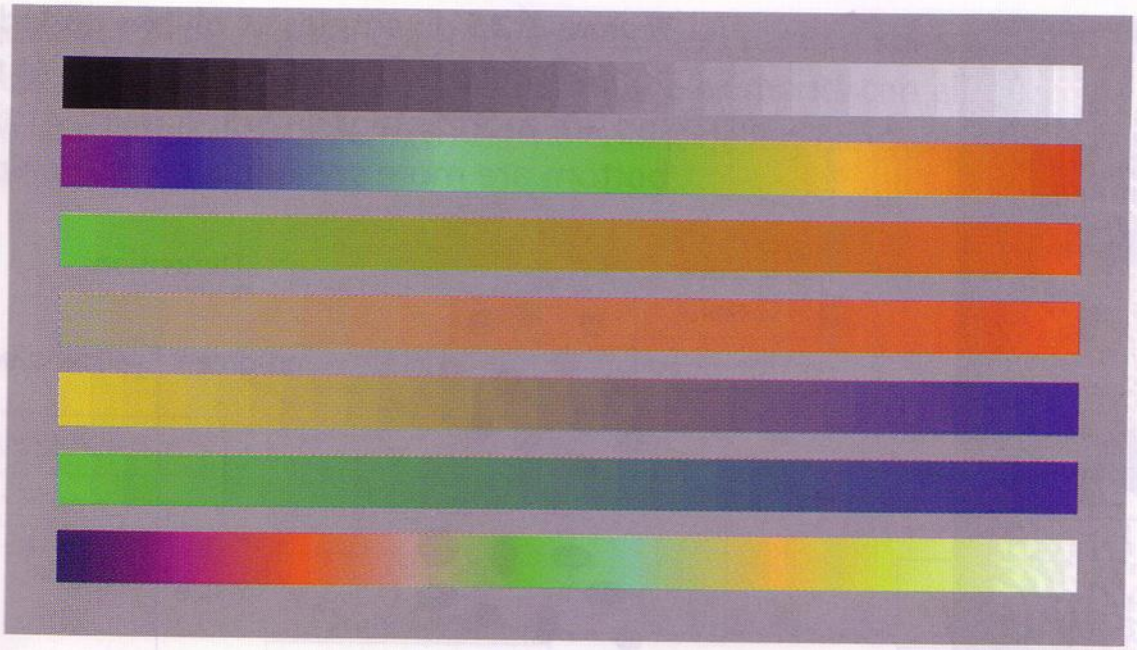
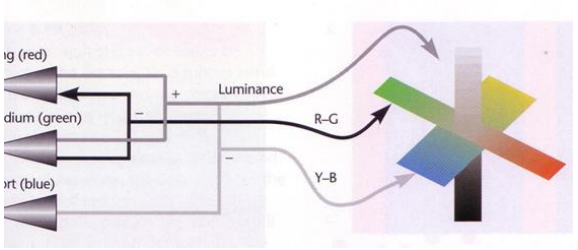
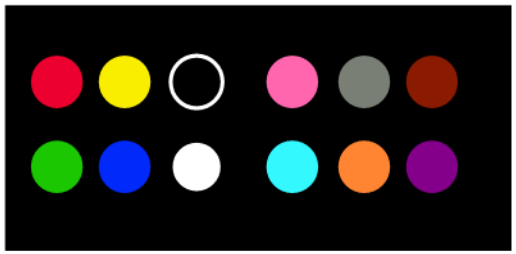


Figure 4.24
Seven different color sequences: (a) Gray scale. (b) Spectrum approximation. (c) Red-green. (d) Saturation. (e) and (f) Two sequences that will be perceived by people suffering from the most common forms of color blindness. (g) A sequence of colors in which each color is lighter than the previous one.

Colors /Categorical data



- Colors are fine with categorical data
- Do not reinvent the wheel (again)
- The Ewald Hering idea is that there are only 6 elementary colors arranged in three pairs
- That gives us up to 12 (6+6) colors easily distinguishable (11!)



12 Colors
for labeling

Some new considerations

- Chartjunk is not the unique enemy...
- Before PCs building graphs was a matter of paper and pencil
  - requiring time and effort
  - pushing you to better understand :
    - the meaning of numbers
    - the graph purpose
    - the graph organization
    - …
- now, with Excel you can produce graphs so fast that you might loose control...
  - you select predefined solutions
  - you might not understand how the graph is built (row, columns, headings, ...)
  - you can make mistakes (e.g., missing a row...)

So...

1. Look at the numbers and at the task
2. Plan a graph (even on the paper!), considering perceptual issues
3. Look for an Excel implementation of your design
4. If 3 fails, proceed without Excel !

Outline

- New ideas about good and bad graphs
- Meaning of numbers
- Tables and graphs
- Basic table variations
- Basic graph variations

Type of data

- Quantitative data (allows arithmetic operations)
- Categorical data (group, identify & organize; no arithmetic !)
  - Nominal
  - Ordinal
  - Interval
  - Hierarchical
- Relationships !

Types of Data

- Quantitative (allows arithmetic operations)
  - *123, 29.56, …*
- Categorical (group, identify & organize; no arithmetic)
  - Nominal (name only, no ordering)
    - *Direction: North, East, South, West*
  - Ordinal (ordered, not measurable)
    - *First, second, third …*
    - *Hot, warm, cold*
  - Interval (starts out as quantitative, but it is made categorical by subdividing into ordered ranges)
    - *0-999, 1000-4999, 5000-9999, 10000-19999, …*
  - Hierarchical (successive inclusion)
    - *Region: Continent > Country > State > City*
    - *Animal > Mammal > Horse*
- Data are arranged using relationships

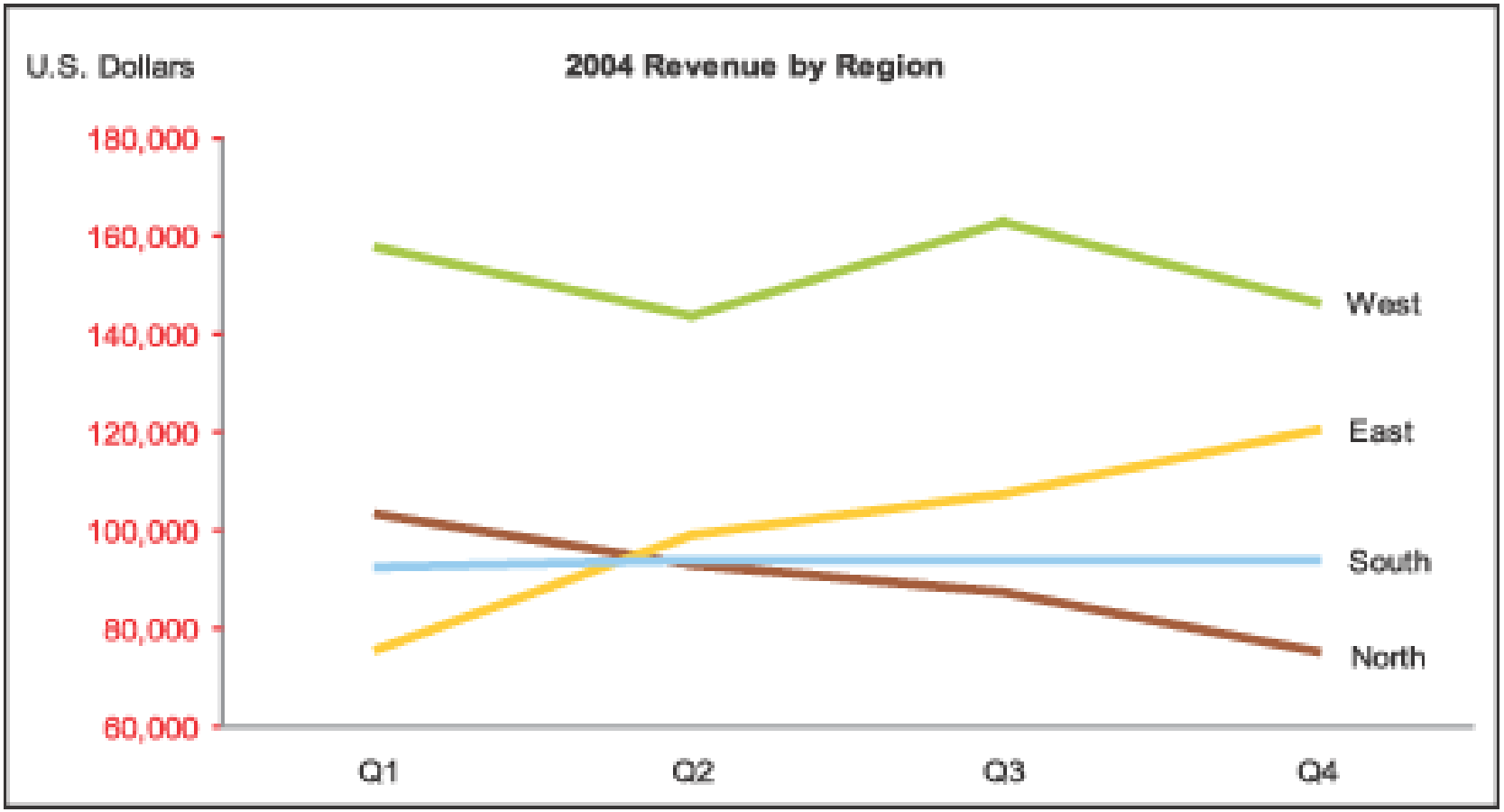
Adapted from Stone & Zellweger

Relationships

Quantitative information	**Relationship**
Unit of products sold per geographical region	Sales related to geography
Expenses by department and month	Expenses related to organizational structure and time
The number of students that got one of the possible exam score	Students counts related to exam's performance

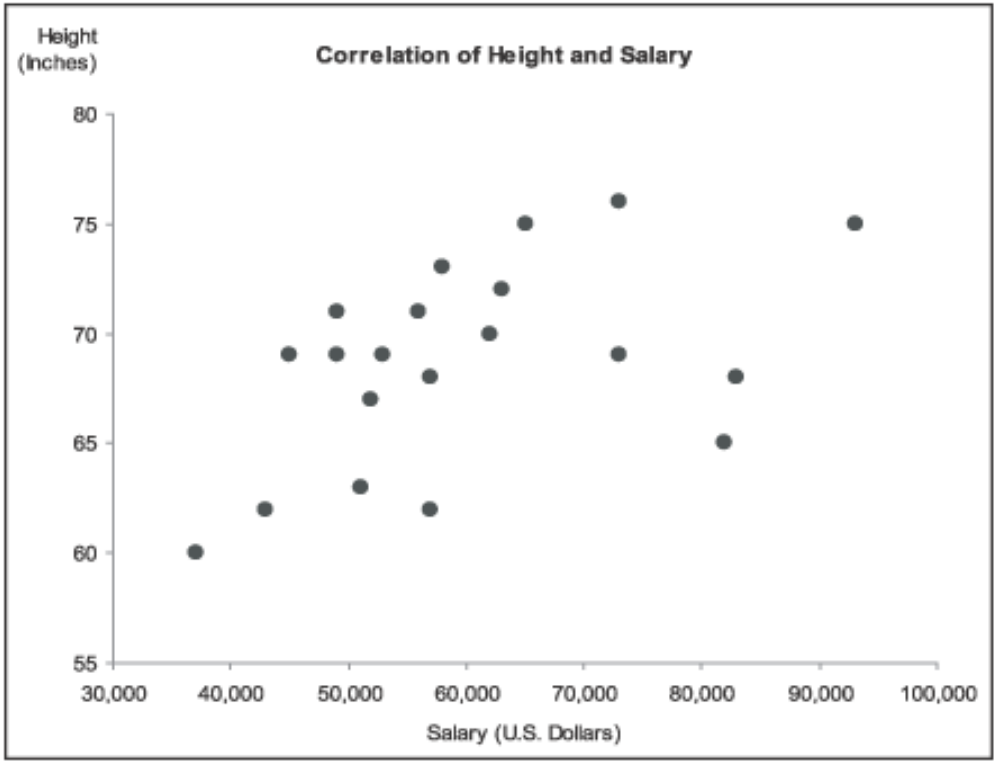
Categories 

A quick example



Quantitative (y axis) vs categorical data (x axis and colors)

A quick example



- Quantitative vs quantitative data

Nominal relationship

Region	Sales
North	50,000
South	20,000
East	40,000
West	20,000
Total	130,000

- Order is not relevant
  - Be aware of some artificial orders (conventional/ alphabetical order)
  - Maintain consistence across different graphs
- Just divide up the quantitative value

Ordinal relationship

Production office	**Sales**
First office (1977)	50,000
Second office (2000)	20,000
Third office (2005)	40,000
Total	110,000

- Order is relevant
- Altering it is not a good idea

Interval relationship

Order size	Count	Sum
[0, 1000)	25	2000785
[1000, 2000)	19	20086356256
[2000, 3000)	13	134555
[4000, 5000)	14	700005254

- Several equal intervals (bins) covering the whole range
  - Frequency distribution
  - Other math's

Time series relationship

Dept	Jan	Feb	Mar	Qtotal
Marketing	83,883	98,883	95,939	273,655
Sales	38,838	39,848	39,488	118,174

- Which kind of relationship best describes the categorical subdivision of time?
  - Obviously is ordinal
  - But months represent **intervals** as well

Hierarchical relationship

Division	Dept	Group	Expenses
G&A	Human Resources	Recruiting	42,292
		Compensation	118,174
	Info Systems	Operations	512,885
		Applications	442,909
Finance	Accounting	AP	73,302
		AR	83,392
	Corp Finance	Fin Planning	93,027
		Fin Reporting	74,383

- Multiple categories, closely related to each other as separate levels in a ranked arrangement
- Commonly used in tables to arrange quantitative information (e.g., OLAP, On-Line Analytical Processing)
- http://www.tableausoftware.com/products/desktop

Relationships among quantities

- Ranking
- Ratio / Proportion
- Correlation

Ranking

Rank	Order Number	Order Amount
1	100303	1,939,393
2	100374	875,203
3	100482	99,303
4	100310	87,393
5	100398	67,939
		$3,069,231

- It is an ordinal relationship in which the order is based on the associated quantitative values

Ratio/Proportion

- It is a relationship involving two quantitative values, compared by dividing one by the other
- If one is a part of the whole (e.g., a/a+b) it is a **proportion** and it is typically represented as a percentage (ranging between 0 and 100)
- If the two values come from different sets it is a **ratio**, and it can assume any value, also above 100 and if the two values come from the same domain it makes sense consider the difference as well, that could be negative

Proportion example

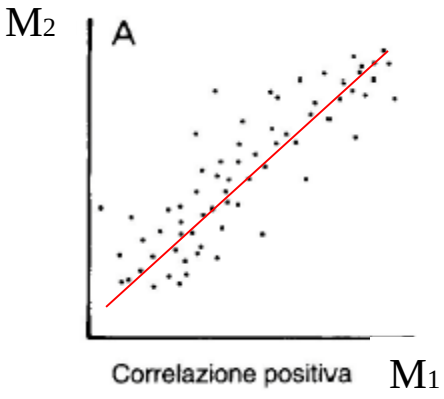
Company	Sales	Sales %
Company A	239,949,993	15%
Company B	873,777,473	54%
Company C	37,736,336	2%
Company D	63,874,773	4%
Company E	399,399,948	24%
Total	$1,614,738,523	100%

Ratio example

Department	Jan	Feb	Feb/Jan	Variation	Change %
Sales	9,933	9,293	0.93	-640	-6%
Marketing	5,385	5,832	1.08	+447	+8 %

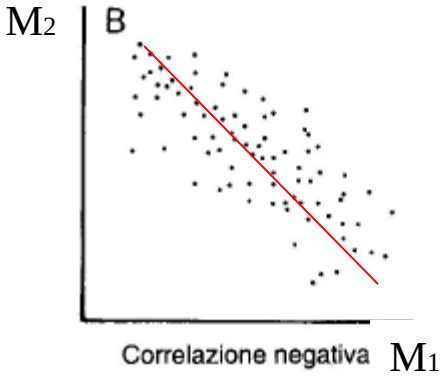
Correlation relationship

- Correlation is a relationship in which the values of two paired set of quantities are compared, looking for a (usually linear) function between them



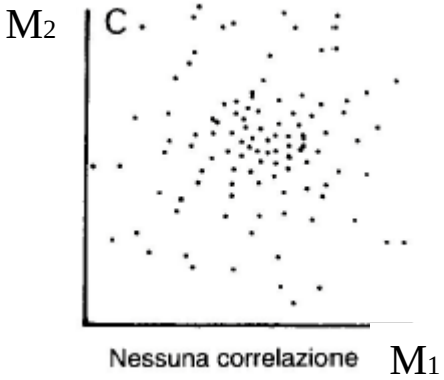
Directly proportional

+1



Inversely proportional

-1

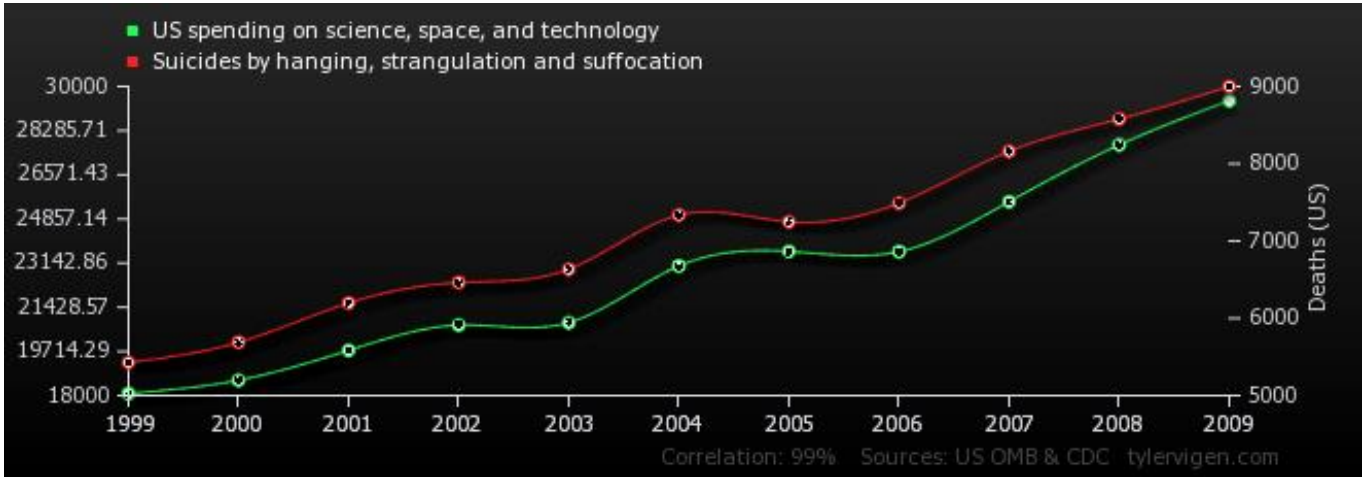


No correlation

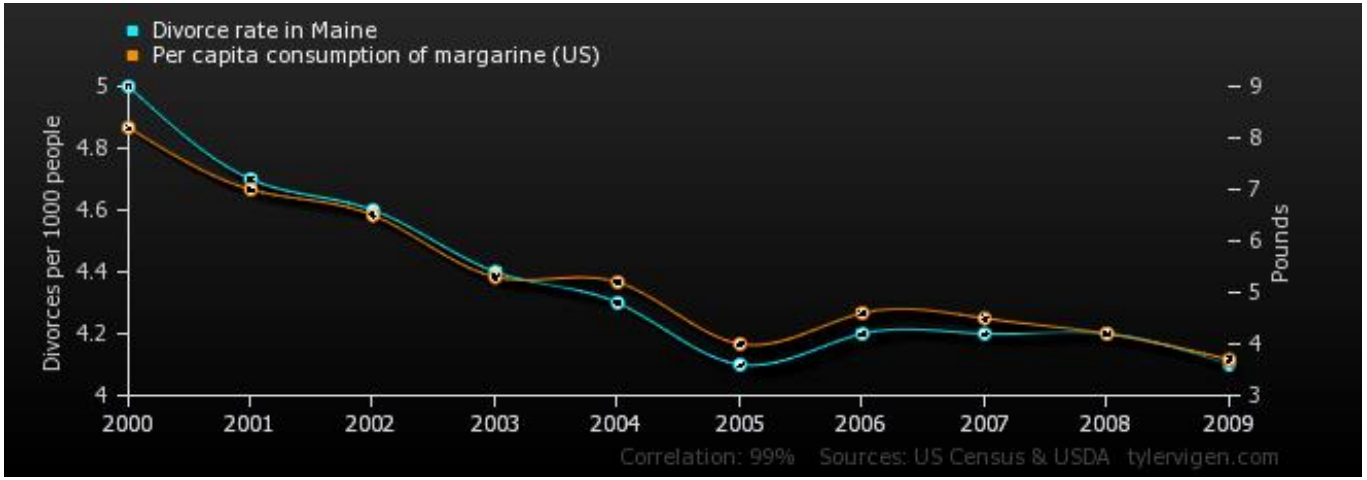
0

Do not always trust statistics… spurious correlation site

http://www.tylervigen.com/



Correlation: 0.992082



Correlation: 0.992558

Data & relationships summary

- Information consist of two types of data
  - Quantitative
  - Categorical
- Relationship among data could be
  - Simple associations between quantitative and categorical subdivision
  - More complex association among multiple set of values
- Four types of relationship within categories
  - Nominal
  - Ordinal
  - Interval
  - Hierarchical
- Three types of relationships between quantitative values
  - Ranking
  - Ratio
  - Correlation

Numbers that summarize (do not lie)

- Measures of average
  - Mean
  - Median
  - Mode
  - Midrange
- Measures of distribution
  - Range
  - Variance
  - Standard deviation

Mean

- Sometimes it is not informative

Quarter	Units Sold
Q1	339
Q2	373
Q3	437
Q4	563
Sum	1,712
Count	4
Mean (per Qtr)	428

Employee	Position	Annual Salary
Employee A	Vice President	475,000
Employee B	Manager	165,000
Employee C	Manager	165,000
Employee D	Admin Assistant	43,000
Employee E	Admin Assistant	39,000
Employee F	Analyst	65,000
Employee G	Analyst	63,000
Employee H	Writer	54,000
Employee I	Writer	52,000
Employee J	Graphic Artist	64,000
Employee K	Graphic Artist	62,000
Employee L	Intern	28,000
Employee M	Intern	25,000
	Mean Salary	$100,000

Median

- It splits the sorted distribution in two

Rank	Position	Annual Salary
1	Vice President	475,000
2	Manager	165,000
3	Manager	165,000
4	Analyst	65,000
5	Graphic Artist	64,000
6	Analyst	63,000
7	Graphic Artist	62,000
8	Writer	54,000
9	Writer	52,000
10	Admin Assistant	43,000
11	Admin Assistant	39,000
12	Intern	28,000
13	Intern	25,000
	Median Salary	$62,000

Distribution

Warehouse	Sum of shipping days	Delivery mean	Delivery median
A	51	4.25	4.5
B	51	4.25	4.5

- Performances of delivery time of 12 orders of two warehouses
- Do they perform the same?
- What is missing?

Distribution

Order #	Warehouse A	Warehouse B
1	3	1
2	3	1
3	3	1
4	4	3
5	4	3
6	4	4
7	5	5
8	5	5
9	5	5
10	5	6
11	5	7
12	5	10

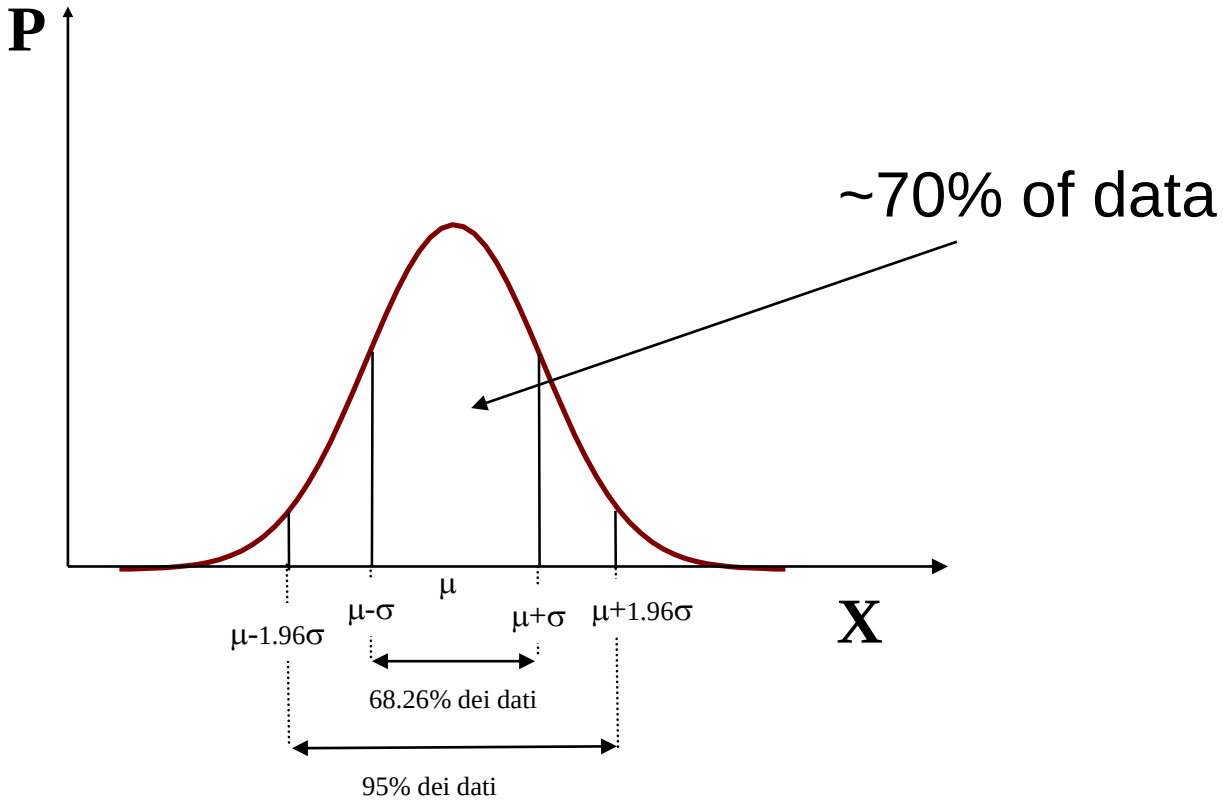
Range and midrange

Order #	Warehouse A	Warehouse B
1	3	1
2	3	1
3	3	1
4	4	3
5	4	3
6	4	4
7	5	5
8	5	5
9	5	5
10	5	6
11	5	7
12	5	10

- Range is just max-min
- Range A = 5-3=2
- Range B = 10-1=9
- Midrange is just (max+min)/2
- Midrange A=(5+3)/2=4
- Midrange B=(10+1)/2=5.5

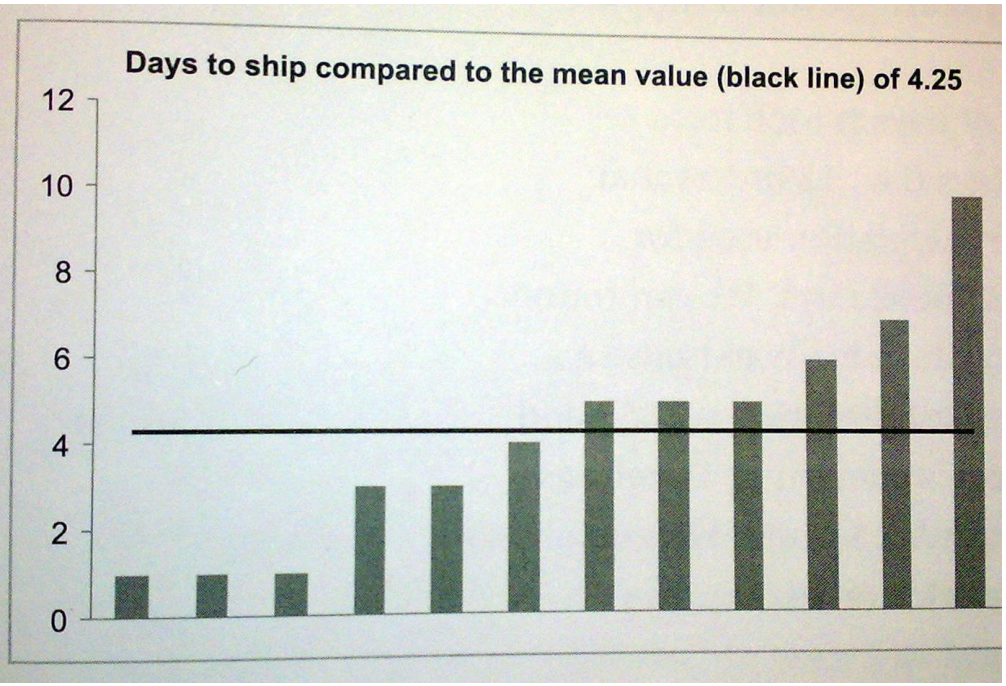
Standard deviation

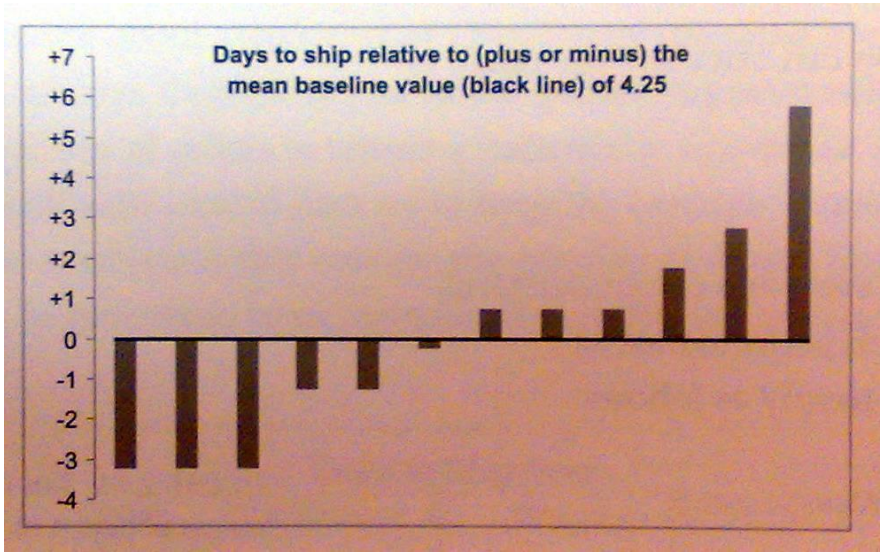
- This variability is well described by variance and standard deviation
- mean: $\mu = (x_1 + x_2 + \ldots + x_n)/n$
- variance $\mathbf{var} = [(x_1 - m)^2 + (x_2 - m)^2 + \ldots (x_n - m)^2]/n$
- standard deviation $\sigma = var^{1/2}$
- However such concepts are hard to communicate



Standard deviation

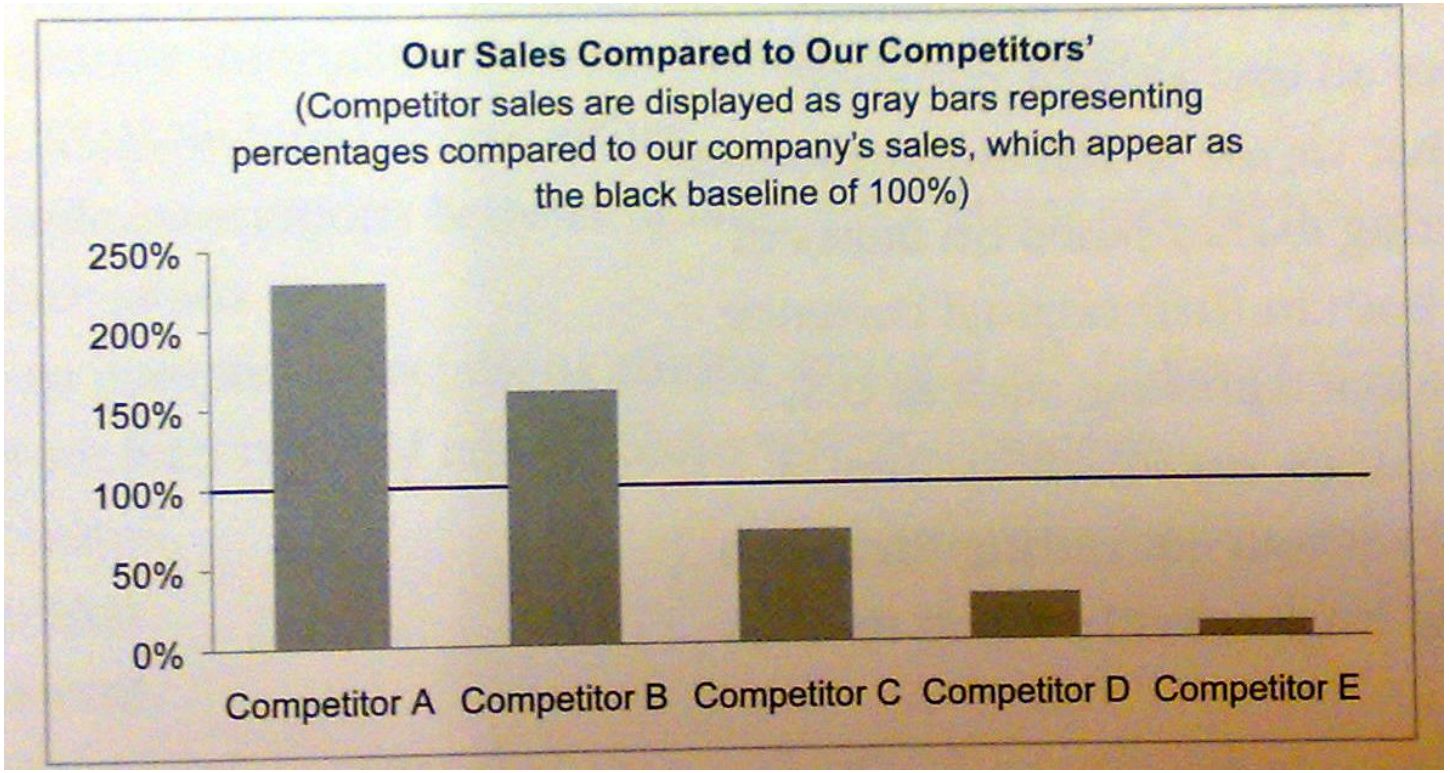
- These bar charts compare values with mean, providing a simpler way of communicating standard deviation





Measures of ratio

- Simple numerical relationship between two values
- It can be used to summarize data as well



Number that summarize

Type of Summary	*Method*	*Note*
Average	Mean	Measures the center of a set of values in a manner that is equally sensitive to all values, including extremes
	Median	Measures the center of a set of values in a manner that is insensitive to extreme values
Distribution	Range	Simple to calculate, relying entirely on the highest and lowest values, but only roughly defines a ranges of values
	Standard Deviation	Provides a rich expression of the distribution of a set of values across its entire range
Correlation	Linear Correlation Coefficient	Indicates whether a correlation exists between two paired sets of values, and if so, its direction (positive or negative) and its strength (strong or weak)
Ratio	Rate or Percentage	Measures the direct relationship between two quantitative values

Outline

- New ideas about good and bad graphs
- Meaning of numbers
- Tables and graphs
- Basic table variations
- Basic graph variations
- Relationships in graphs

Table and graphs

- Table and graphs are widely used to communicate quantitative information
- Sometimes it is better to just show the (few) numbers
- The goals of presenting quantitative data are
  - Analyzing
  - Monitoring
  - Planning
  - Communicating
- Remember that we are dealing with data that is
  - Quantitative
  - Categorical
- Not all numbers carry quantitative information
  - Categorical intervals
  - IDs (e.g., order number)

Table

- Data are arranged in columns and row
- Data are encoded as text (usually)
- They are used also for non quantitative information (just spatial arrangement)

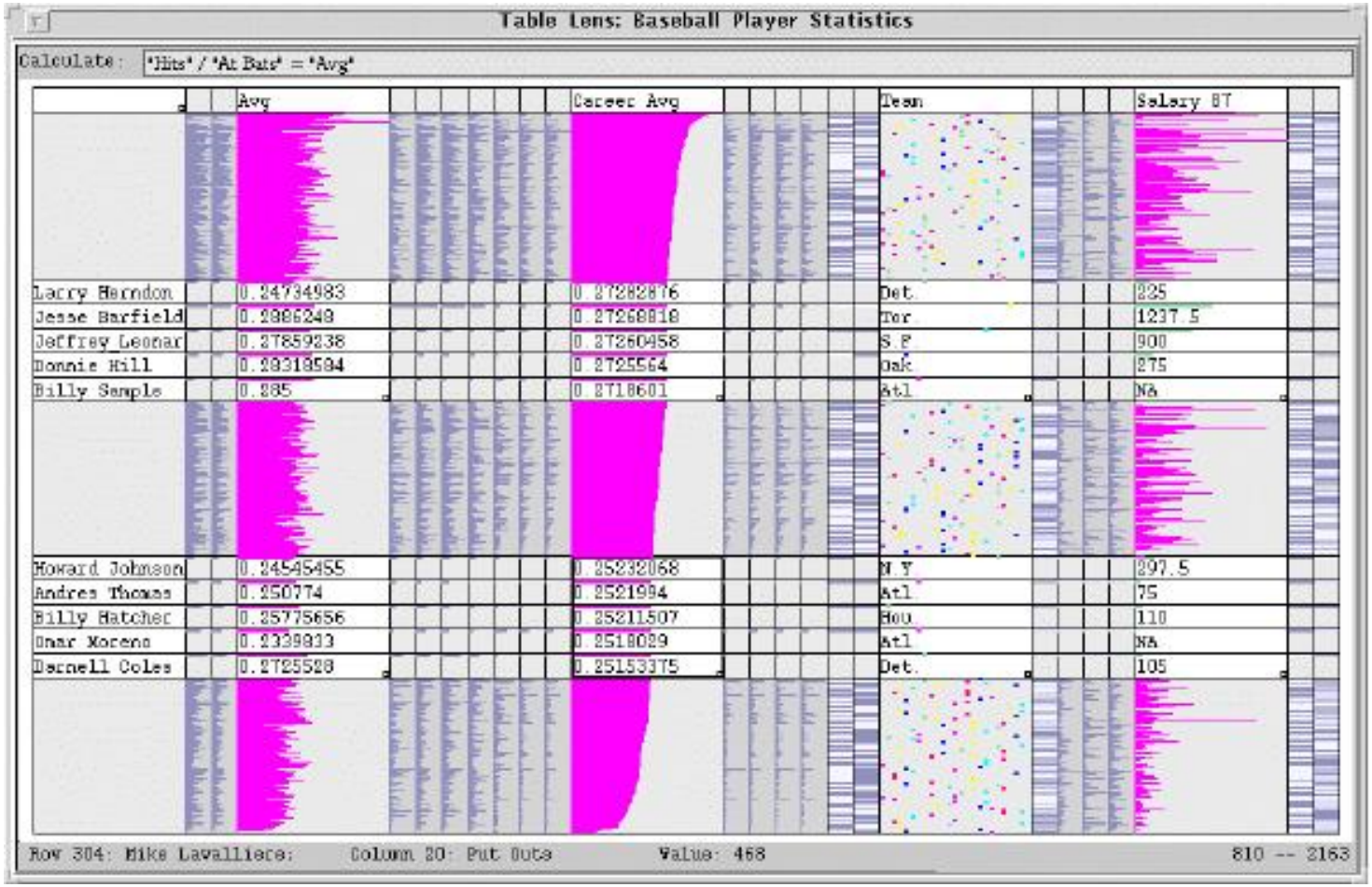
1. Table make easy **look up** values
2. Tables allow for displaying simple relationships between **quantitative** and **categorical** subdivision
3. Table allow for **local** comparisons
4. Tables provide for **high precision**
5. Table allow for easy management of **different units** of measure

Choose a table when...

- If one of the following is true, a table could be a good choice

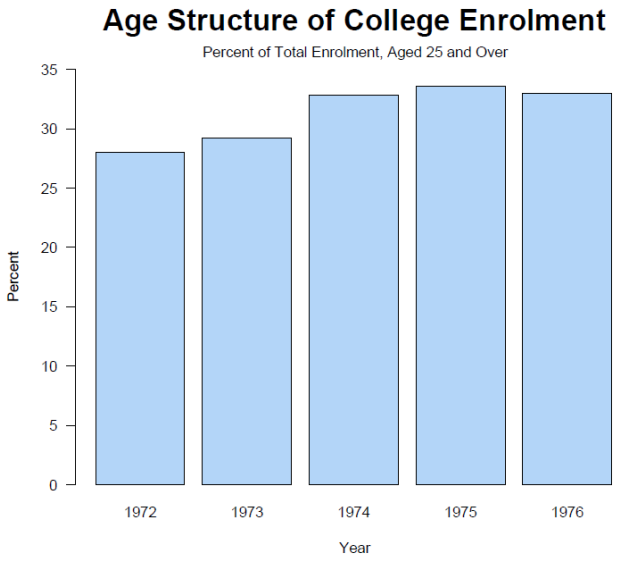
1. The report you produce will be used to look up single values
2. It will be used to compare individual values
3. Precise values are required
4. Different units of measure are involved

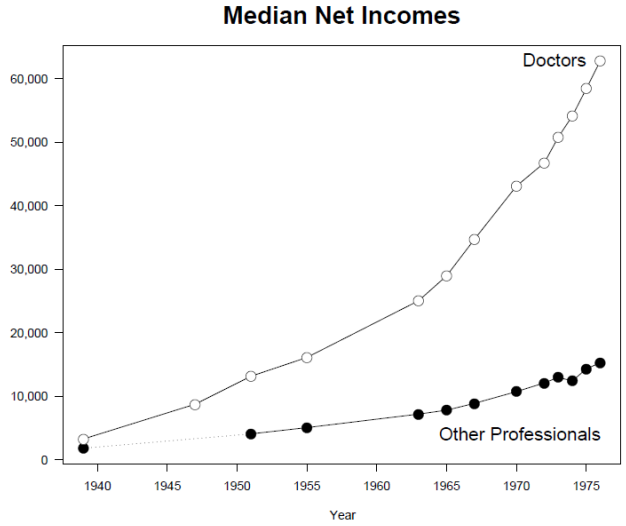
A table with non numerical values



Graphs

- A graph is a visual display of quantitative information
- **Quantitative** information **is encoded visually**
- More precisely, values are represented and presented on one or more axes
- Axes provide scales (quantitative or categorical)





Graphs

- A graph provides the overall shape of the data
- Trends
- Outliers
- Similarities and differences

- Low precision
- Not easy look up
- Not easy local comparison
- Not easy handling of different units

Outline

- New ideas about good and bad graphs
- Meaning of numbers
- Tables and graphs
- Basic table variations
- Basic graph variations
- Relationships in graphs

Fundamental variation in table design

- Relationships in table
  - Quantitative to categorical
- Variation in table design
  - Unidirectional
  - Bidirectional
  - Table design solutions

Categorical to quantitative relationships

1:1 - One categorical subdivision and **one** quantitative values (sales)

Salesperson	QTD Sales
Robert Jones	13,803
Mandy Rodriguez	20,374
Terri Moore	28,520
John Donnelly	34,786
Jennifer Taylor	36,973
Total	$134,456

nominal

n:1 – n categories (salespersons & months) to **one quantitative** value (sales)

Salesperson	Jan	Feb	Mar
Robert Jones	2,834	4,838	6,131
Mandy Rodriguez	5,890	6,482	8,002
Terri Moore	7,398	9,374	11,748
John Donnelly	9,375	12,387	13,024
Jennifer Taylor	10,393	12,383	14,197
Total	$35,890	$45,464	$53,102

nominal + interval (time)

hn:1- **hn** **hierarchical categories**

(Product Line -> Family -> Product) and **one quantitative** value (sales)

Product Line	Product Family	Product	Sales
Hardware	Printer	PPS	6,131
		PXT	8,002
		PQT	11,748
	Router	RRZ	13,024
		RTS	14,197
		RQZ	23,293
Software	Business	ACT	12,393
		SPR	9,393
		DBM	5,392
	Game	ZAP	10,363
		ZAM	15,709
		ZOW	13,881
Total			$143,526

Interaction could be a key issue. Interaction? No interaction!

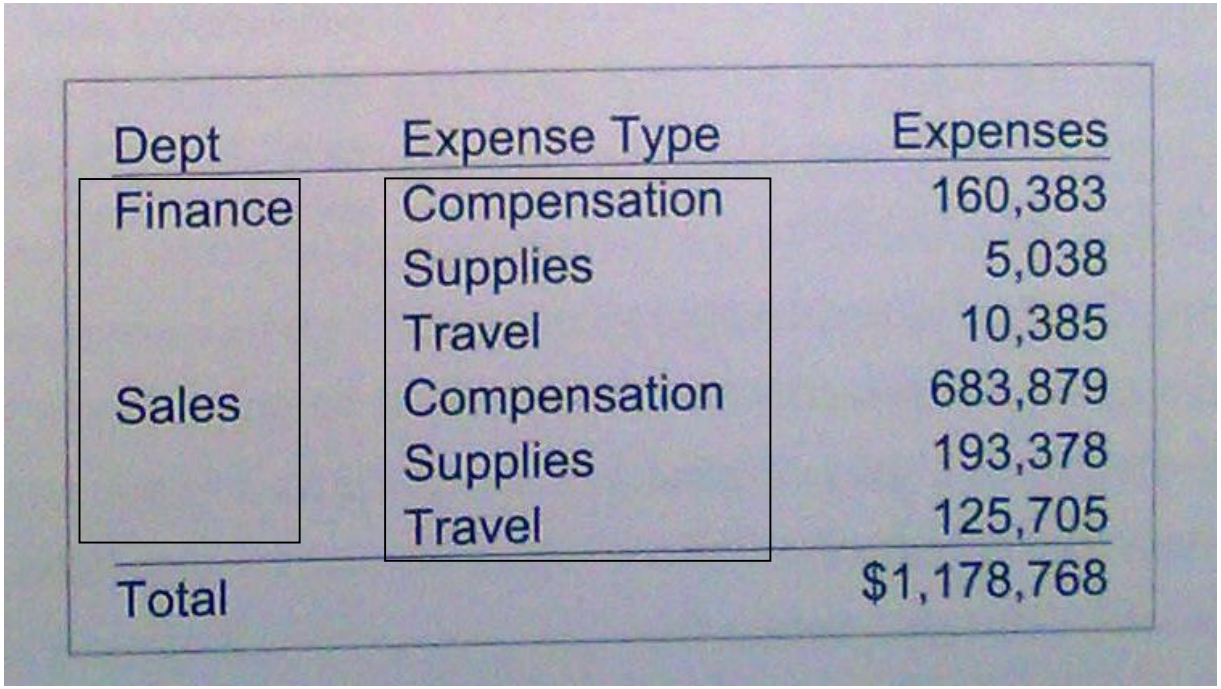
1:n Among **one** categorical subdivision (a salesperson) and n quantitative values (sales, returns, net)

Salesperson	Sales	Returns	Net Sales
Robert Jones	13,803	593	13,210
Mandy Rodriguez	20,374	1,203	19,171
Terri Moore	28,520	10,393	18,127
John Donnelly	34,786	483	34,303
Jennifer Taylor	36,973	0	36,973
Total	$134,456	$12,672	$121,784

- Here the focus is the comparison among **NOT** homogeneous numerical values

Variation - Unidirectional

- Categories are arranged across columns or rows but not in both directions (here we have two categories)



Dept	Expense Type	Expenses
Finance	Compensation	160,383
	Supplies	5,038
	Travel	10,385
Sales	Compensation	683,879
	Supplies	193,378
	Travel	125,705
Total		$1,178,768

Variation - Bidirectional

- Categories are on both axes
- Such tables are called crosstab or **pivot table**

	Departments		
Expense Types	Finance	Sales	Total
Compensation	160,383	683,879	844,262
Supplies	5,038	193,378	198,416
Travel	10,385	125,705	136,090
Total	$175,806	$1,002,962	$1,178,768

Variation - Bidirectional

- They save space

Dept	Expense Type	Expenses
Finance	Compensation	160,383
	Supplies	5,038
	Travel	10,385
Sales	Compensation	683,879
	Supplies	193,378
	Travel	125,705
Total		$1,178,768

Unidirectional

Expense Type by Dept	Finance	Sales	Total
Compensation	160,383	683,879	844,262
Supplies	5,038	193,378	198,416
Travel	10,385	125,705	136,090
Total	$175,806	$1,002,962	$1,178,768

Bidirectional

Graphs

- Several components
  - scales on axes
  - grid lines
  - bar
  - legends
  - ...
- Quantitative values
- Categorical subdivision

Graphs' variation

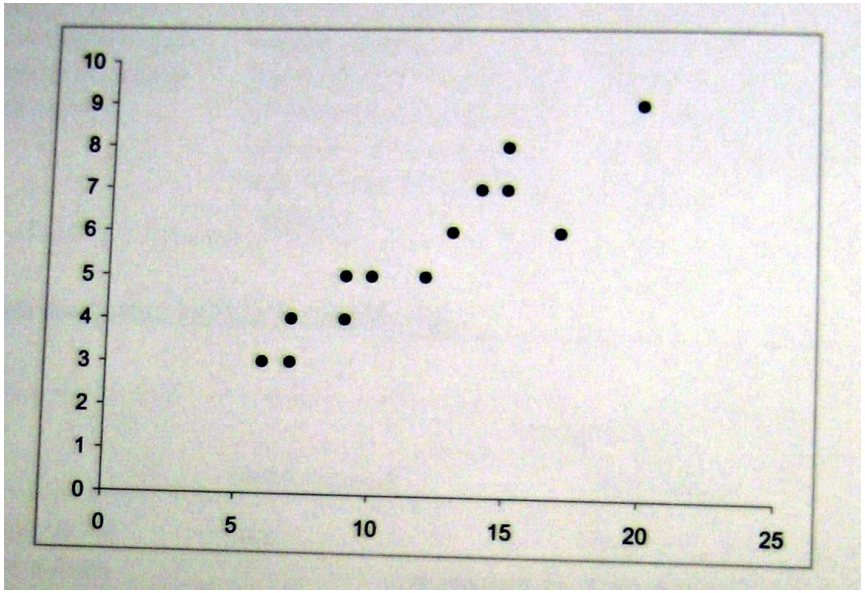
- The primary source of variation is the choice (or combination) of the different **visual variables** used to encode **quantitative values** and **categorical subdivision**. The most common choices are:

Shape
Position
Length
Area
Color
Pattern

Encoding quantitative values

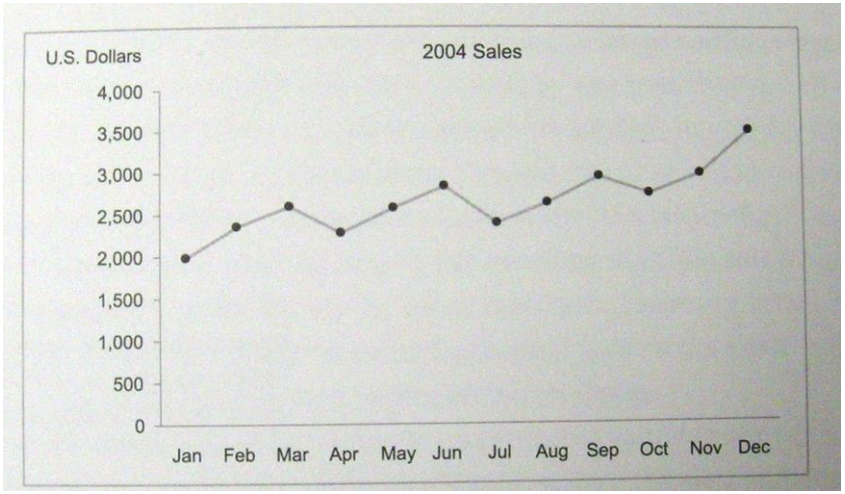
- Position
- Length
- Areas

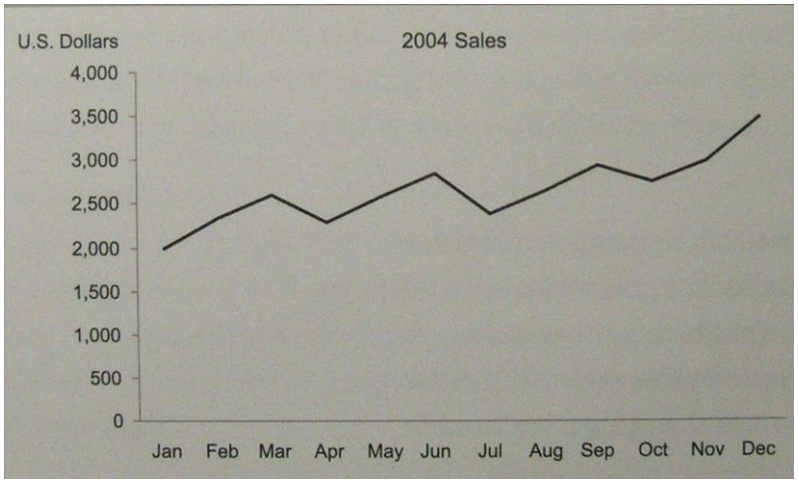
Position using points



- Scatter plot

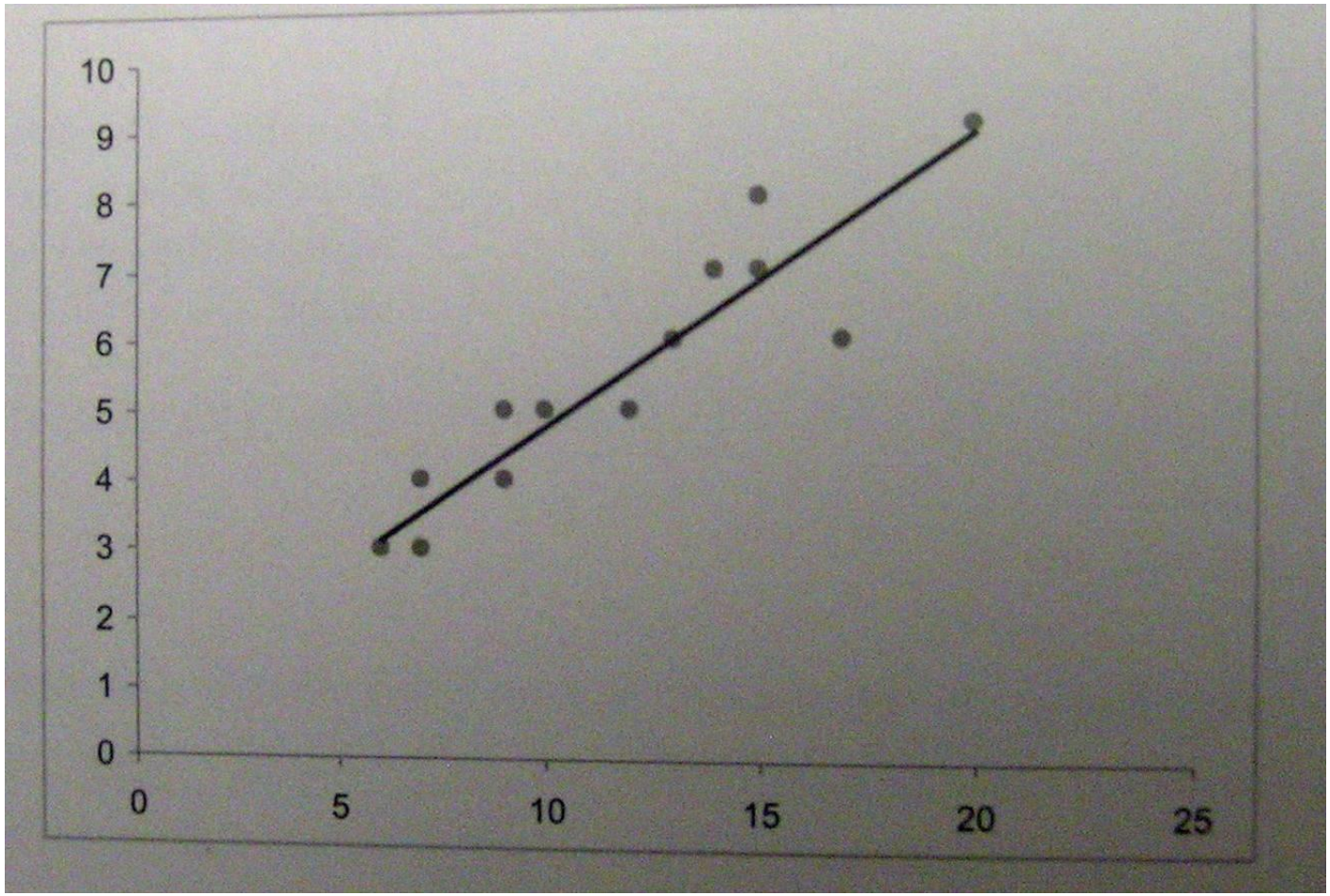
Position using points and/or lines



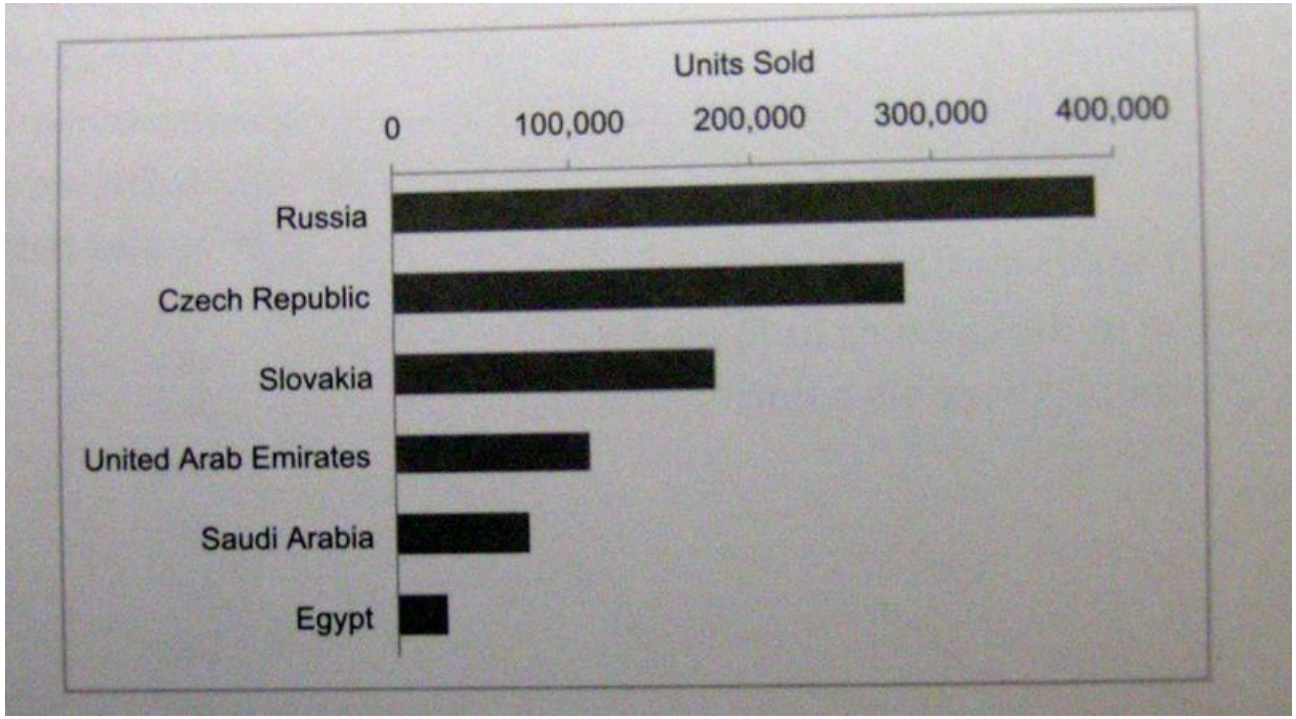


- Points and lines
- Only lines
  - Use lines **only** when
    - both axes are numerical
    - there exists an order on the categorical axe (e.g., intervals)

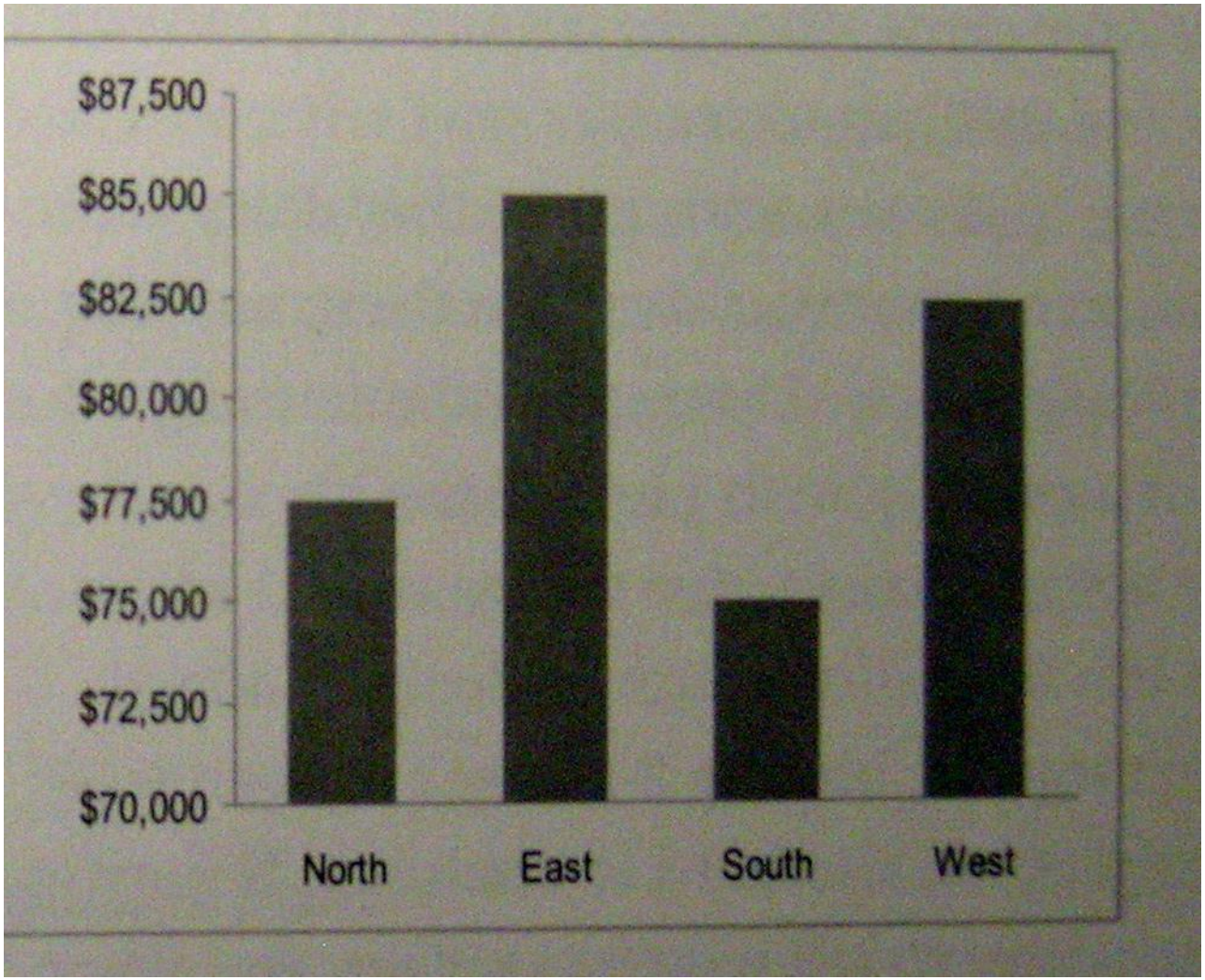
Position using line (correlation)



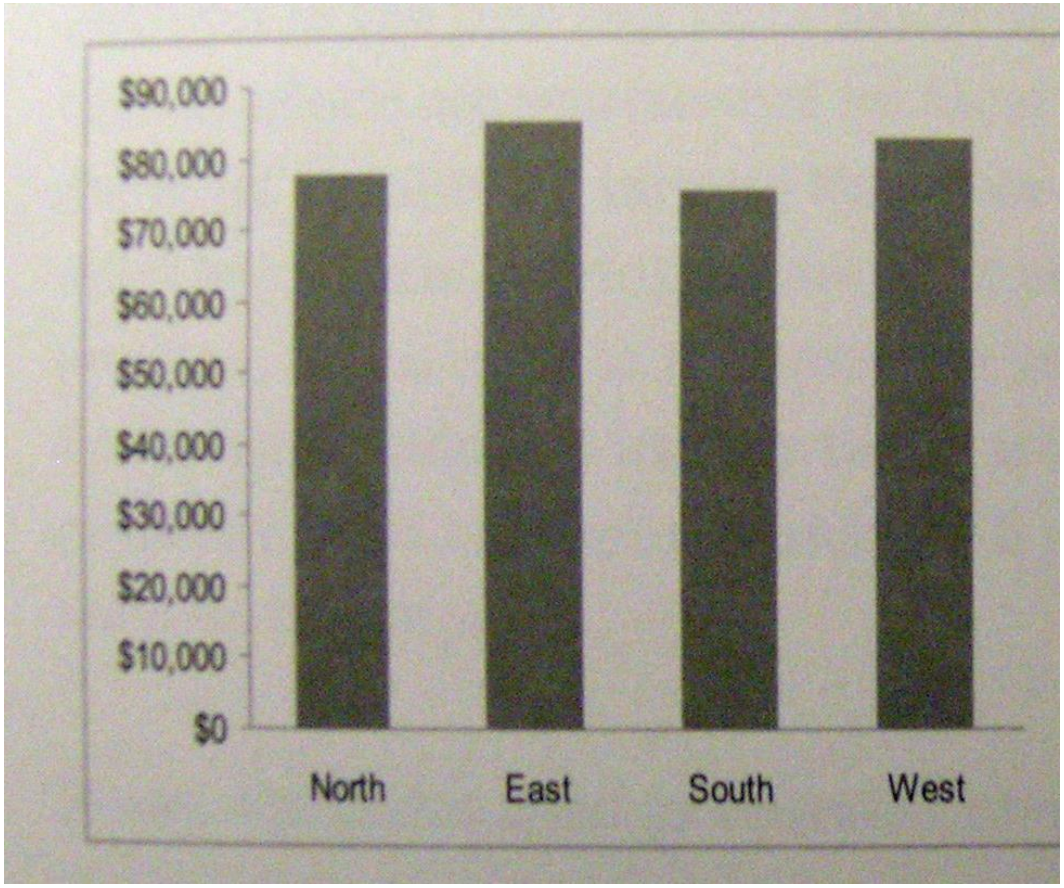
Length using bars



- Thickness is not relevant
- Thickness must be constant (and little)


$87,500
$85,000
$82,500
$80,000
$77,500
$75,000
$72,500
$70,000
North
East
South
West

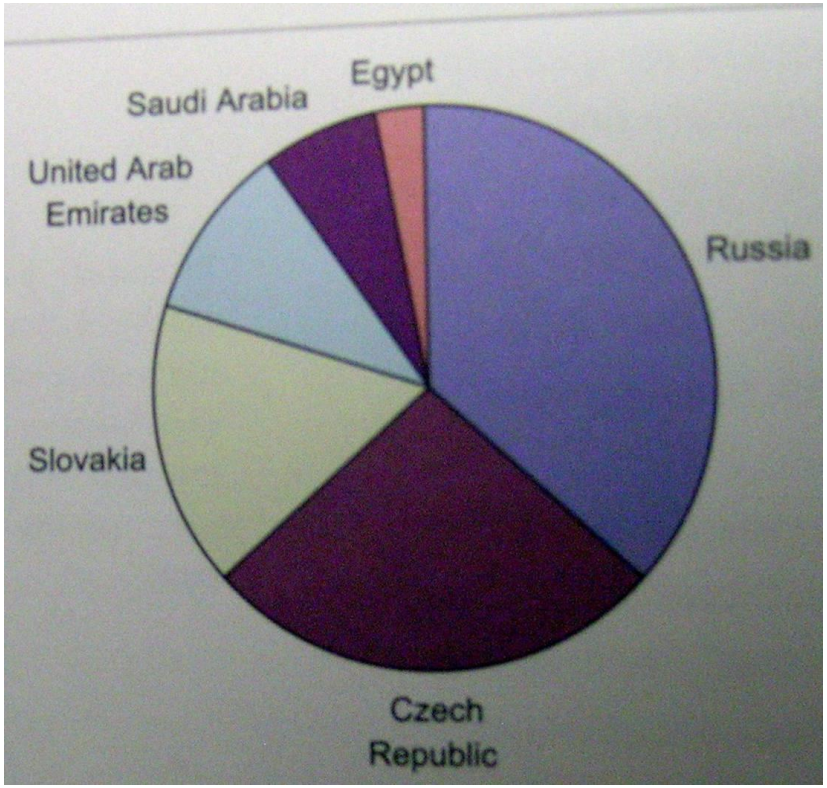
- Do not lie!



- Start scale by zero, allowing full lengths to be compared!

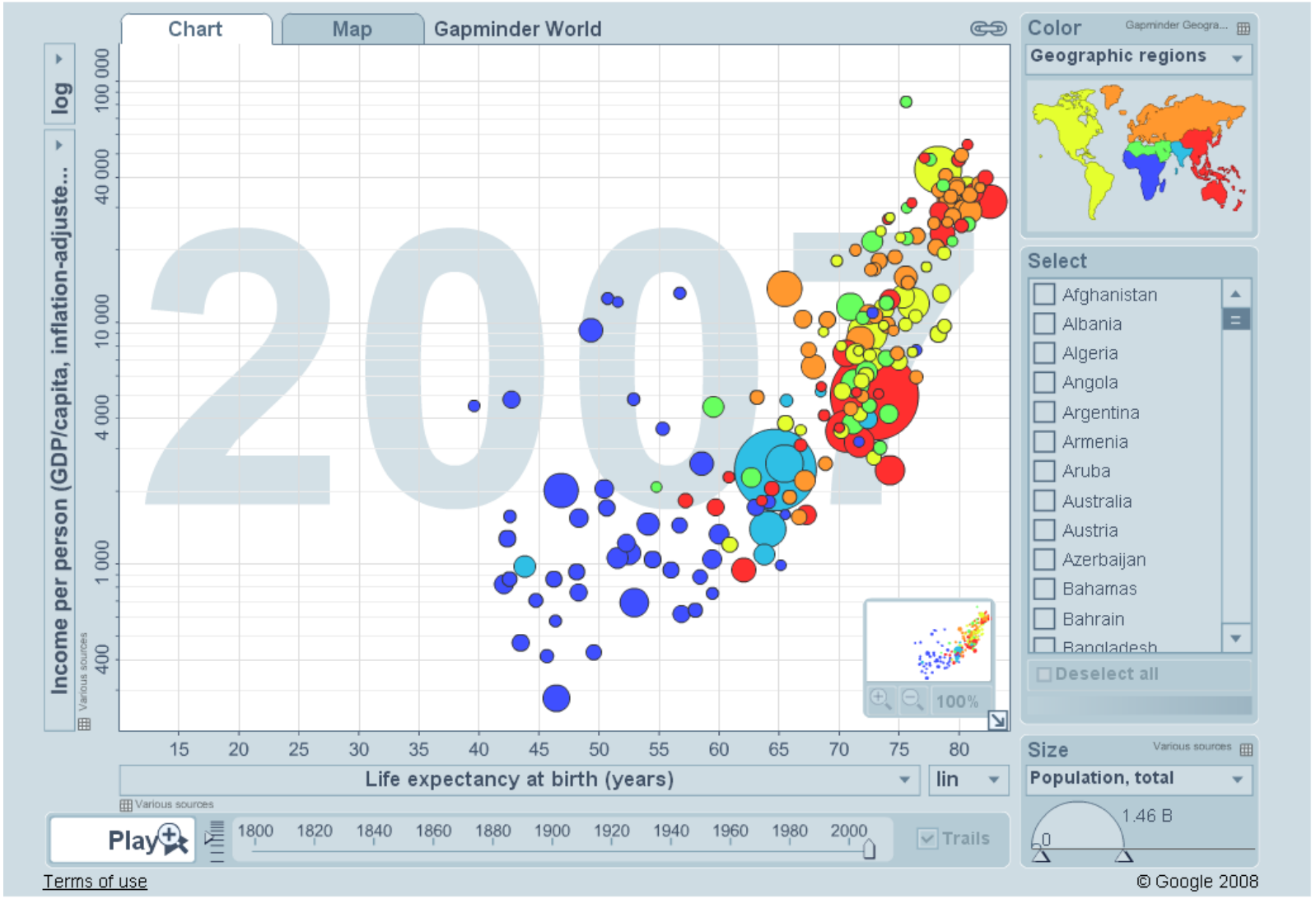
Areas

- Classical pie chart
- Part of a larger family of area graphs
- Remember its limitations
- Where is the scale ?
- Our visual perception is not good to accurately assess and compare quantitative values using areas (or worst, slices)



So, simply, do not use them at all !!

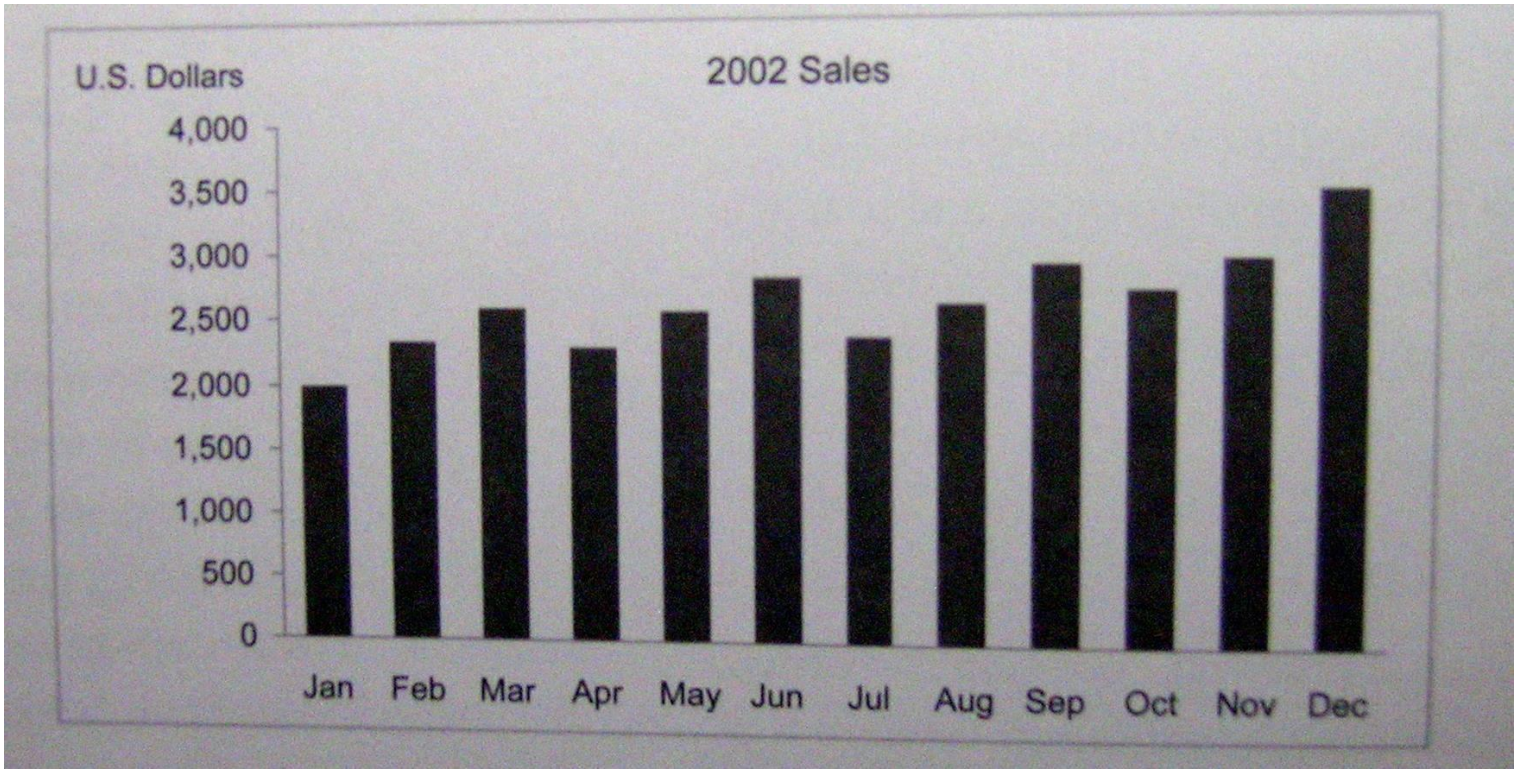
Bargrams (not used in business)



Encoding categorical subdivision

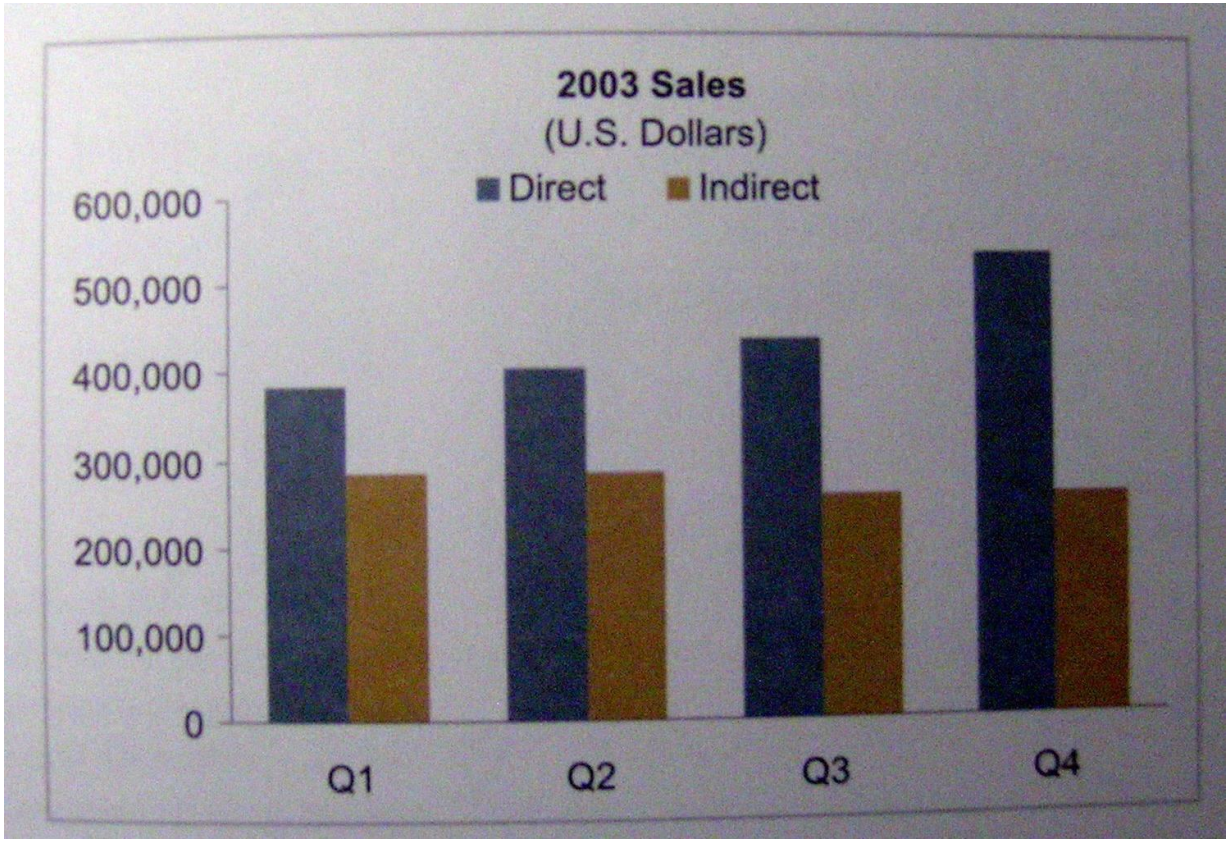
- Position
- Color
- Point shape
- Fill pattern
- Line style

Position



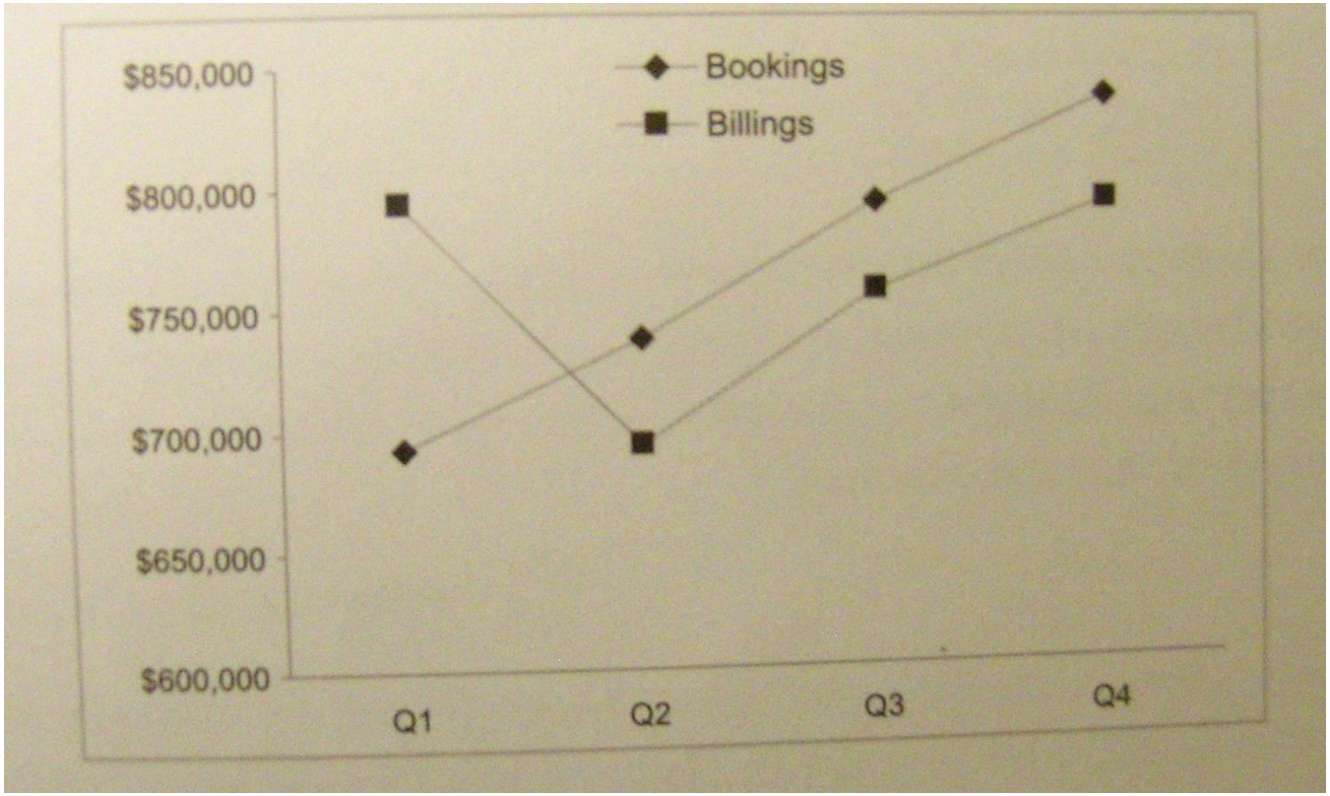
- X axis

Color



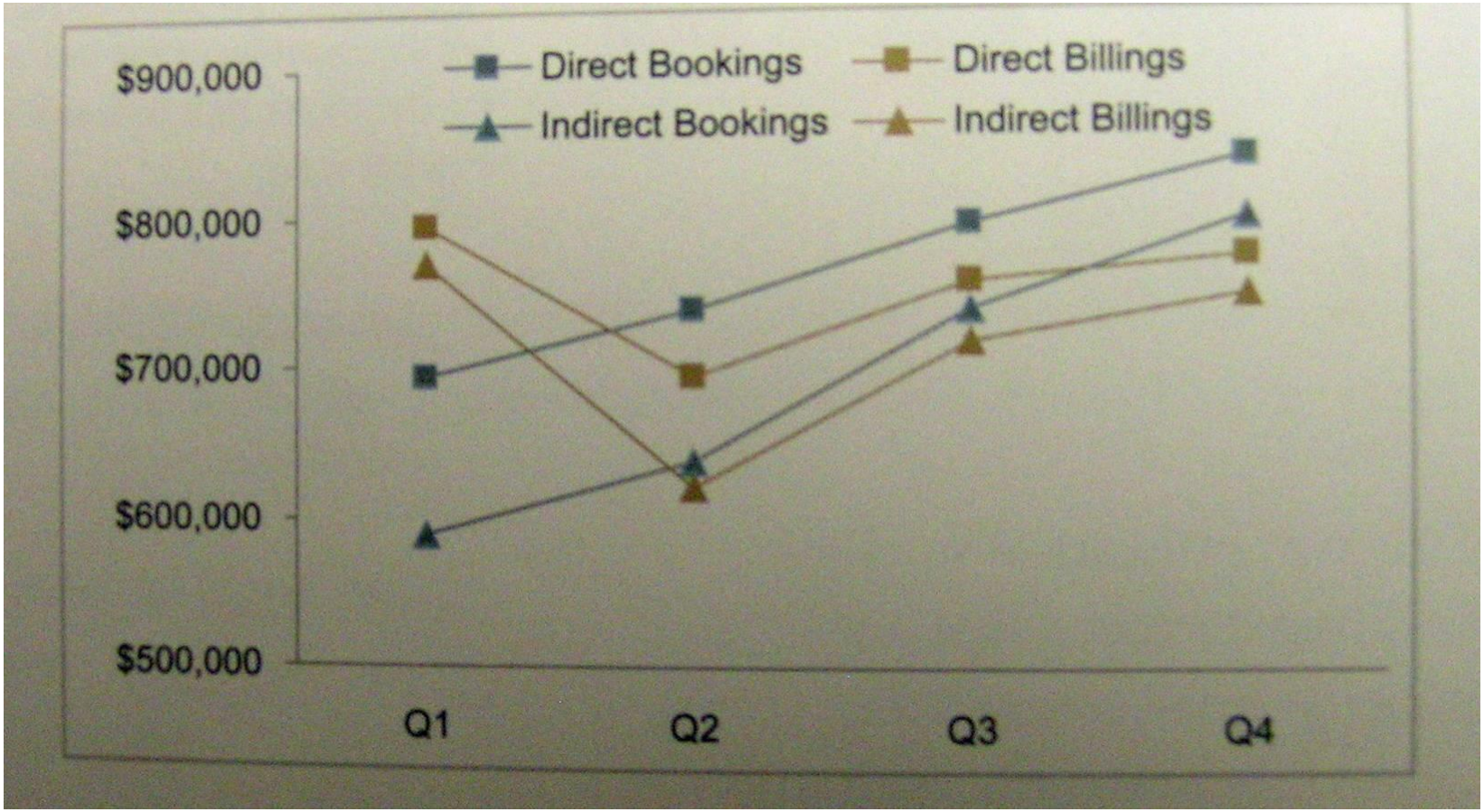
- We will see perceptual issues about colors...

Point shape

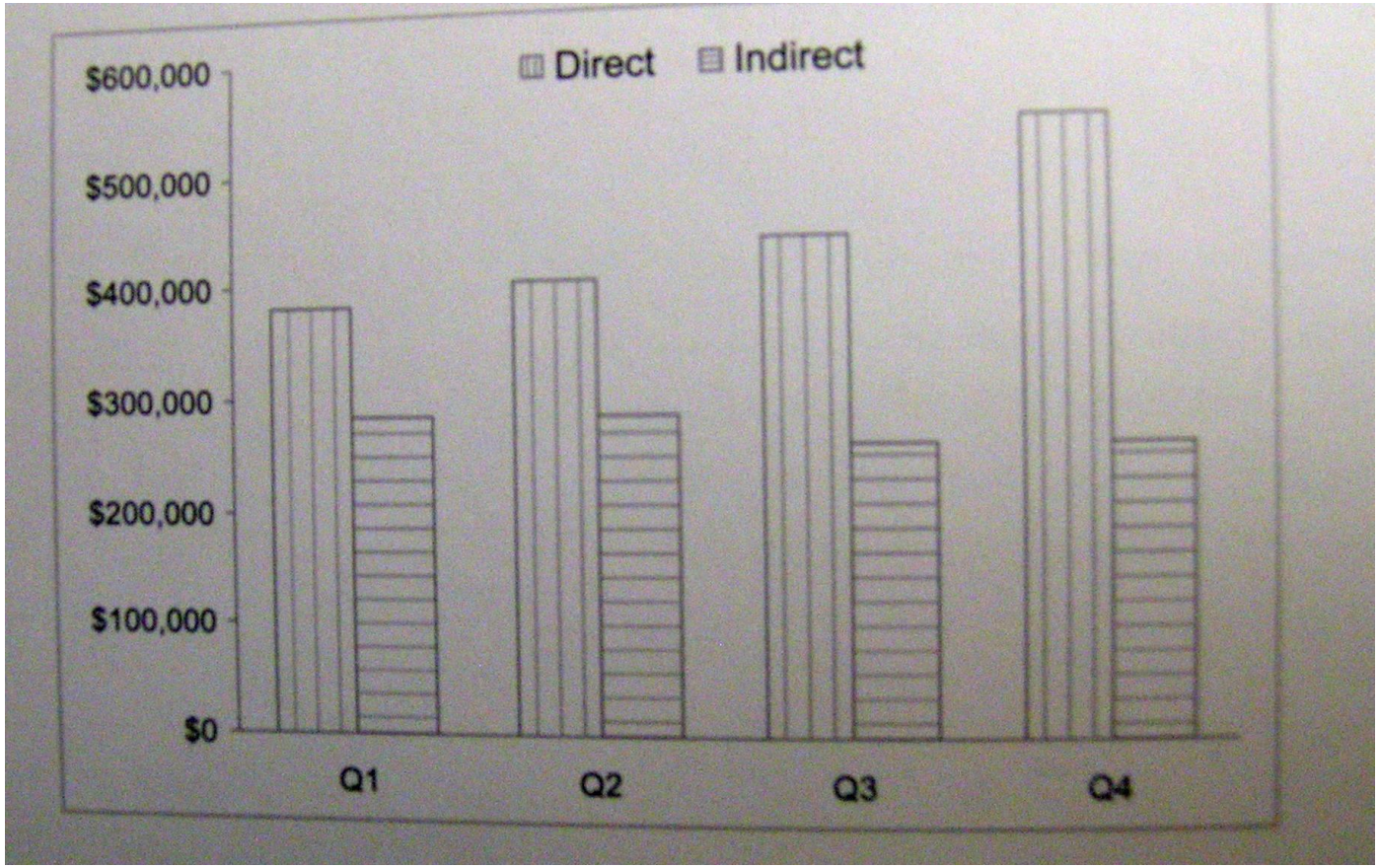


- Only applicable when points represents quantitative values

Position, Color, Point shape

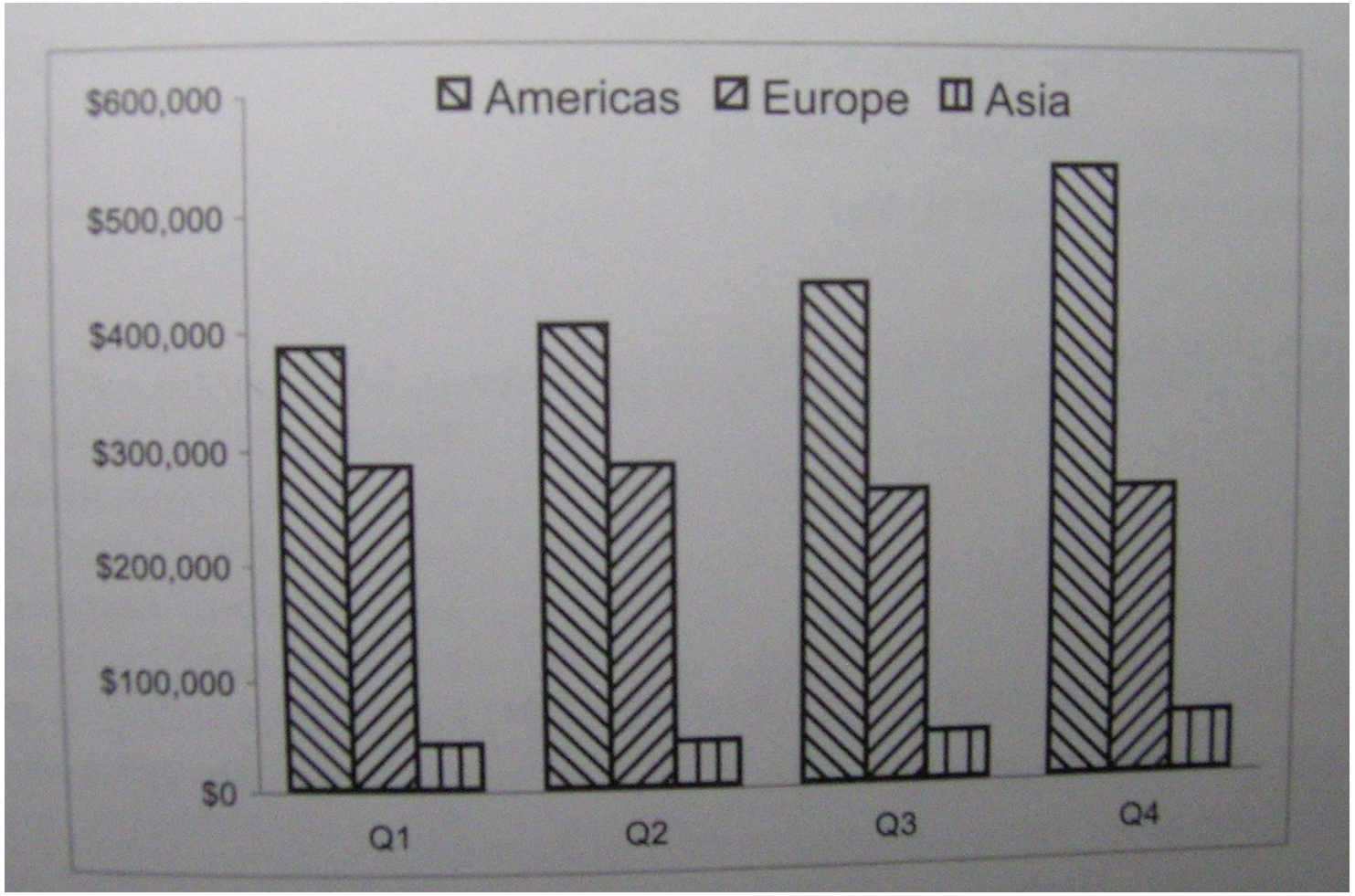


Fill pattern



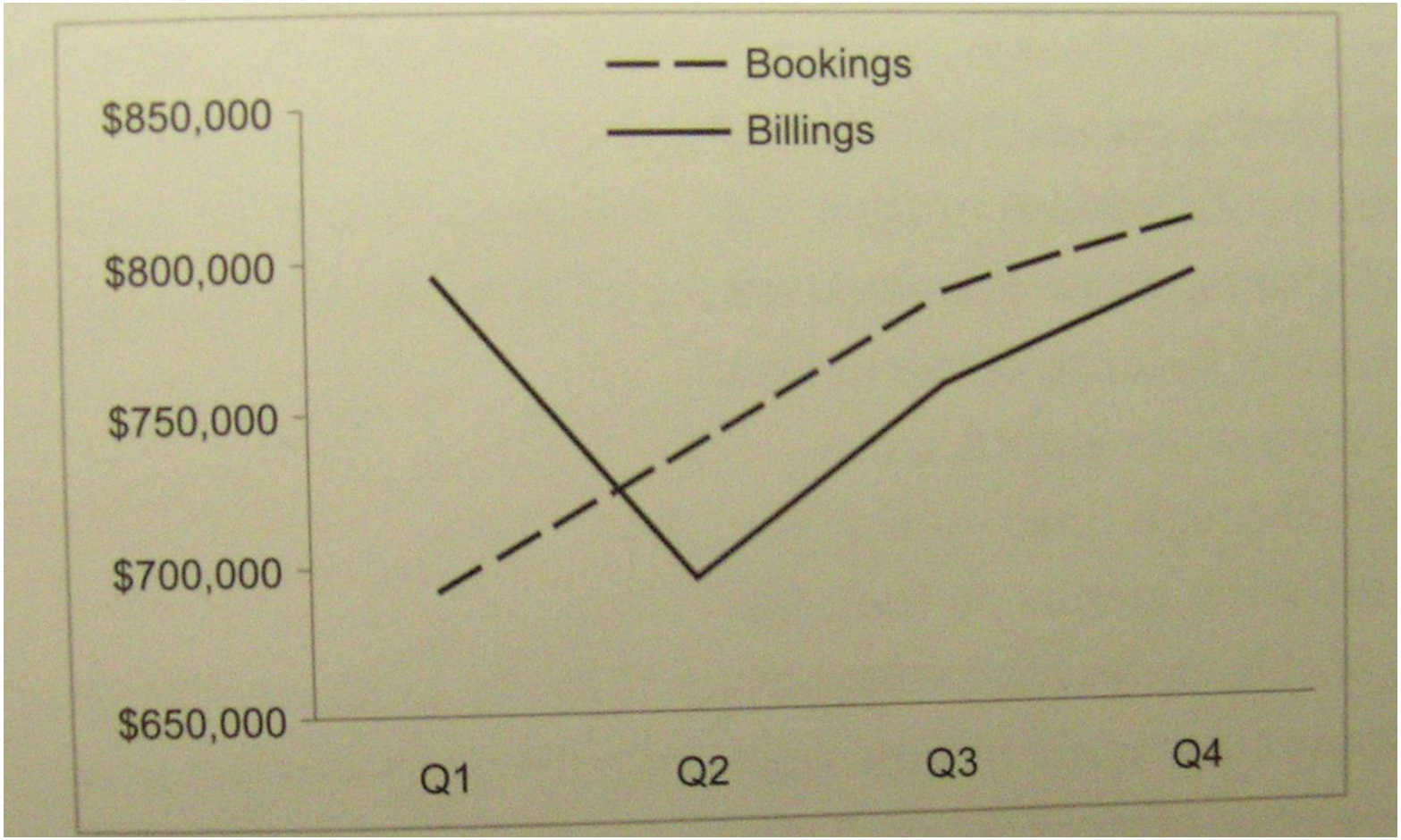
mmm, hard to see and causing **moirè vibration**

Moirè vibration



use as the last resource

Line style


Bookings
Billings
$850,000
$800,000
$750,000
$700,000
$650,000
Q1
Q2
Q3
Q4

Outline

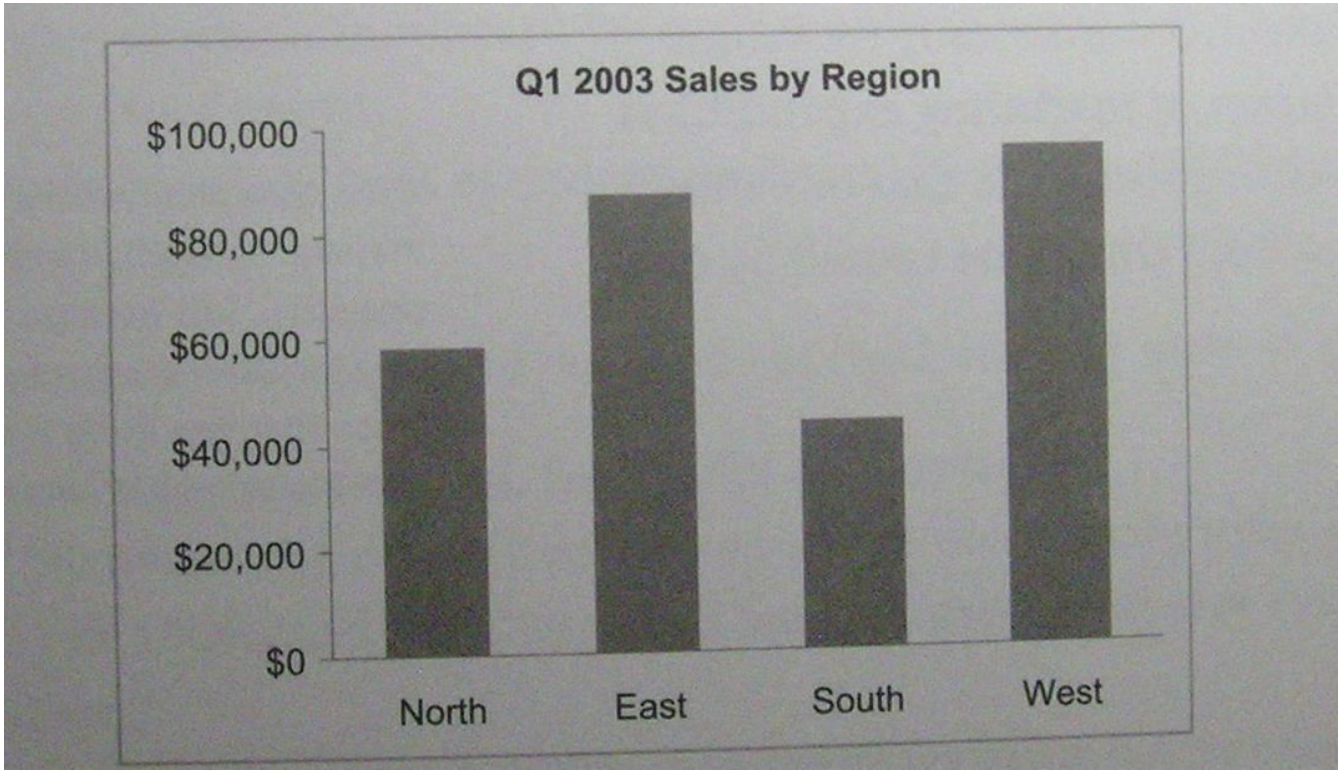
- New ideas about good and bad graphs
- Meaning of numbers
- Tables and graphs
- Basic table variations
- Basic graph variations
- Relationships in graphs

Relationships in Graphs

- Nominal comparison
- Time series
- Ranking
- Part-to-whole
- Deviation
- Distribution
- Correlation

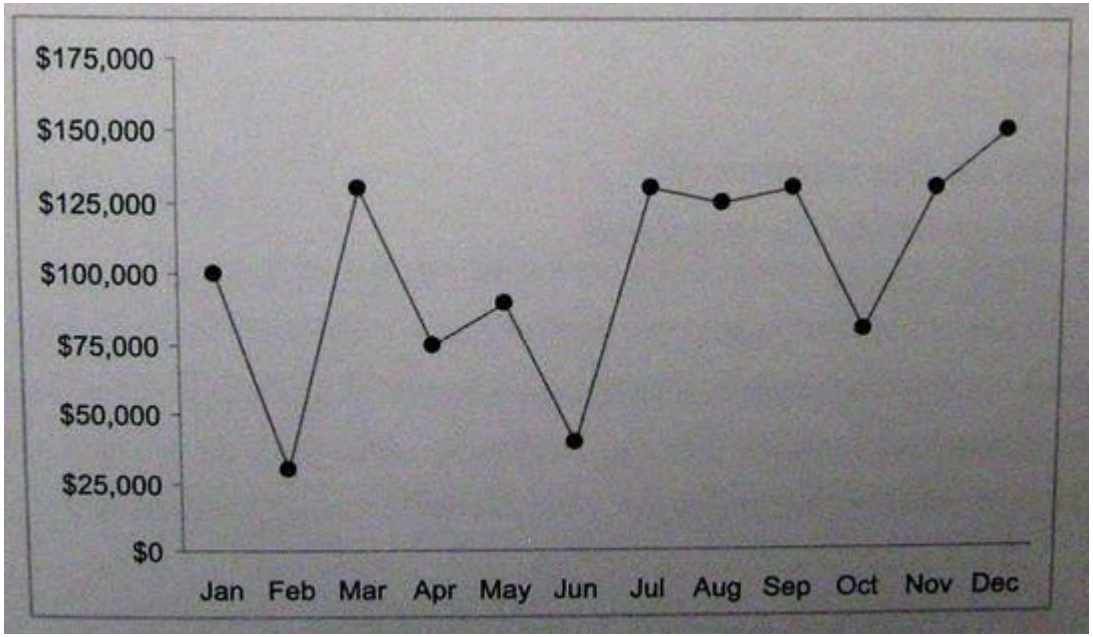
Nominal comparison

- Nominal categorical attribute
- Quantitative values that are compared each other



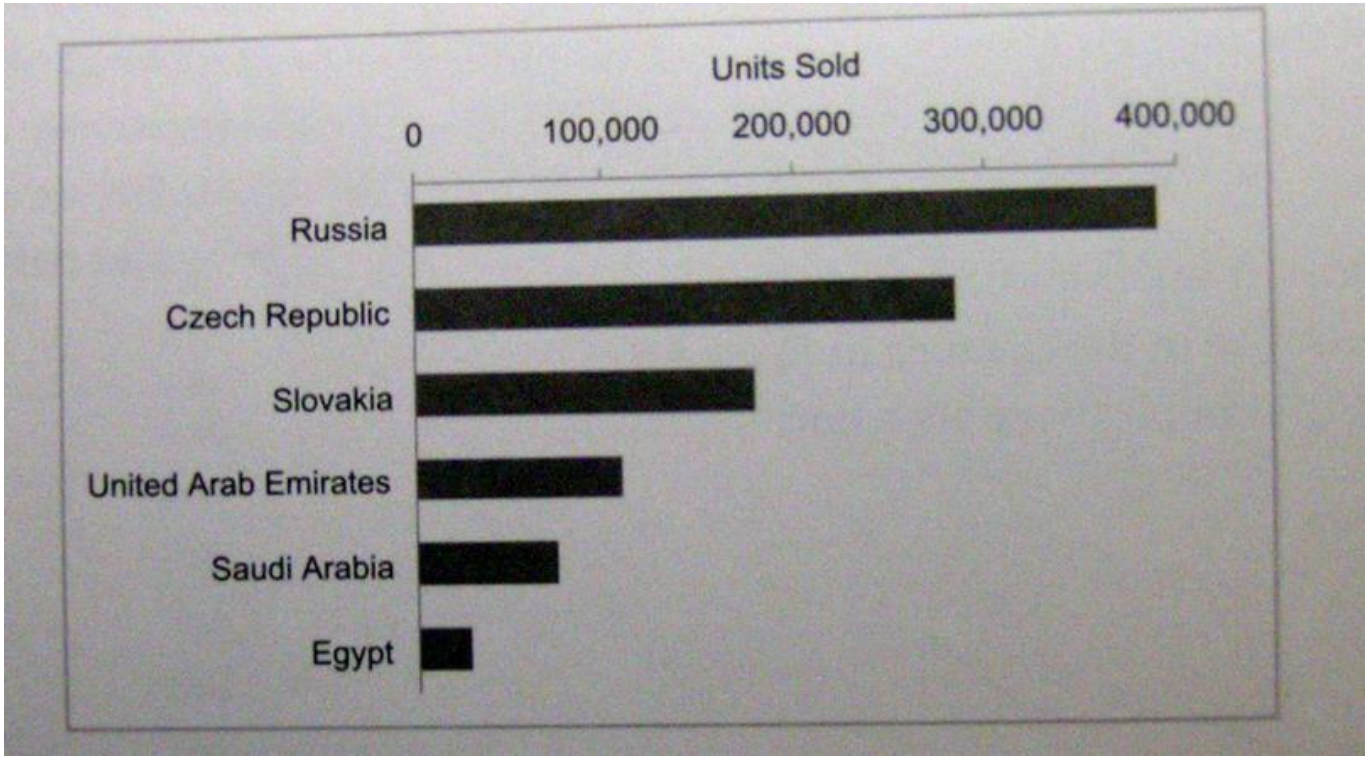
Time series

- Time categorical subdivision
- Quantitative values that are compared each other for
  - Change
  - Rise
  - Fluctuate
  - Decline
  - Trend
  - ..



Ranking

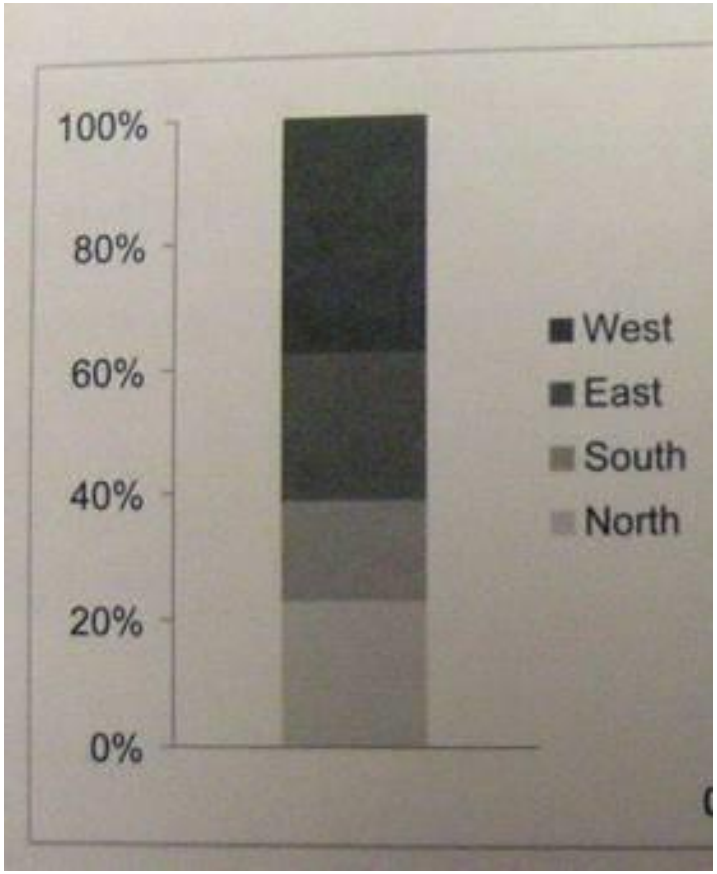
- Categorical subdivision sorted by size
- Quantitative values that are compared each other for
  - Larger than
  - Smaller than
  - Equal to
  - n^{th} position
  - ...



Part-to-whole (Proportions)

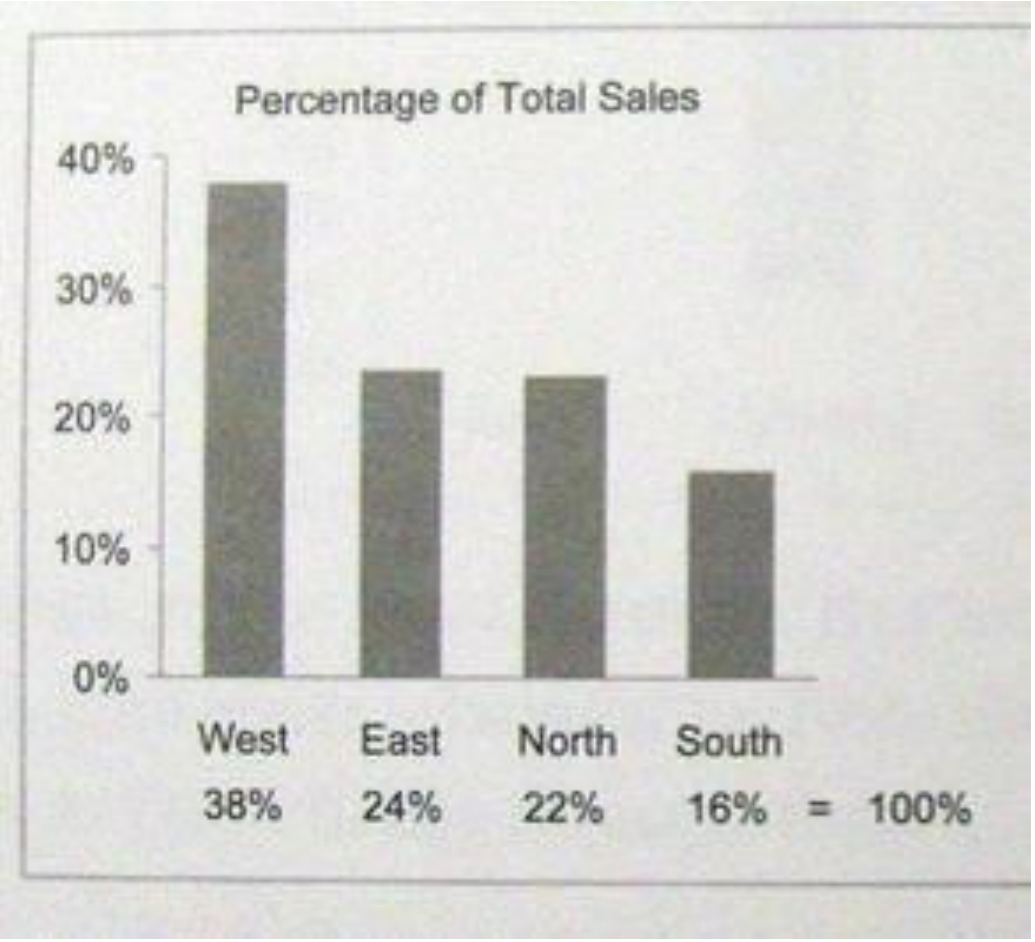
- How individual quantitative values, associated to categorical relate to the complete set of values
- Usually expressed as percentage
- Quantitative values that are compared each other for
  - Percent
  - Share
  - ...

Problems of shapes with 2D areas (like pie charts)



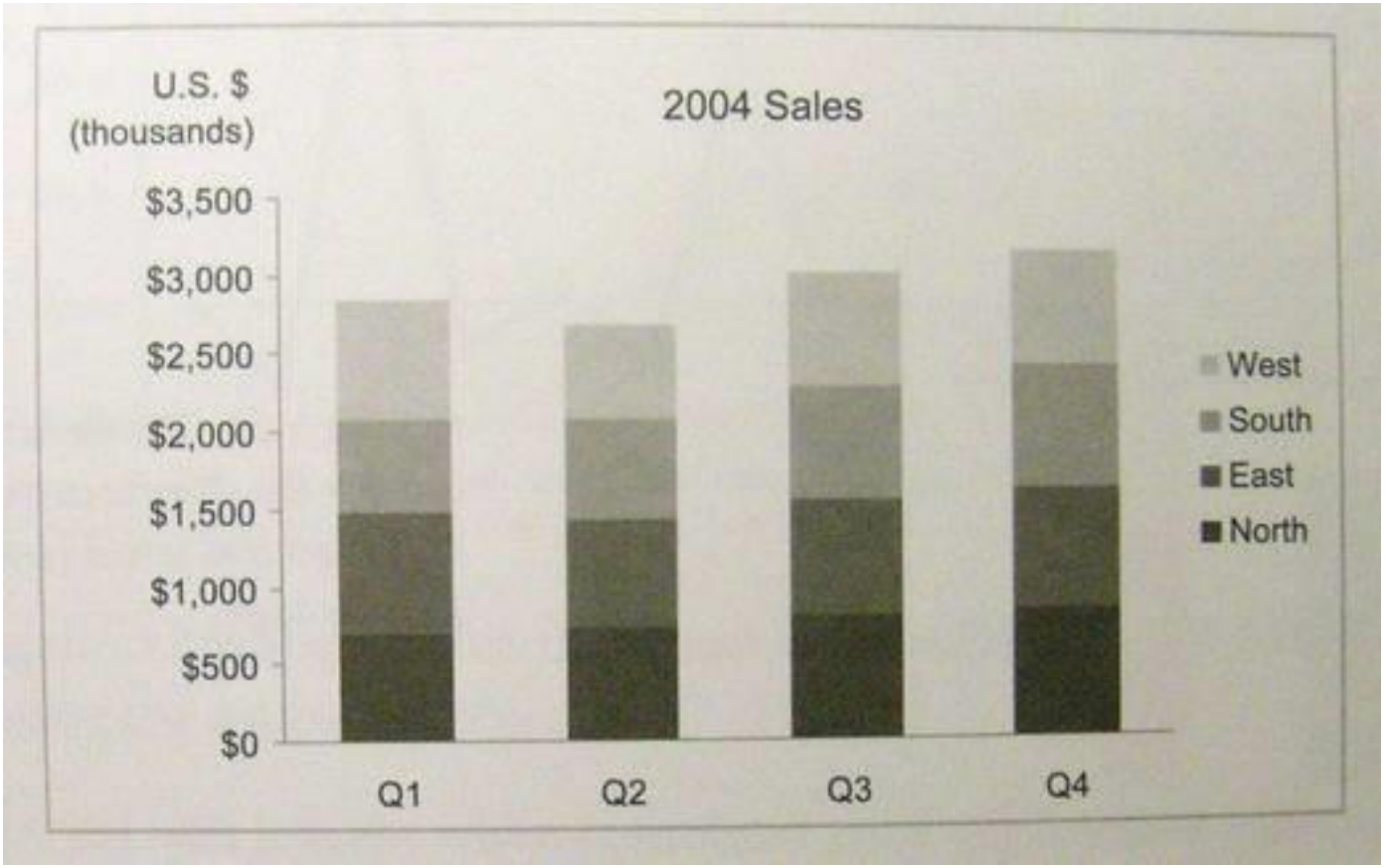
Part-to-whole

- Much better



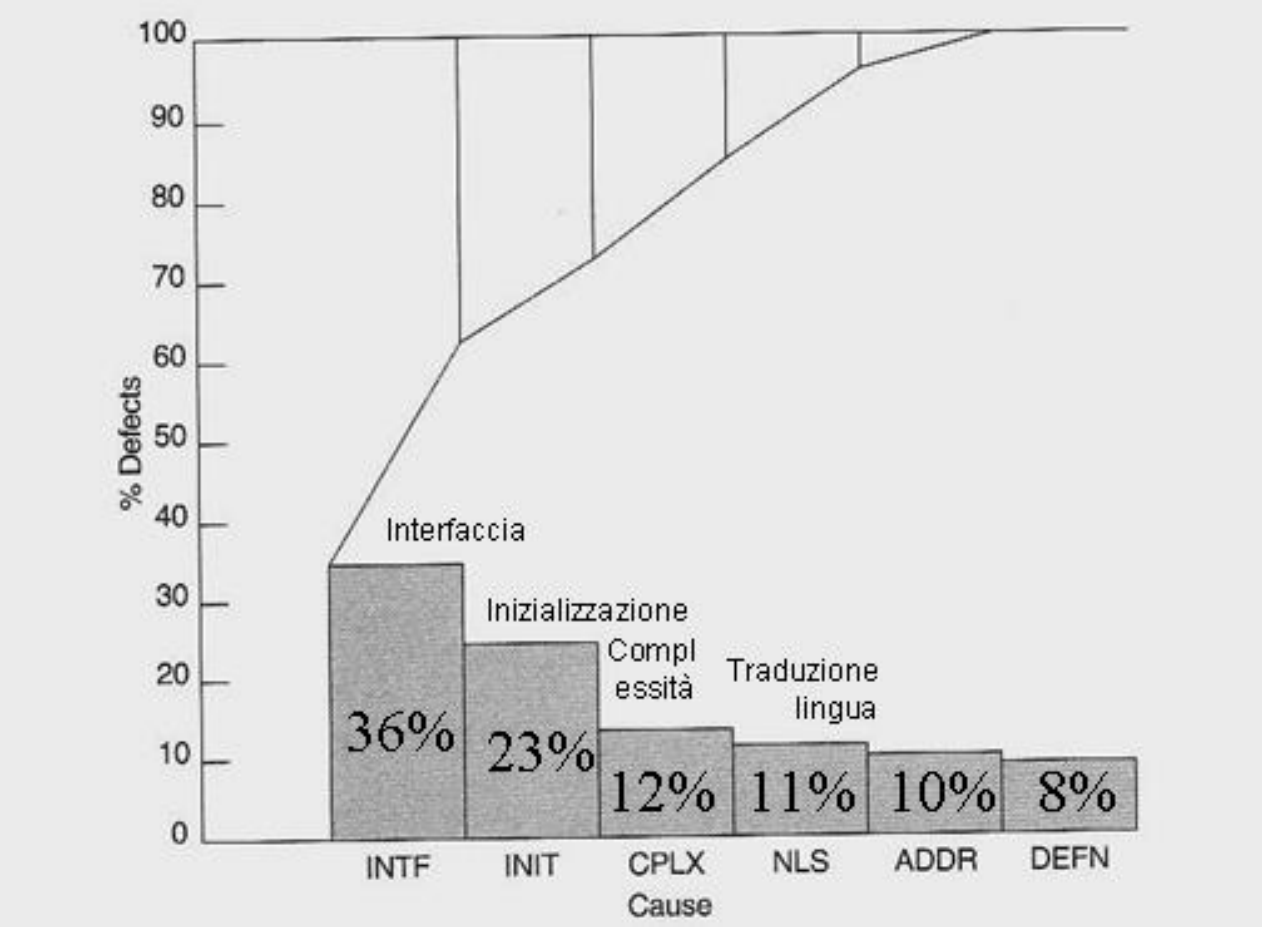
Part-to-whole

- Useful stacked bars (mmm...)



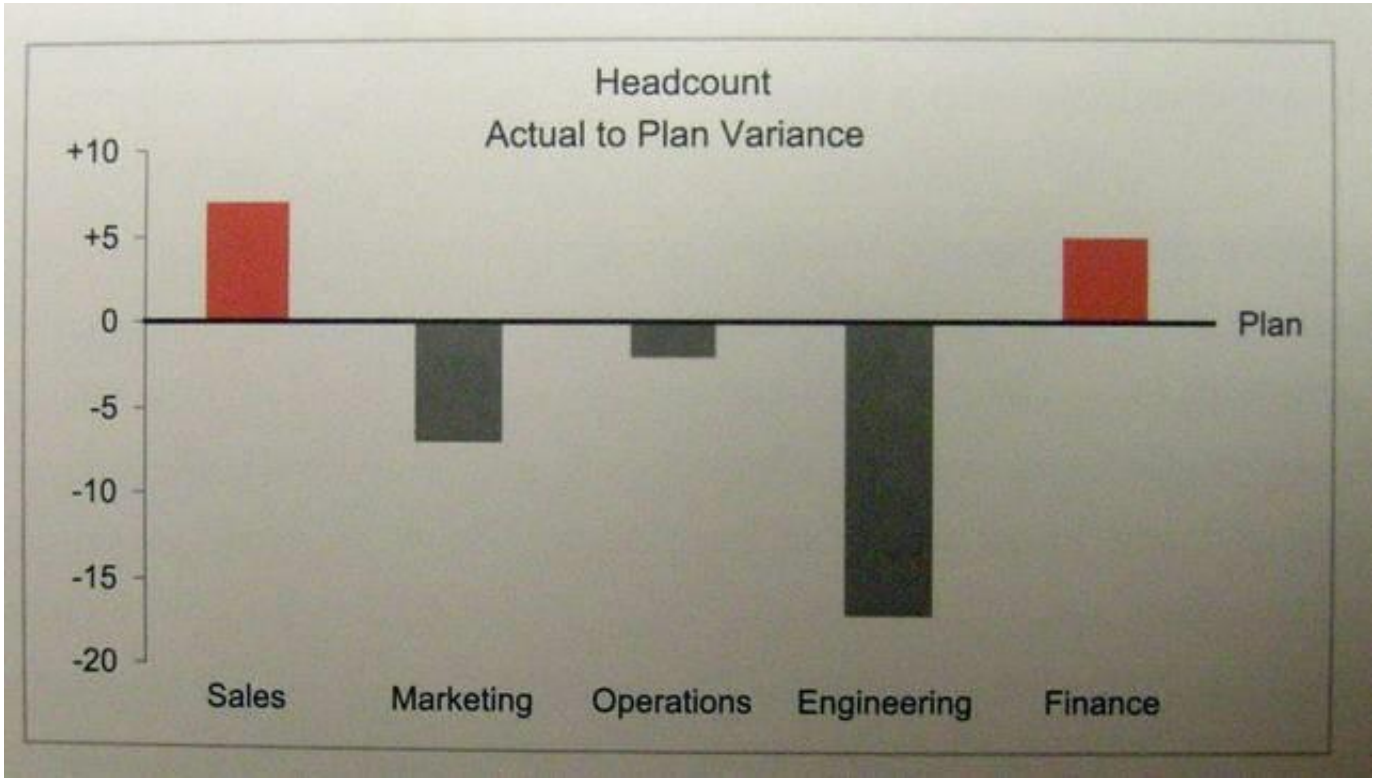
Part-to-whole - Pareto diagrams

- Example: Software errors share
- Less intuitive



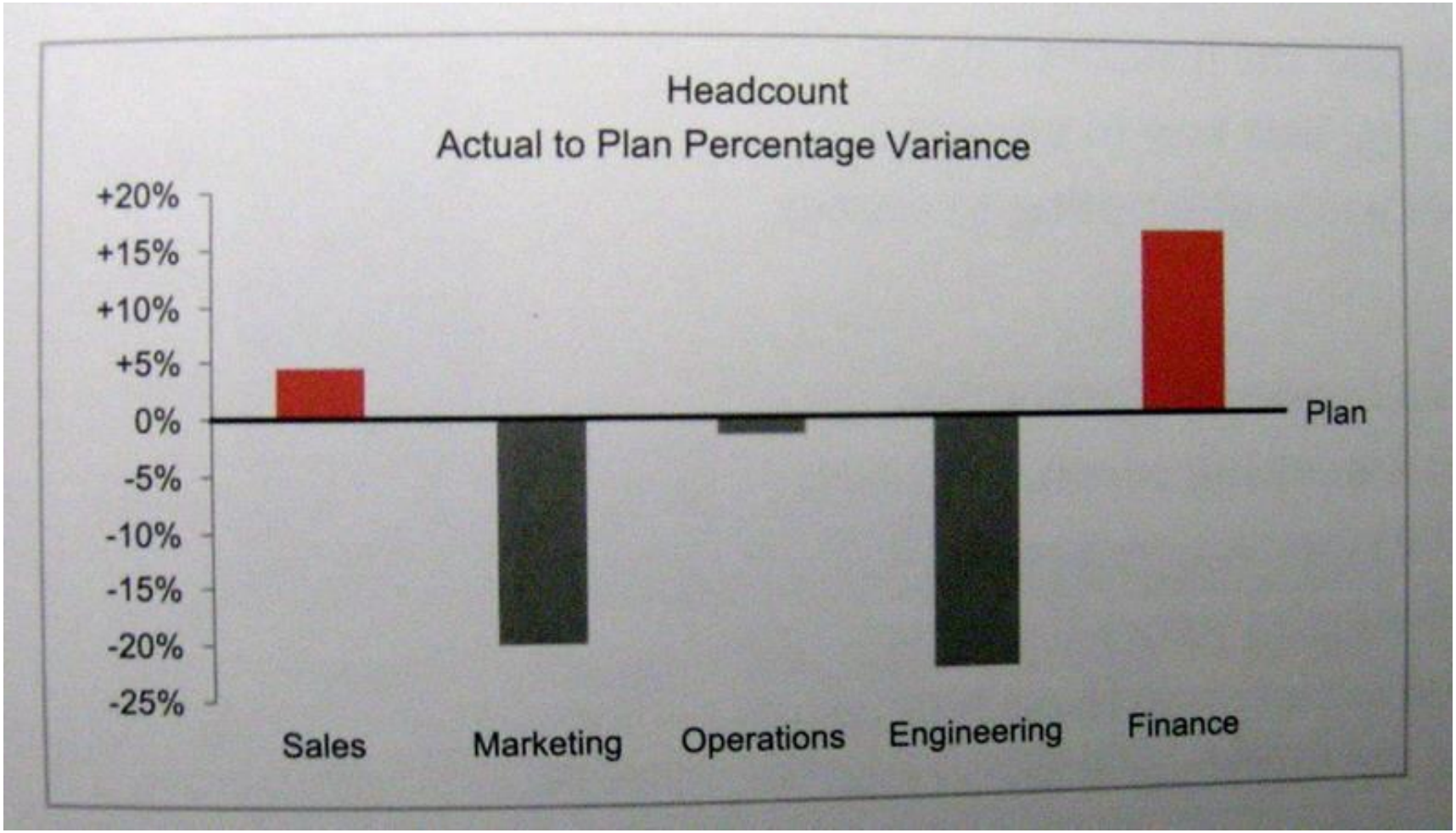
Deviation

- The degree to which one or more quantitative values differ in relation to a primary set of values
- Color is categorical: bad vs good data



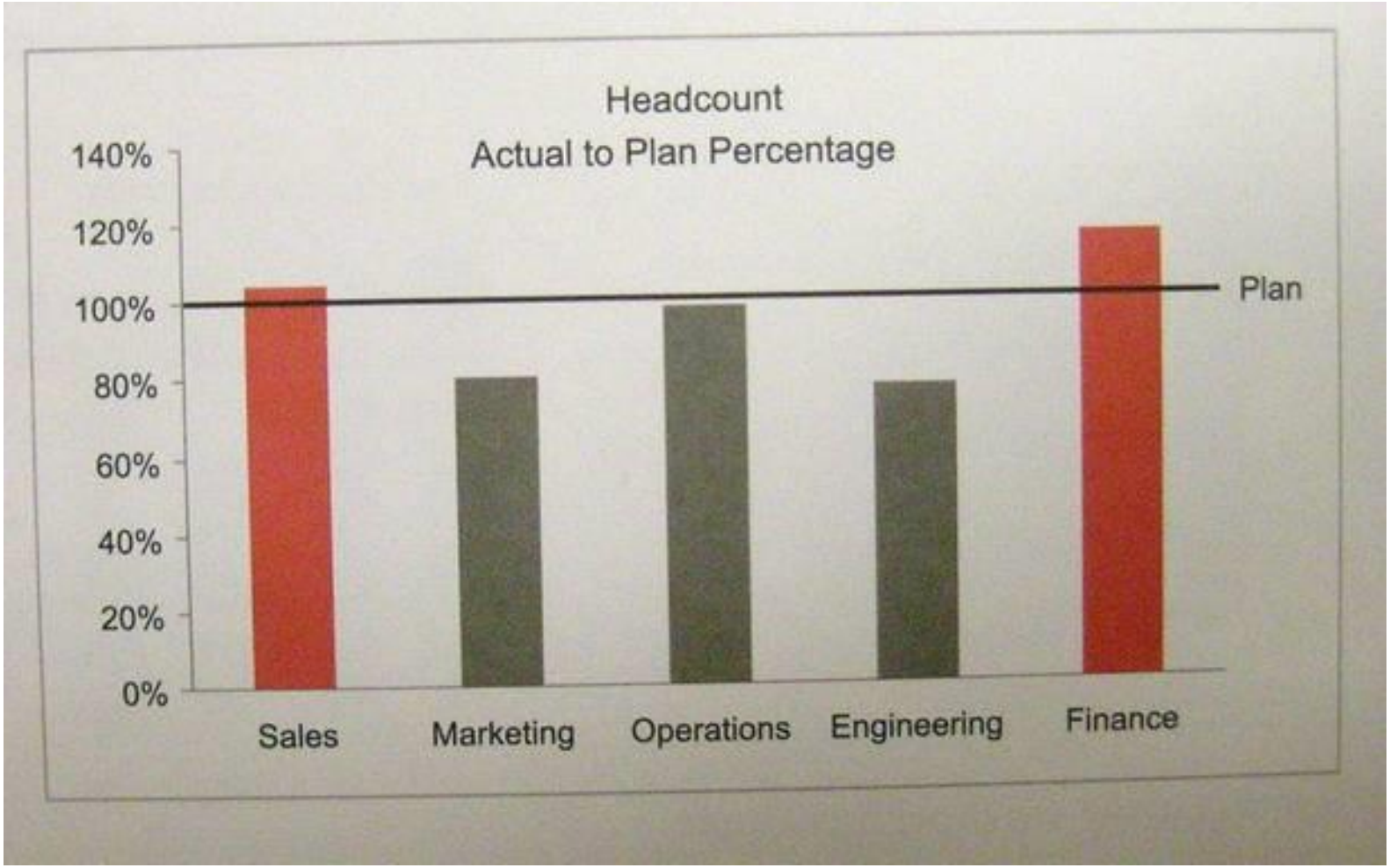
Deviation design

- Same data as percentage

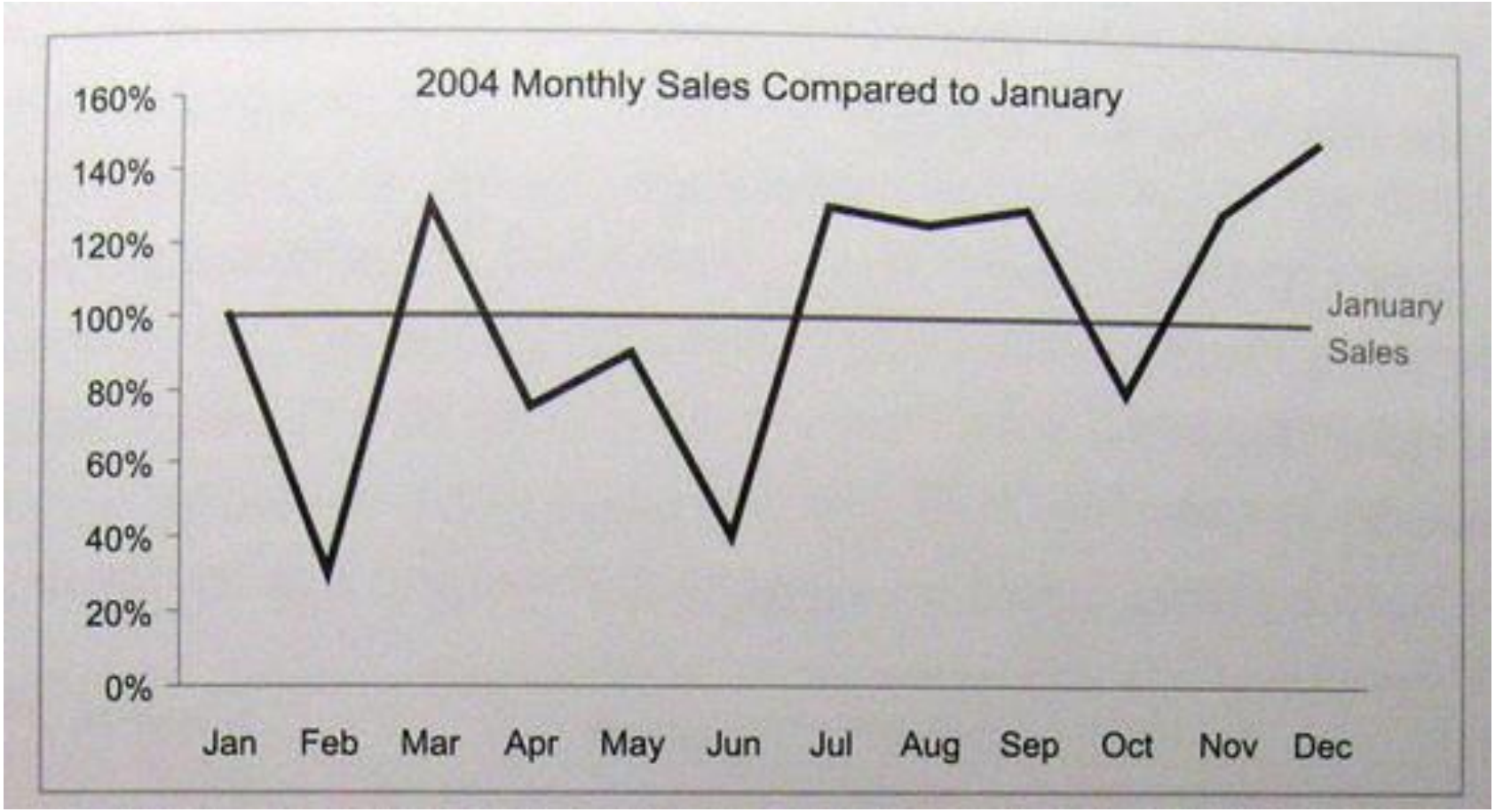


Deviation design

- Same data as percentage

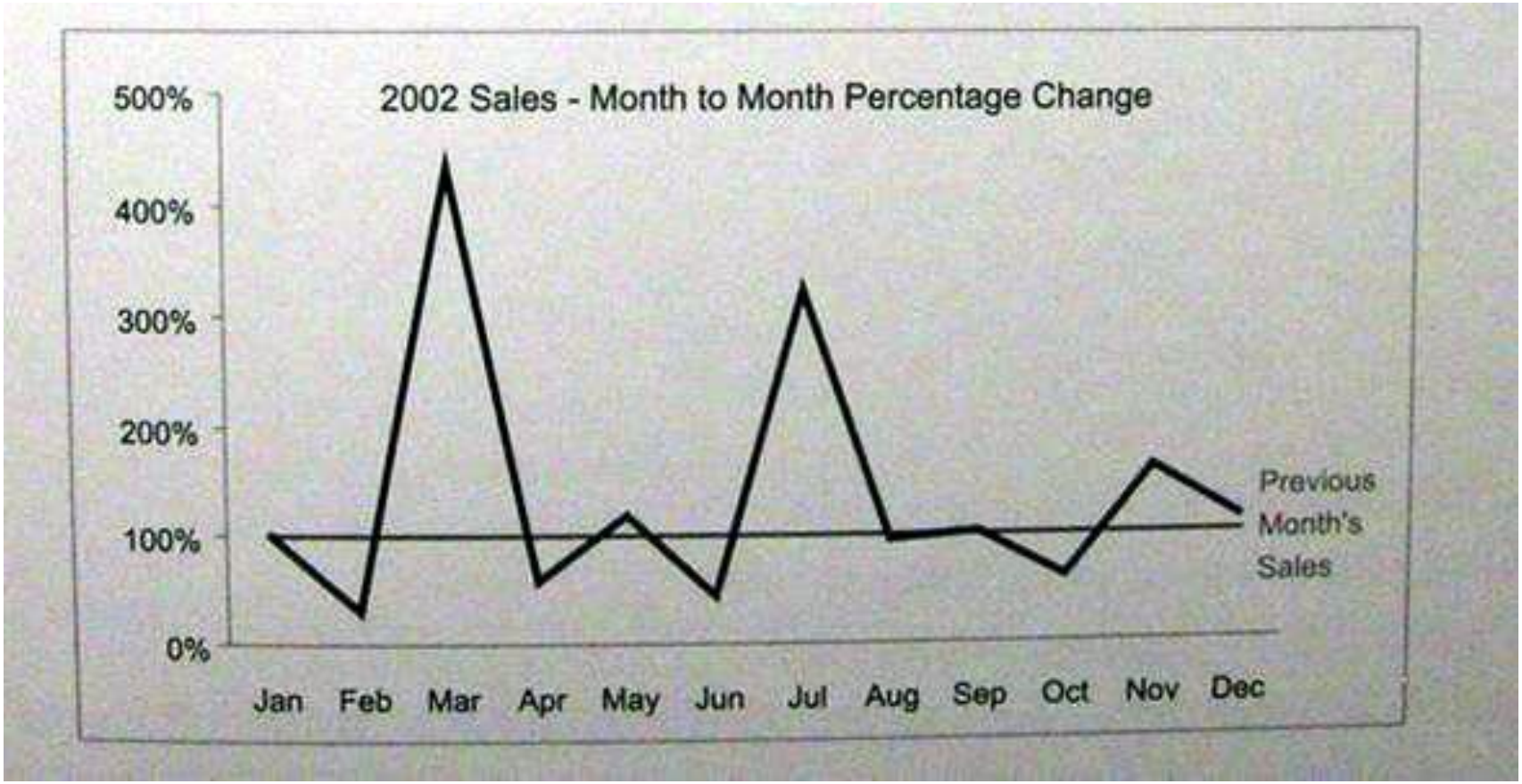


Deviation design + time-series



Deviation design + time-series

- Note that the horizontal line represents very different values



Control chart

μ and σ can give more information to expert people

The graph represents software modules (x) and errors per kloc

In the bottom graph outliers have been removed

What is wrong with this graph?

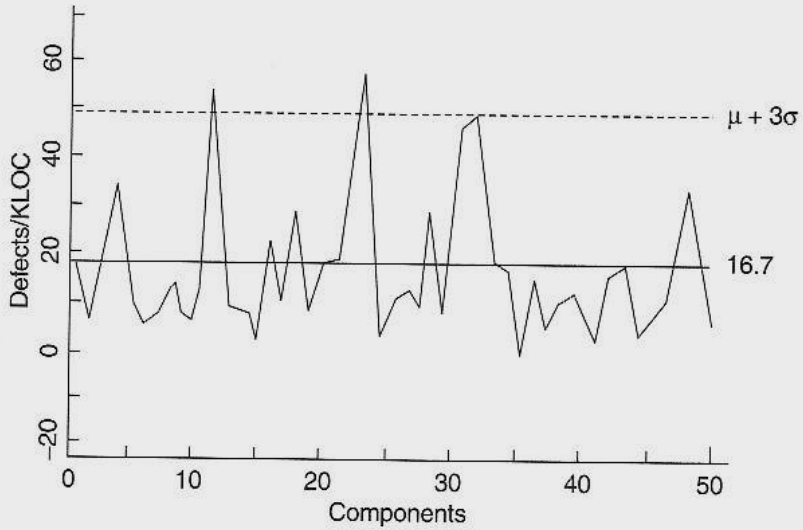
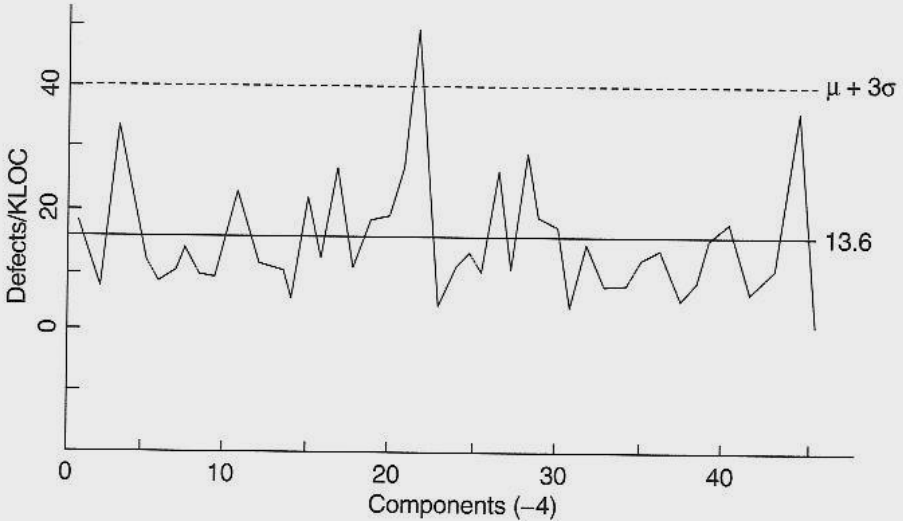
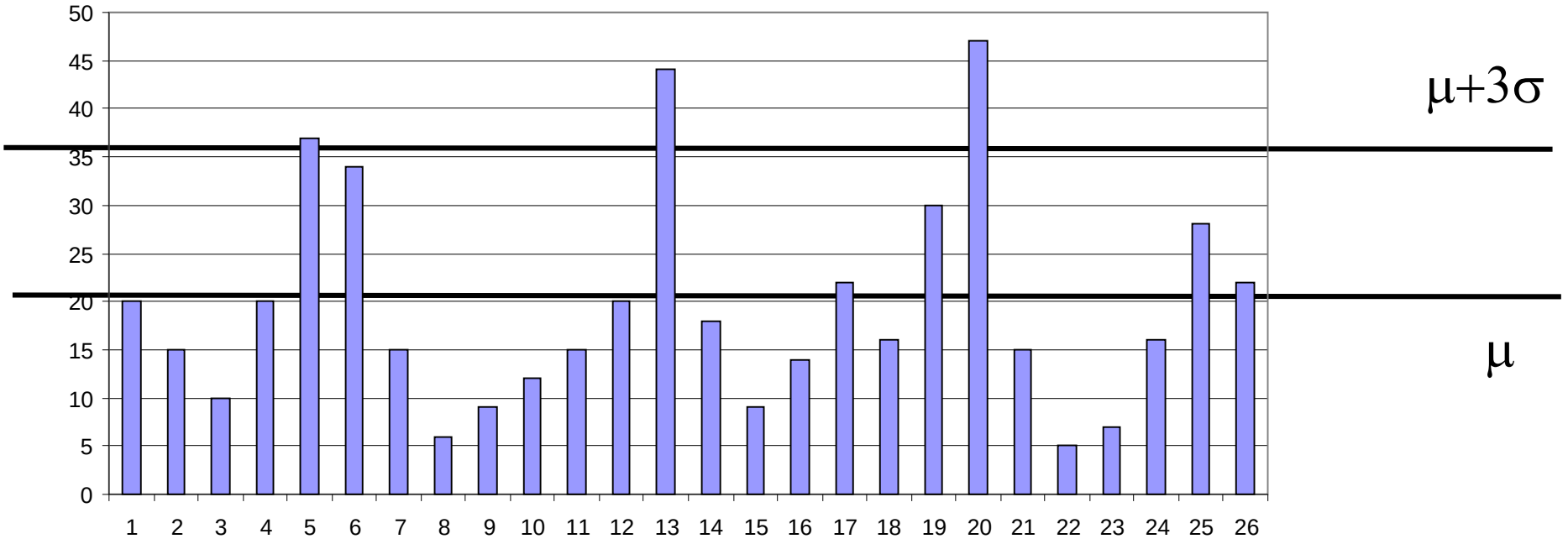


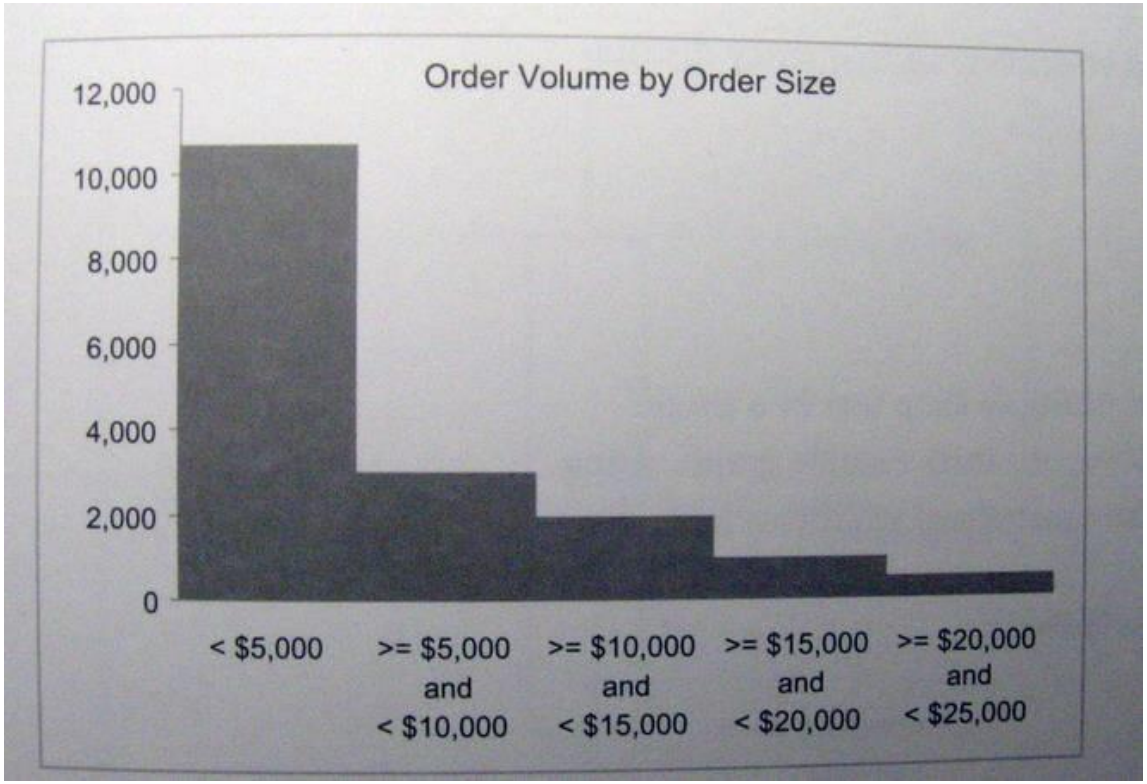
FIGURE 5.12
Pseudo-Control Chart of Test Defect Rate—First Iteration



Lines are wrong here!

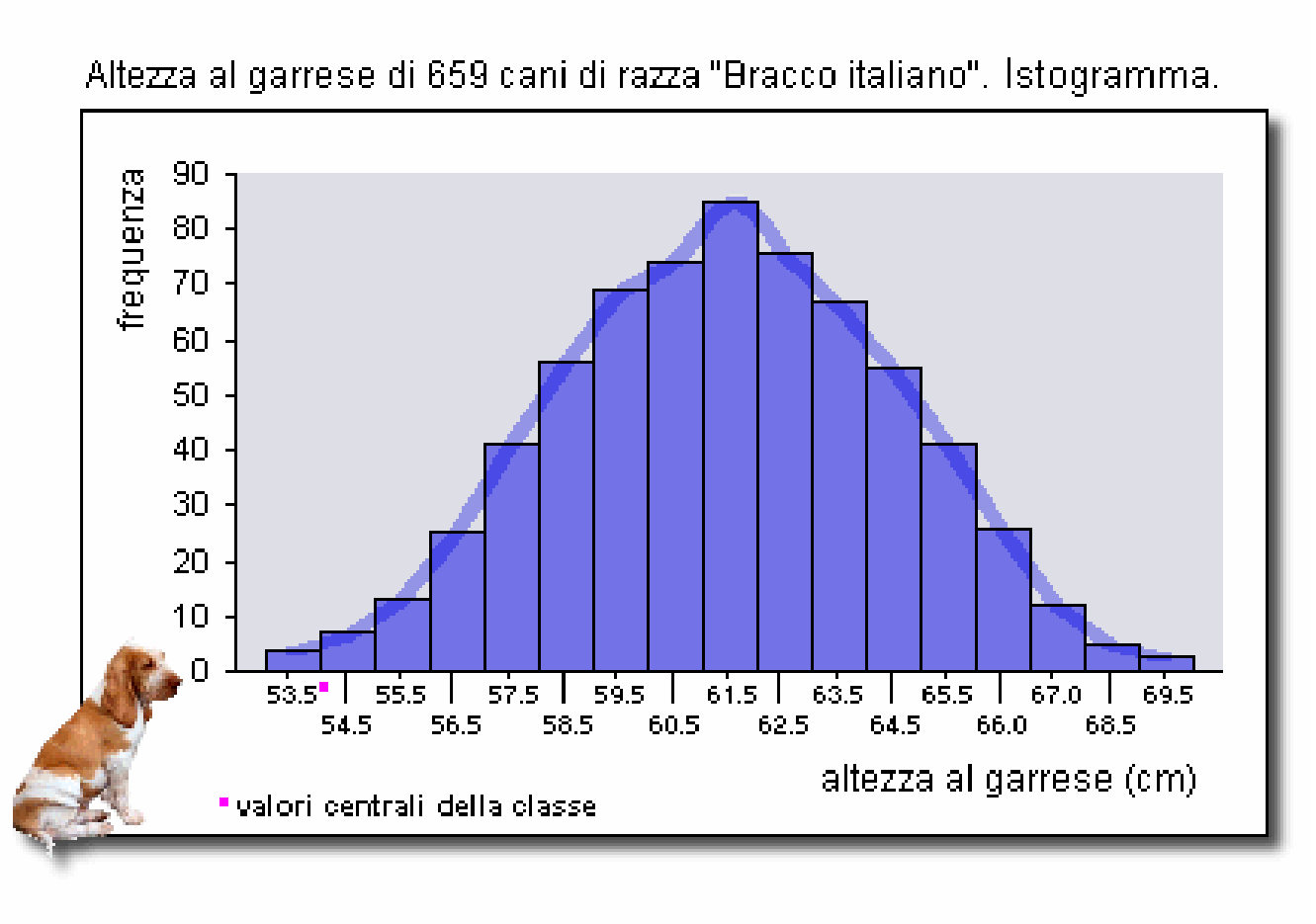


Distribution (values)

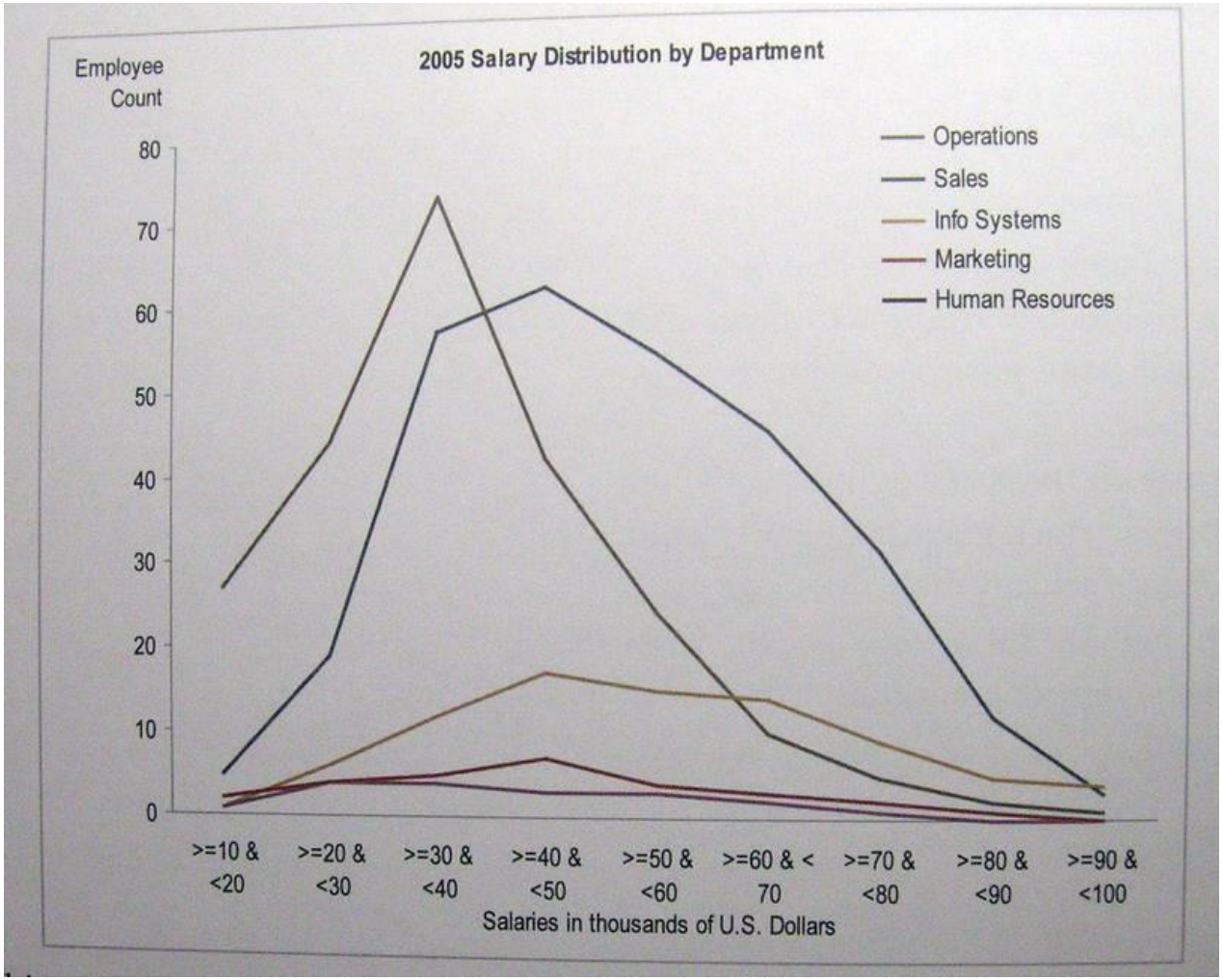


- Histogram

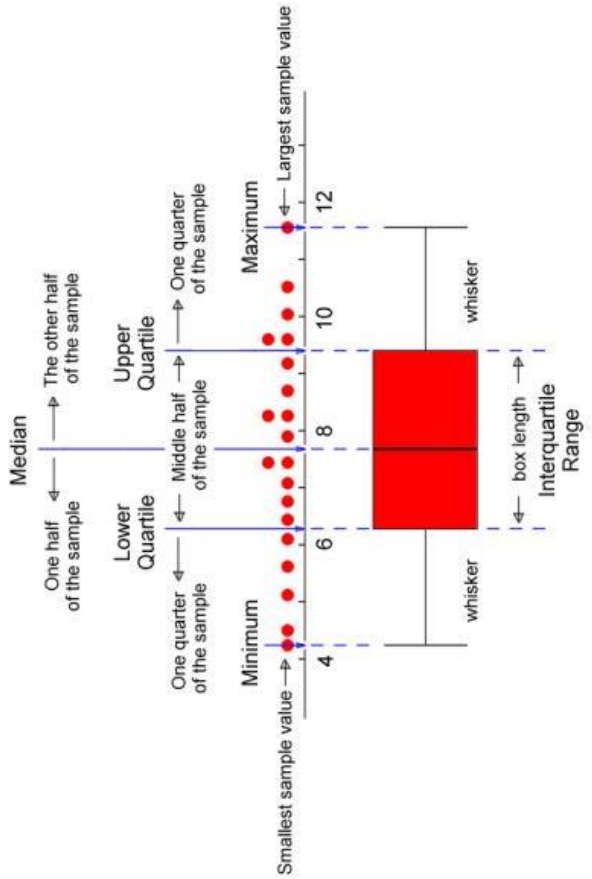
Distribution (values + shape)

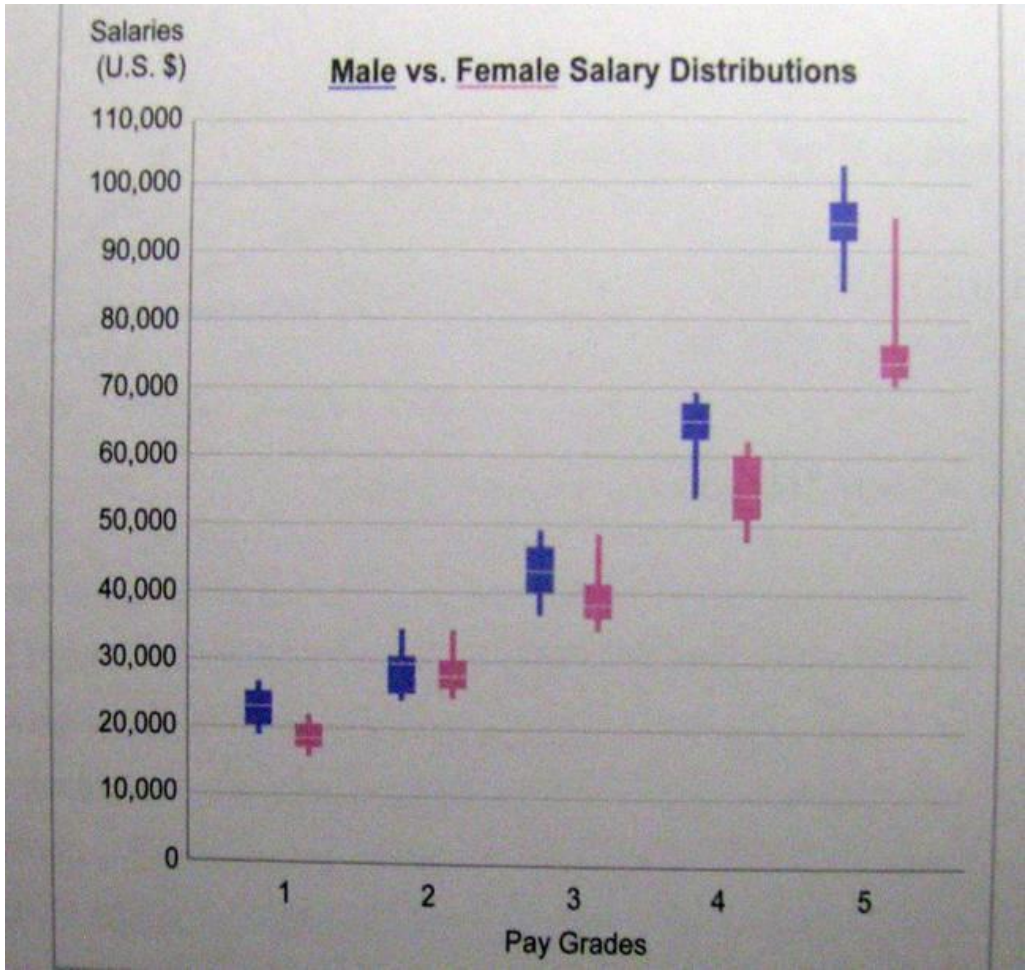


Multiple distributions (shapes)



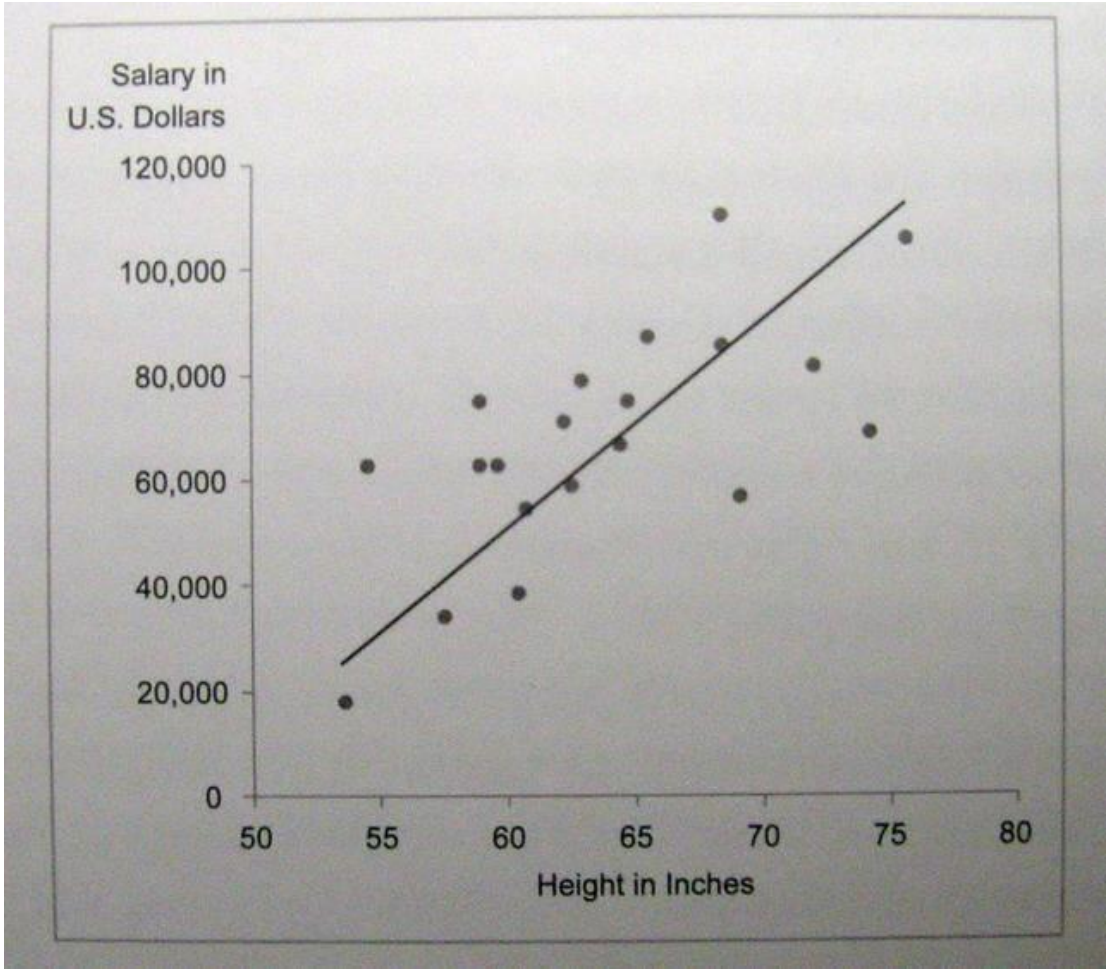
Multiple distributions (boxplots)





1. On average women are paid less
2. The disparity becomes increasingly greater as grade increases
3. Salaries vary the most for women in the highest salary grades (long right tale)

Correlation

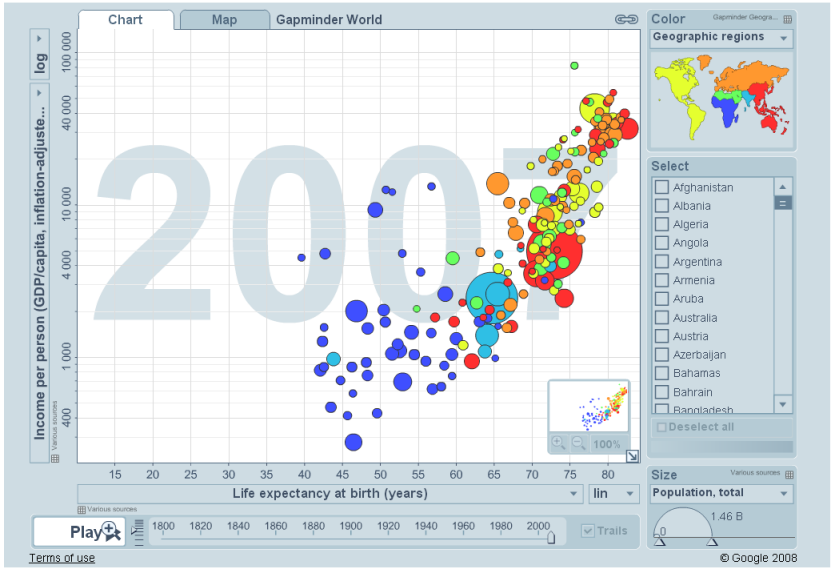


Relationships Summary

Relationship	Points	Lines	Points & Lines	Bars
Nominal comparison	When narrowing the scale and removing the zero	Avoid	Avoid	horizontal or vertical
Time series	Avoid	x=time y= quantitative emphasis on trends	x=time y= quantitative emphasis on trends and individual values	x=time y= quantitative emphasis on individual values
Ranking	When narrowing the scale and removing the zero	Avoid	Avoid	horizontal or vertical
Part-to-whole	Avoid	Avoid	Avoid	horizontal or vertical
Deviation	Avoid	Useful combined with time series	Useful combined with time series and emphasis on individual values	horizontal or vertical vertical with time series
SingleDistribution Multiple Distribut.	Avoid Use to mark median in boxplots	emph. on pattern up to 5 distributions	Avoid Avoid	Histogram As boxplots
Correlation	Scatter plot	Avoid	Only as a trend (not connecting points)	horizontal or vertical

Last Remark!
If time is involved take care of scales
e.g., money (but also college grades)

- It is one of the measure whose scale changes across time
  - inflation / deflation
  - change rate
- In comparisons you have to take that into account



http://www.gapminder.org/

Summarizing

1. Have a good understanding of:
   - involved data (categorical, numerical)
   - involved relationships
     - categorical (nominal, ordinal, interval …)
     - quantitative (ranking, ratio, proportion …)
2. If numerical data is involved :
   - select the right summarizing numbers (task, people) to add to the original data (mean, sigma, etc.) Do not lie!
   - Consider time dependent values (e.g., money)
3. Analyze the task(s) (comparison, trend, lookup, etc.)
4. To table or to graph!
5. Table: select table variation
6. Graph: select visual variables
   - Data
   - Relationships