THE UNIVERSITY OF MELBOURNE

GEOM90007

SPATIAL VISUALISATION

LECTURE 1: INTRODUCTION

SEMESTER 2, 2018

(x, y, z)

BIG DATA

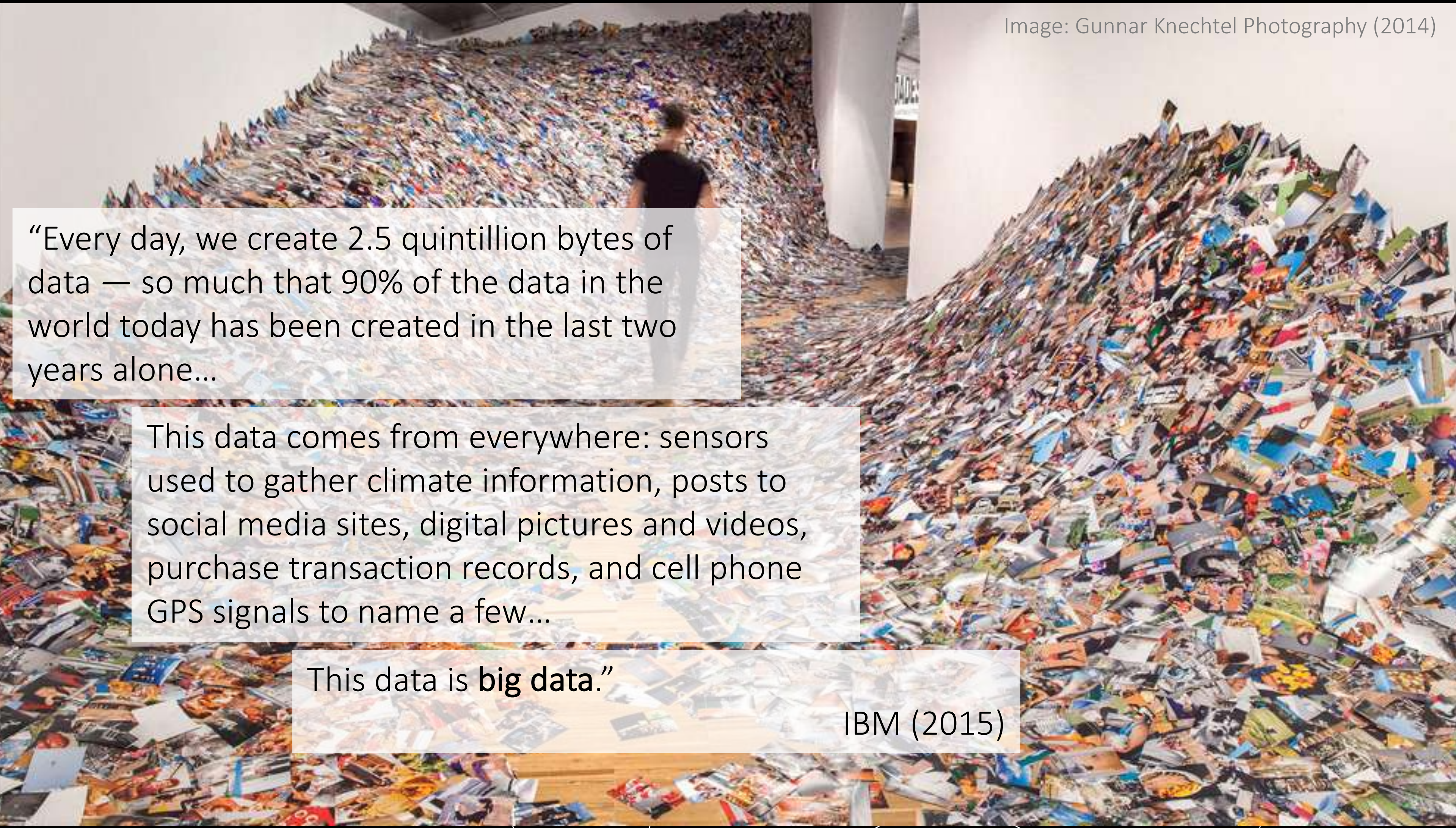


Image: Gunnar Knechtel Photography (2014)

"Every day, we create 2.5 quintillion bytes of data — so much that 90% of the data in the world today has been created in the last two years alone…

This data comes from everywhere: sensors used to gather climate information, posts to social media sites, digital pictures and videos, purchase transaction records, and cell phone GPS signals to name a few…

This data is **big data**."

IBM (2015)

BIG BANG DATA - EXHIBITION THEMES

Data deluge, avalanche, explosion

A new era of knowledge

I am data, We are data

Data for the common good

What data can't tell us

What data means to us

Mobile Lovers (Banksy, 2014)

ARTSCIENCE Museum, Marina Bay Sands (2016), http://www.marinabaysands.com/museum/big-bang-data.html

DATA SCIENTISTS

"In the age of Big Data, facts, figures and opinions are easier than ever to collect. *Sorting through it all is more of a challenge—as is getting your message across*... People are no longer passive consumers of media; they want to interact, explore and share"

(FFunction, 2016)

GISCIENTISTS

"We have access to an unprecedented amount of fine-grained data on cities, transportation, economies, and societies, much of these data referenced in geo-space and time. There is a tremendous opportunity to discover new knowledge about spatial economies that can inform theory and modelling…"

(Miller, 2010)

BUT BIG (A LOT OF) DATA IS NOT THE PROBLEM…..

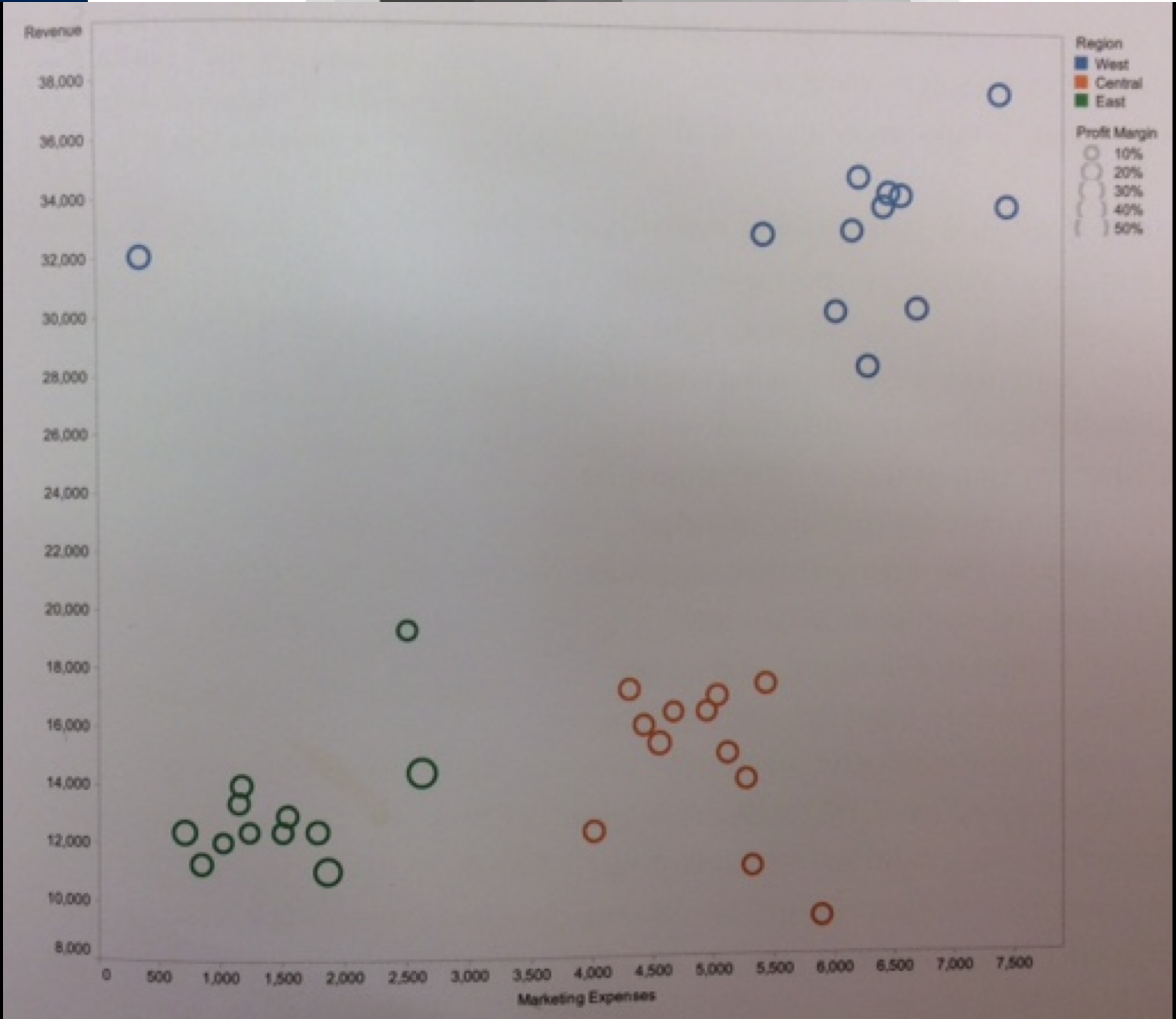
- Most of us don’t understand it well enough to make good use of it
- Progress in technology helps us collect, store, and access data
- …but we need our brains and specific data analysis skills
- Apart from statistics, good data analysis skills include graphs — *visual representations* of quantitative data — to explore numbers and discover meaningful patterns
- Good data analysis allows us to:
    1. Better understand the data and manage what is going on now
    2. To better predict what will likely happen in the future
    3. Thus, make better choices and decisions

USE YOUR EYES….

- Most *business intelligence* (BI) software has failed on the intelligence promise
- BI makes data available – but it requires human intelligence to make it understandable, and therefore valuable.
- True BI leverages the strengths of human eyes and minds and augments our cognition

- Traditional BI relies on tables of text, good for looking up individual facts but restrict thinking to one or two facts at a time. These alone are not enough for a picture of the whole story that enables us to see the relations and dependencies in the data.

- What we need are: proper *visualisations* of the data


Revenue
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
6,500
7,000
7,500
Marketing Expenses
Region
West
Central
East
Profit Margin
10%
20%
30%
40%
50%

VISION

- While statistics can reduce large, complex data into a few numbers, it can also shear away much of its richness and subtlety

- ***Visual*** data analysis provides a simple, yet illuminating window through which information can be seen, explored and understood, making thus accessible to a wider audience

> "One great virtue of good graphical representation is that it can serve to display clearly and effectively a message carried by quantities, the calculations or observations of which are farm from simple."
>
> (Tukey, 1965)

- Visual data analysis taps an ability all but a few of us naturally possess: ***vision***

VISION

- Vision is by far the most dominant and powerful sense
- When written as text, numbers must be processed one at a time, because the process of a reading is a ***sequential*** one, limiting the speed of *text analysis*
- However, images and graphical representations are processed faster, because image interpretation is performed ***in parallel*** within the human perception system, and independent of local language.
- Visual representations of quantitative information:
  - ***Enhance our ability to think about it***
  - ***Make patterns, trends, and exceptions visible and understandable faster***
  - ***Extend the capacity of our memory***
- Close relationship between vision and cognition (understanding)
- Visual perception alone, although powerful, can only be used effectively if we understand and apply its ***rules***

VISUALISATION

The *communication* of information using *graphical representations*, and the techniques for creating such representations (e.g., diagrams, maps, images, etc)

It is part of (good) data analysis

However, data collection, integration, cleaning, transformation, database storing are preparatory activities, but NOT part of data analysis, therefore, NOT part of visualisation either

It is NOT photography or image processing

VISUALISATION

“The purpose of visualization is insight, not pictures”

(Shneiderman, 1999)

“[Visualisation is] visual communication for the purpose of the presentation and exploration of data”

(Rhyne et al., 2003)

“Visualisation applies vision research to practical problems of data analysis in much the same way as engineering applies physics to practical problems of building factories”

(Ware 2013)

VISUALISATION

As it applies to visual representation of information, can be preceded by three words, creating three terms with different meanings:

- *Data* visualisation
- *Scientific* visualisation
- *Information* visualisation

Data visualisation: an umbrella term that covers all types of visual representations that support the exploration, examination, and communication of data.

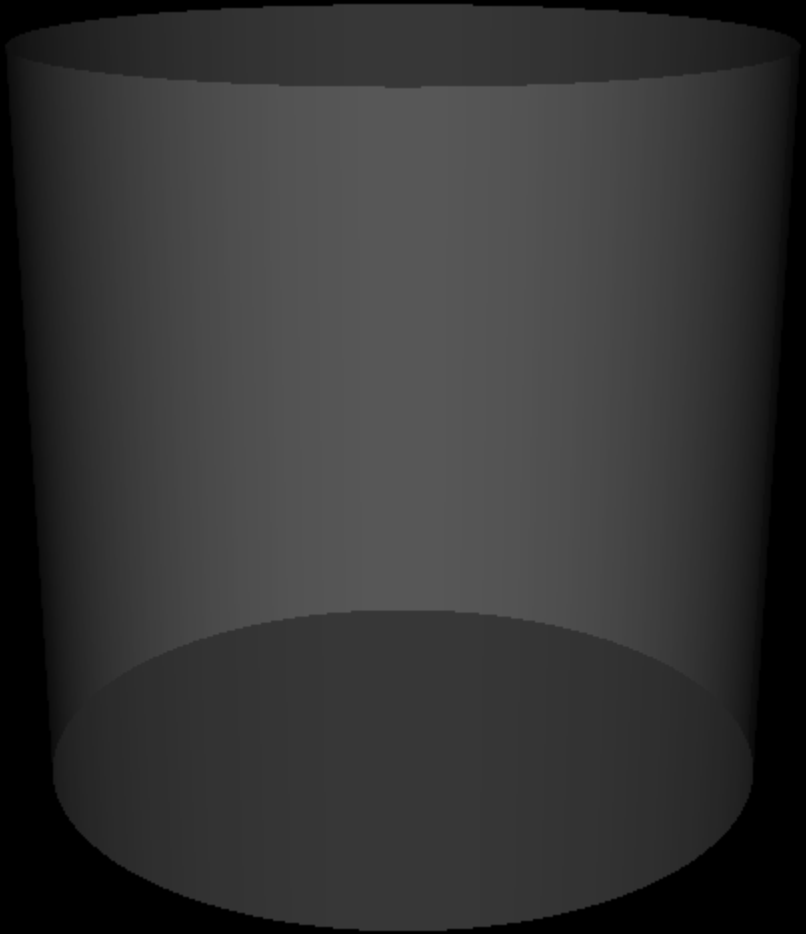
SCIENTIFIC VISUALISATION (SciVis)

"Primarily concerned with the visualization of 3D phenomena (architectural, meteorological, medical, biological, etc.), where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component"

(Friendly, 2008)

Typically confirmatory analysis:
The confirmation or rejection of a hypothesis

SCIENTIFIC VISUALISATION (SciVis)



Evolution of concentration (colour coded) using 250K particles.

http://www.uni-kl.de/sciviscontest/

INFORMATION VISUALISATION (InfoVis)

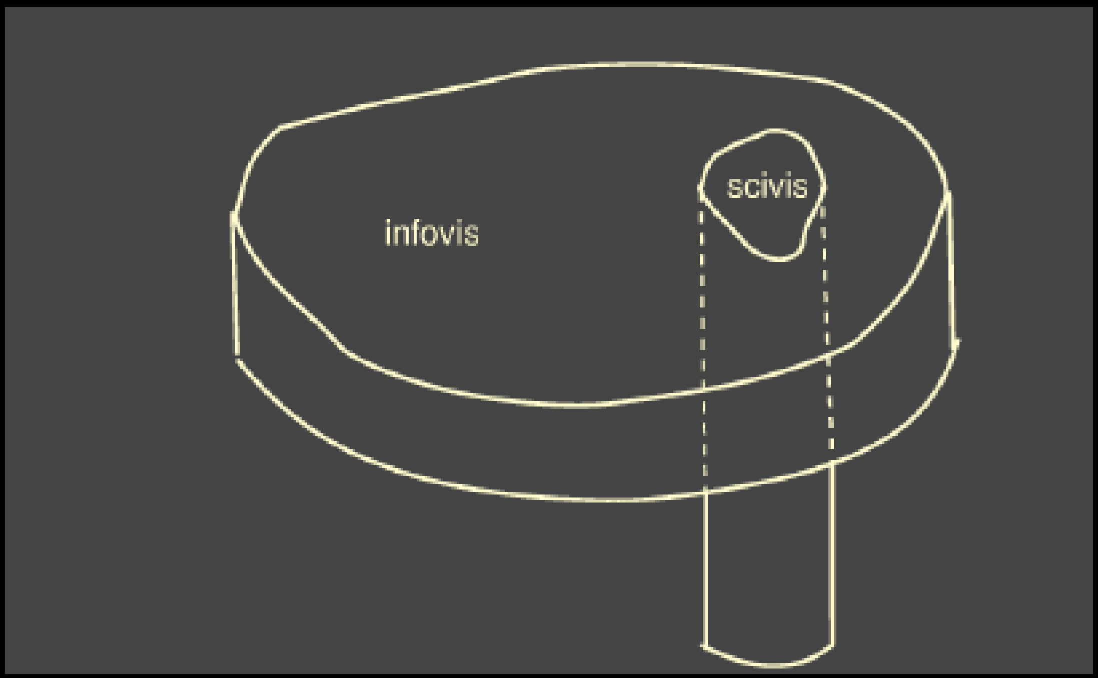
- The study of (interactive) visual representations of (mostly) abstract data to assist human cognition
- Data are both numerical and non-numerical, such as text or geographic (Geovisualisation)
- Data analysis + visual communication
- Draws on the intellectual history of several traditions, including computer graphics, human-computer interaction, cognitive psychology, semiotics, graphic design, statistical graphics, cartography, and art (IEEE VIS, 2016)
- It ***amplifies cognition***

Typically exploratory analysis:
The search for a hypothesis

DATA VISUALISATION

Activities	Exploration Explanatory/Sense-making →	Communication
Techniques/ Technologies	Information Visualisation (Geovisualisation) Scientific Visualisation →	Graphical Presentation
Immediate Goal	Understanding	
End Goal	Good Decision Making	

InfoVis vs. SciVis



(Munzner, 2003)

- Historical divide between InfoVis and SciVis
- Boundaries can be fluid!

- (Recent development) Visual analytics: An outgrowth of InfoVis and SciVis that focuses on *analytical reasoning* facilitated by *interactive visual interfaces*. It couples interactive representations with underlying analytical processes (e.g., statistical procedures, data mining) such that high-level, complex activities can be effectively performed (i.e., sense making , reasoning, decision making)

SPATIAL VISUALISATION

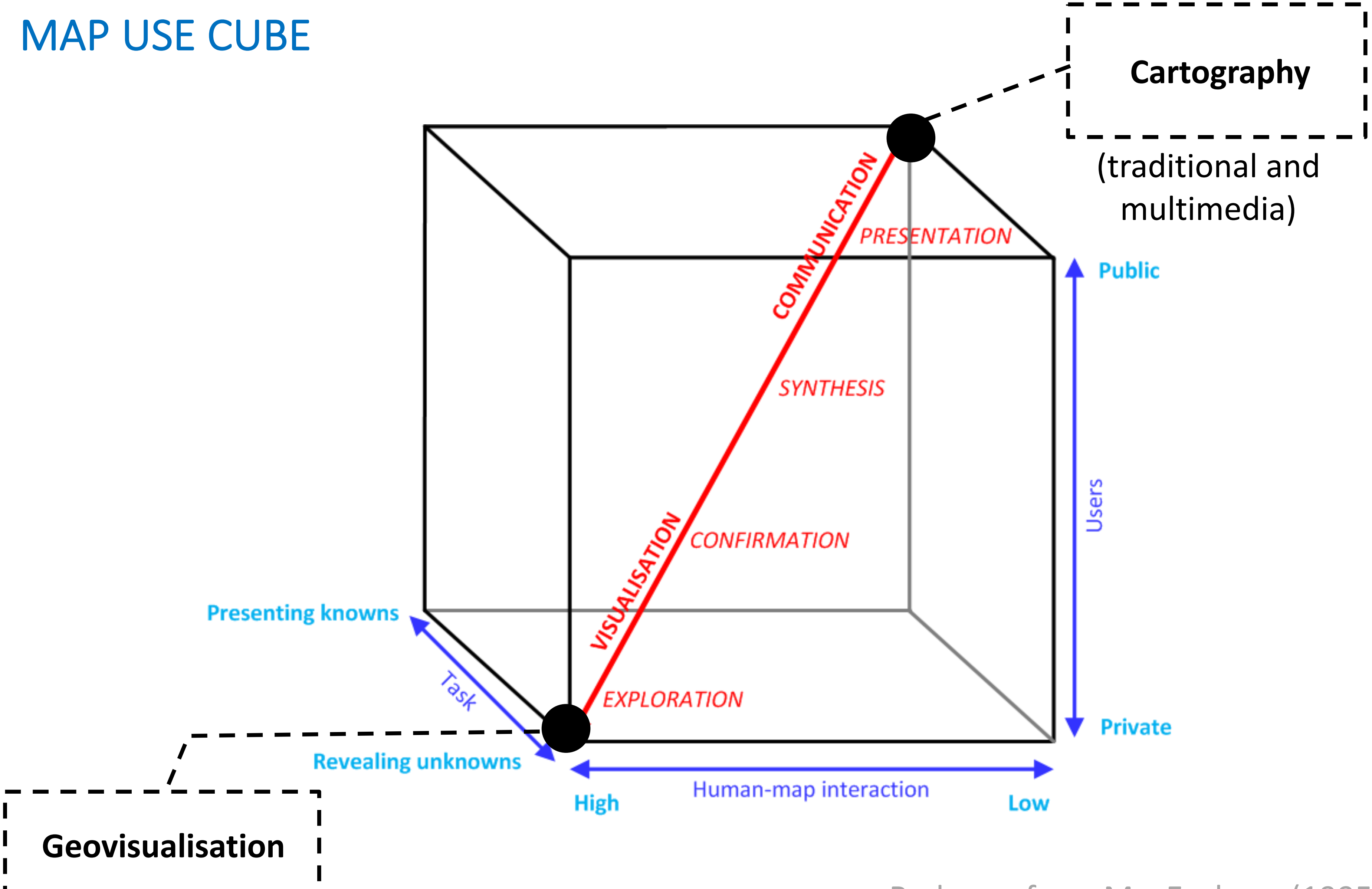
- Based on the earlier definitions, spatial visualisation focuses on the *analysis* and *exploration* of spatial data

- It requires a design process for visual communication

- Four key topics can be identified:
    - *Data graphics*
    - *Cartography*
    - *Geovisualisation*
    - *Human-computer interaction*

- MacEachren's *Map Use Cube* can be used to understand the cartographic perspective

MAP USE CUBE



Redrawn from MacEachren (1995)

DIFFERENT FORMS

	High interaction		Low interaction	
	Revealing unknowns	Presenting knowns	Revealing unknowns	Presenting knowns
Private	Dynamic editing of complex isoline data	Query a city's population using a digital atlas on DVD	Running a script to "see" a storm's development	Judge a city's population from a graduated circle map
Public	Discussing a dynamic "what-if" simulation	Store location using an interactive kiosk	Landform discussion using a digital relief map	Store location using a static You-Are- Here map

Q: How would map users differ?

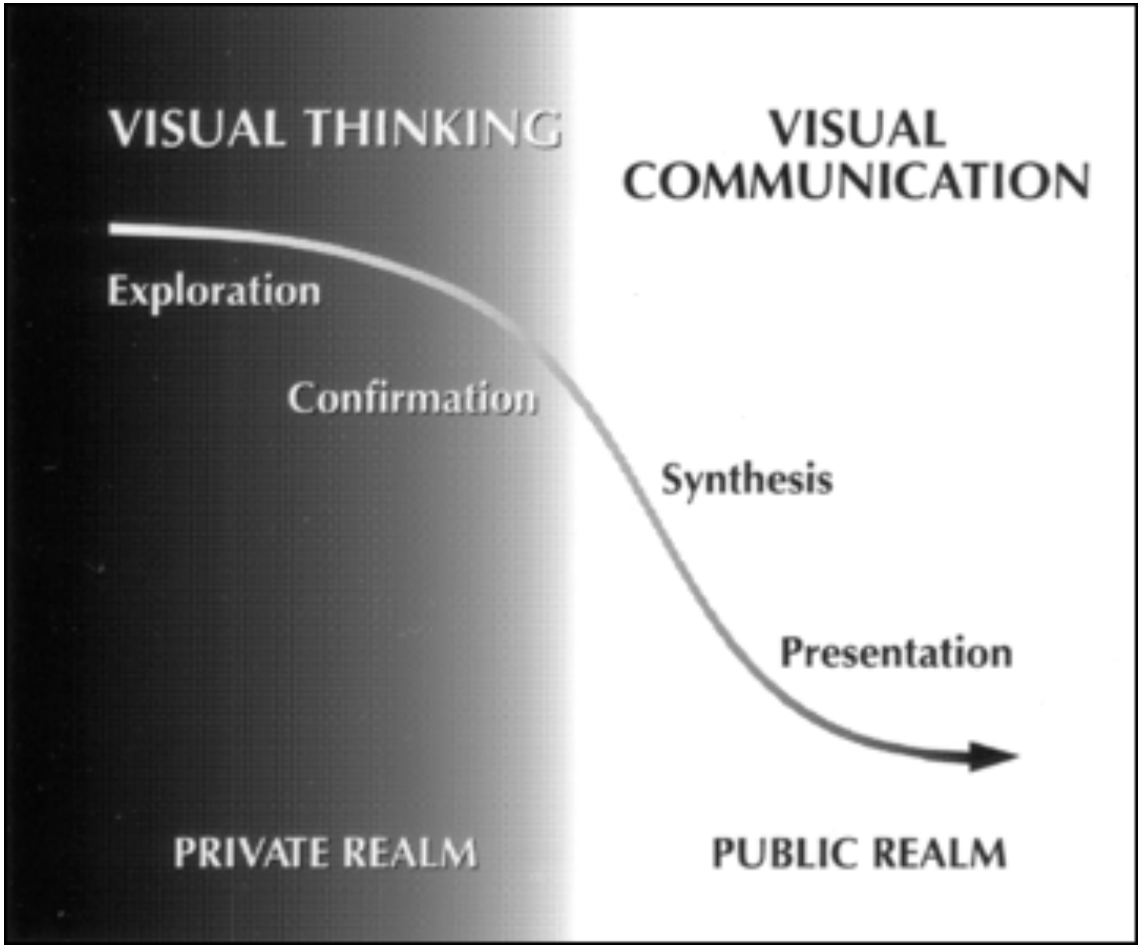
Source: Adapted from MacEachren and the ICA (1998), http://www.geovista.psu.edu/sites/icavis/icavis/poland1.html

VIEW FROM CARTOGRAPHY

“Visualization . . . is definitely not restricted to 'a method of computing,' ... [it is] first and foremost an act of cognition, a human ability to develop mental representations that allow us to identify patterns and create or impose order”

(Ganter and MacEachren 1989)

CARTOGRAPHY - VISUAL THINKING AND COMMUNICATION



The Original Swoopy Diagram

(Dibiase, 1990)

Q: How might this diagram have changed with technology?

GEOVISUALISATION

“Over time… information has become more accessible and a broadening range of types of high-quality spatial data have been recorded.

The result is that greater numbers of geographic information users are now employing highly interactive techniques to achieve insight from a variety of spatial data sets.”

(Dykes et al., 2005)

ADMINISTRATION

POSITIONING SPATIAL VISUALISATION

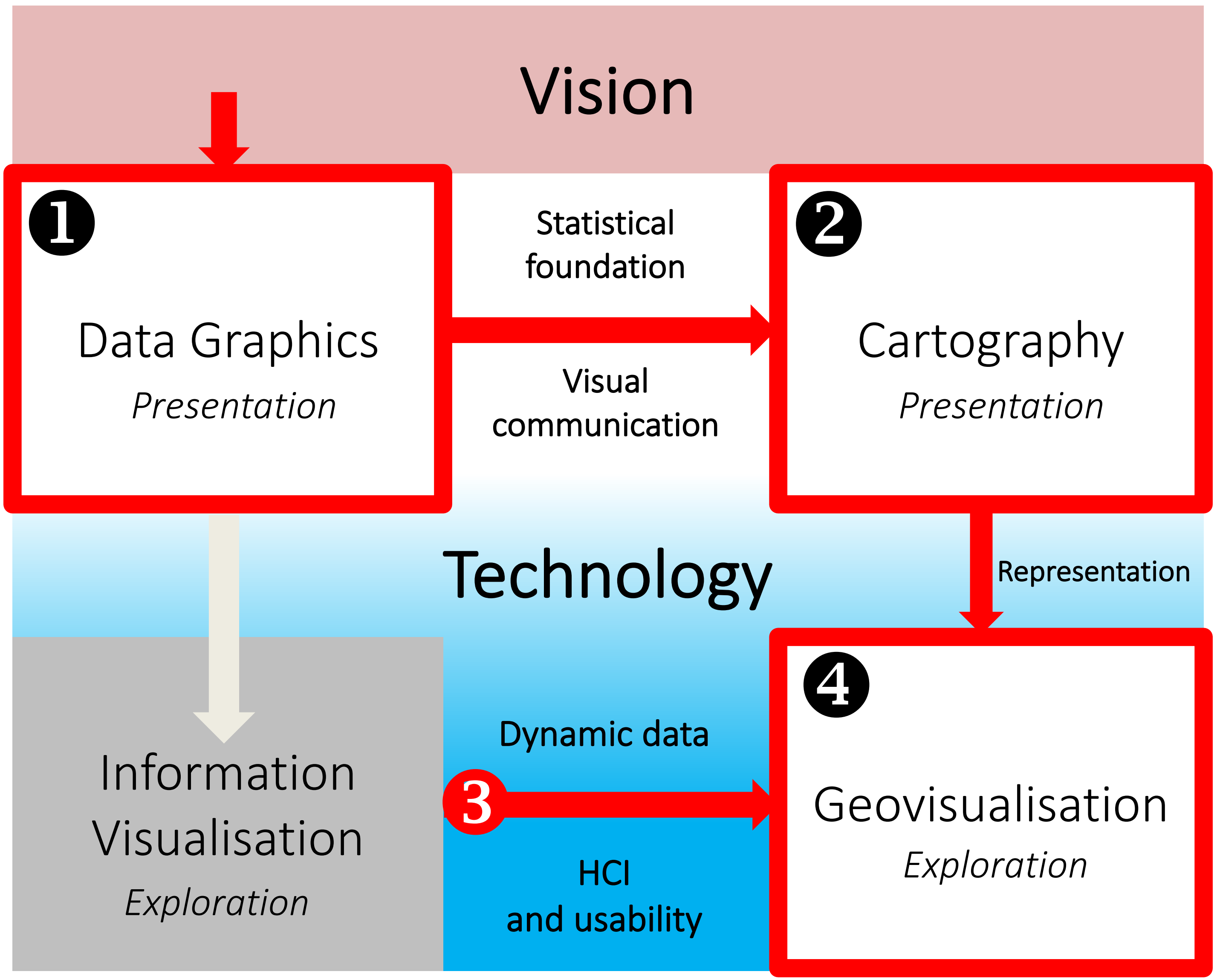
GEOM90008
Foundations of Spatial Information

GEOM90018
Spatial Databases

GEOM90006
Spatial Analysis

GEOM90007
Spatial Visualisation

SUBJECT ROAD MAP



LECTURES

Week	Lecture (part 1)	Lecture (part 2)
1	Introduction	Graphical Excellence
2	Perception	Statistical foundation
3	Data graphics 1	Data graphics 2
4	Data graphics 3	Data graphics 4
5	Cartography 1	Cartography 2
6	Cartography 3	Cartography 4
7	Geovisualisation 1	Geovisualisation 2
8	Midsemester test	Geovisualisation 3
9	Geovisualisation 4	HCI 1
Non-teaching period		
10	Human-centred design 1	Human-centred design 2
11	HCI 2	Revision
12	Group presentations	Group presentations

Proposed program

LABS

Weekly exercises drawing on the lecture material

Day	Start	End	Duration	Location
Tuesday	9:00	11:00	2 hours	Alice Hoy 222 (Comp Lab)

Lab Tutor – Mr David Amores
Email: damores@student.unimelb.edu.au

KEY OUTCOMES

- Critical analysis and problem solving
- Principles of spatial visualisation
- Learning R and Processing languages

ESSENTIALS

- All resources are on LMS
- Reading materials will be provided to address breadth*
  - No subject specific books required
  - Recommended reading on R and Processing languages (can be borrowed)
- Note taking will be beneficial together with review questions

Subject Assesments

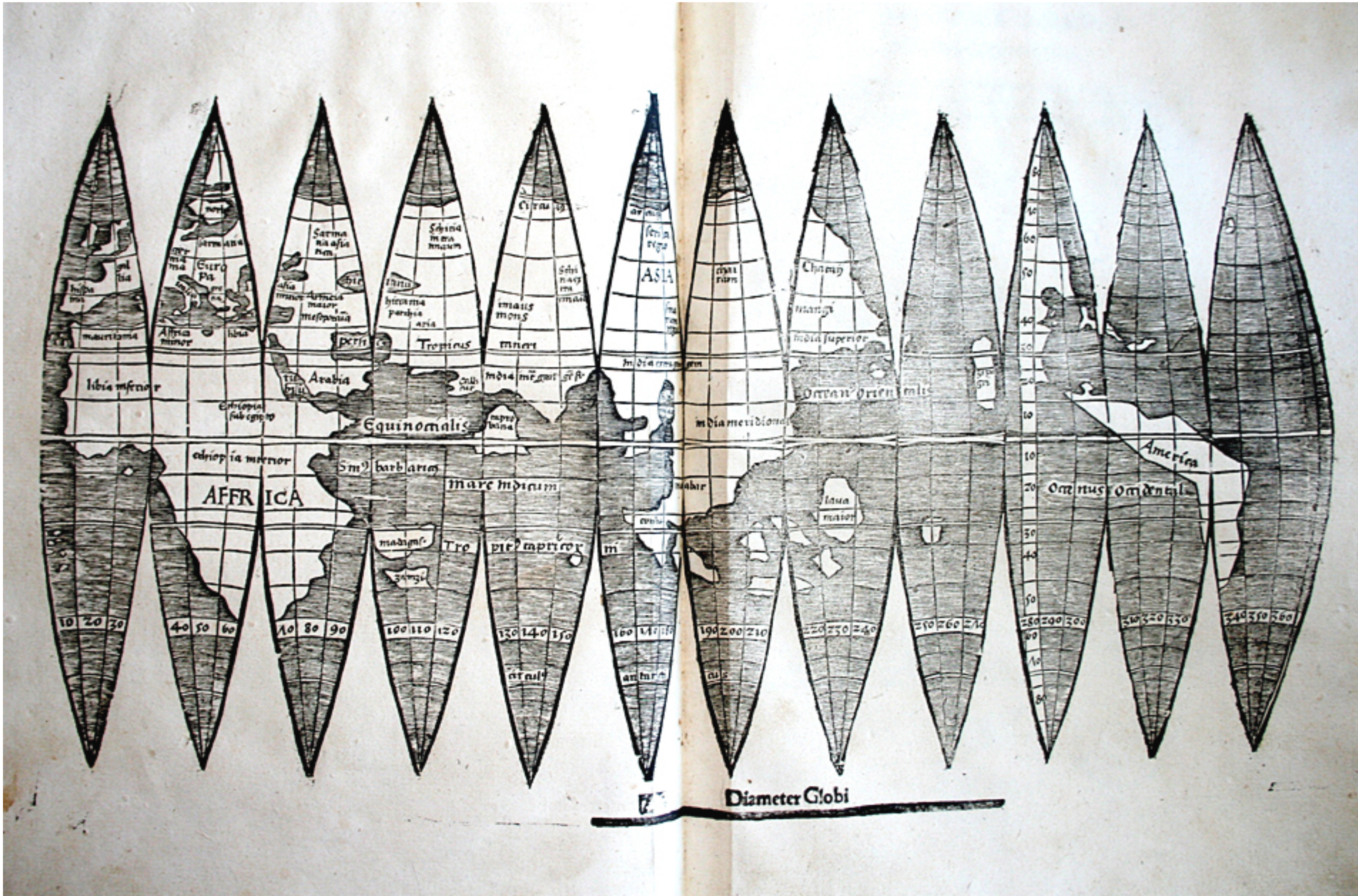
Description	Format	Timing	% Assessment
Assignment 1: R graphics	Individual	Week 4	10%
Mid semester test	Individual	Week 8	25%
Assignment 2: Processing interface	Individual	Week 8	20%
Major project	Group	- Week 12 - Week 14 - Week 14	45% -oral (10%) -report (25%) -individual participation report (10%)

A BRIEF HISTORY OF TOPICS BEHIND SPATIAL VISUALISATION

Ptolemy's Map (150 AD)

Image: Library of Congress, Geography and Map Division

Waldseemüller's **Map – America (1507 – Global Gores**



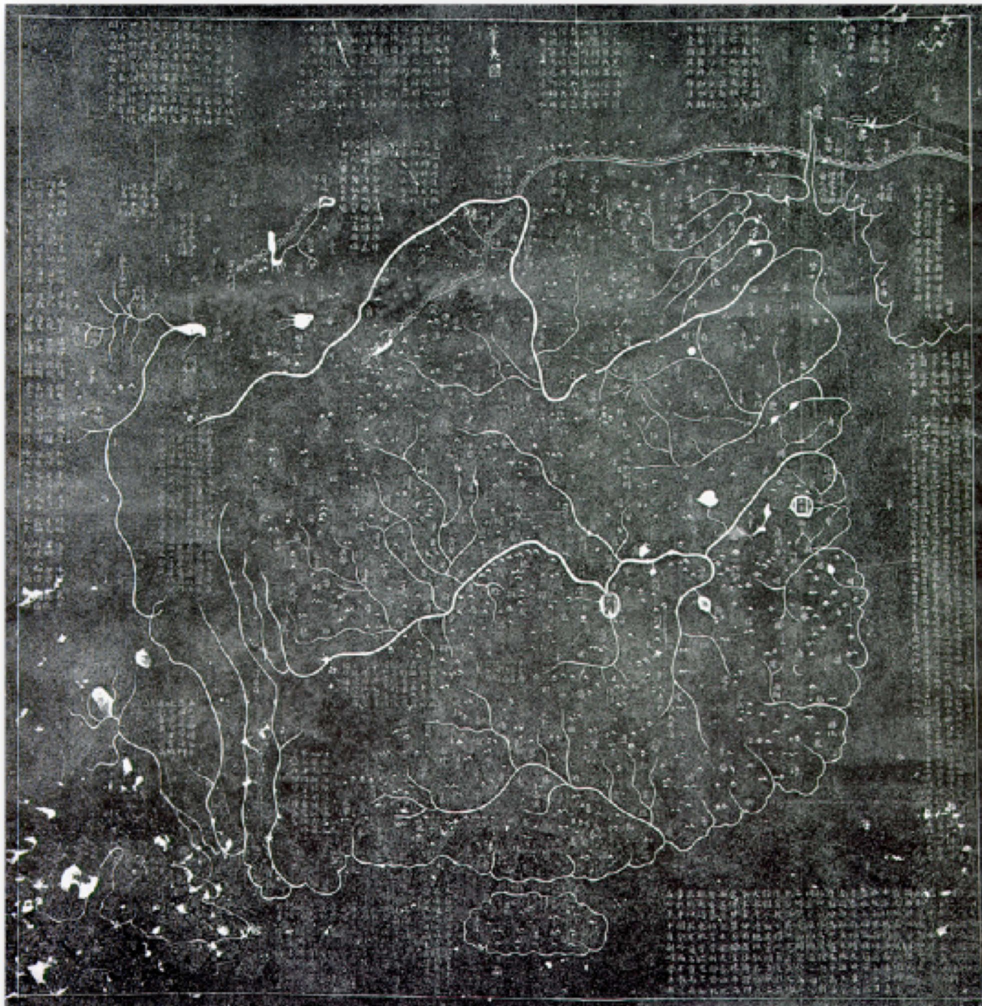


Image: Library of Congress, Geography and Map Division

YU JI TU

- Early cartography example

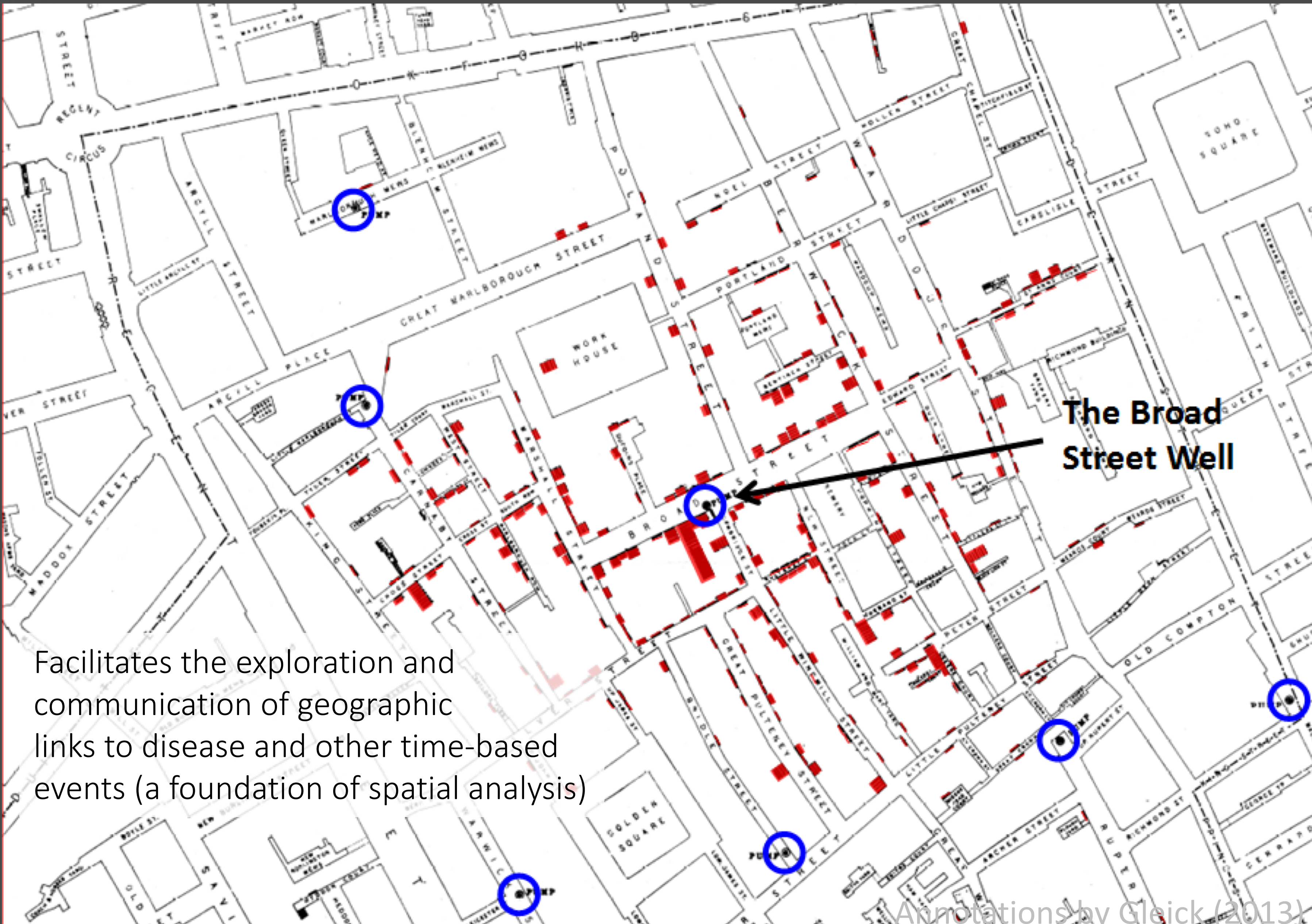
- China coastline with Hainan
- Circa 1137
- Carved into stone
- 1:4,500,000 approx.
- Gridded in *li* (~50km)

Image: Wikimedia Commons

HEREFORD MAPPA MUNDI

- Early cartography example

- The Hereford map
- Circa 1285
- The largest surviving map of the Middle Ages
- Depicts Asia, Africa and Europe



Facilitates the exploration and communication of geographic links to disease and other time-based events (a foundation of spatial analysis)

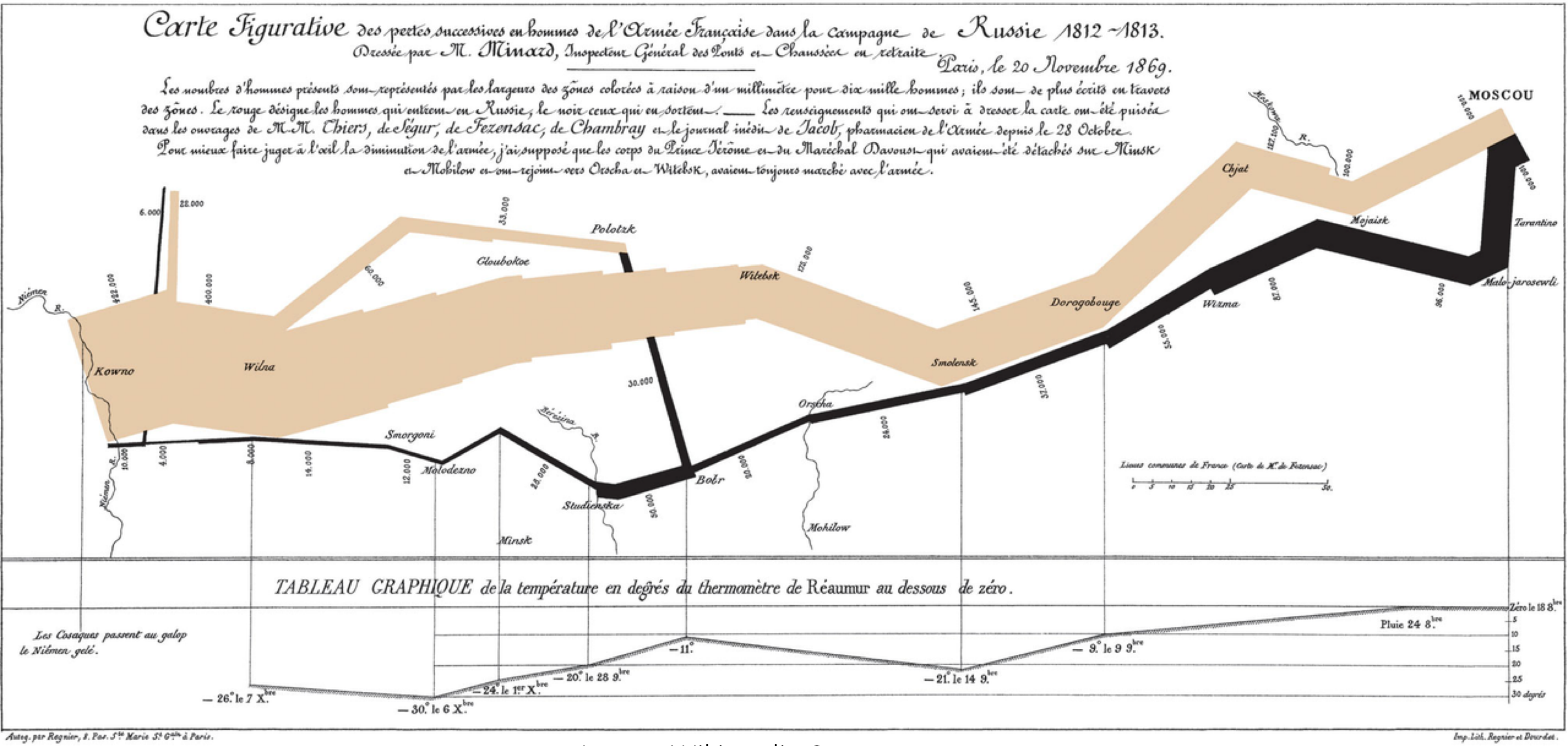
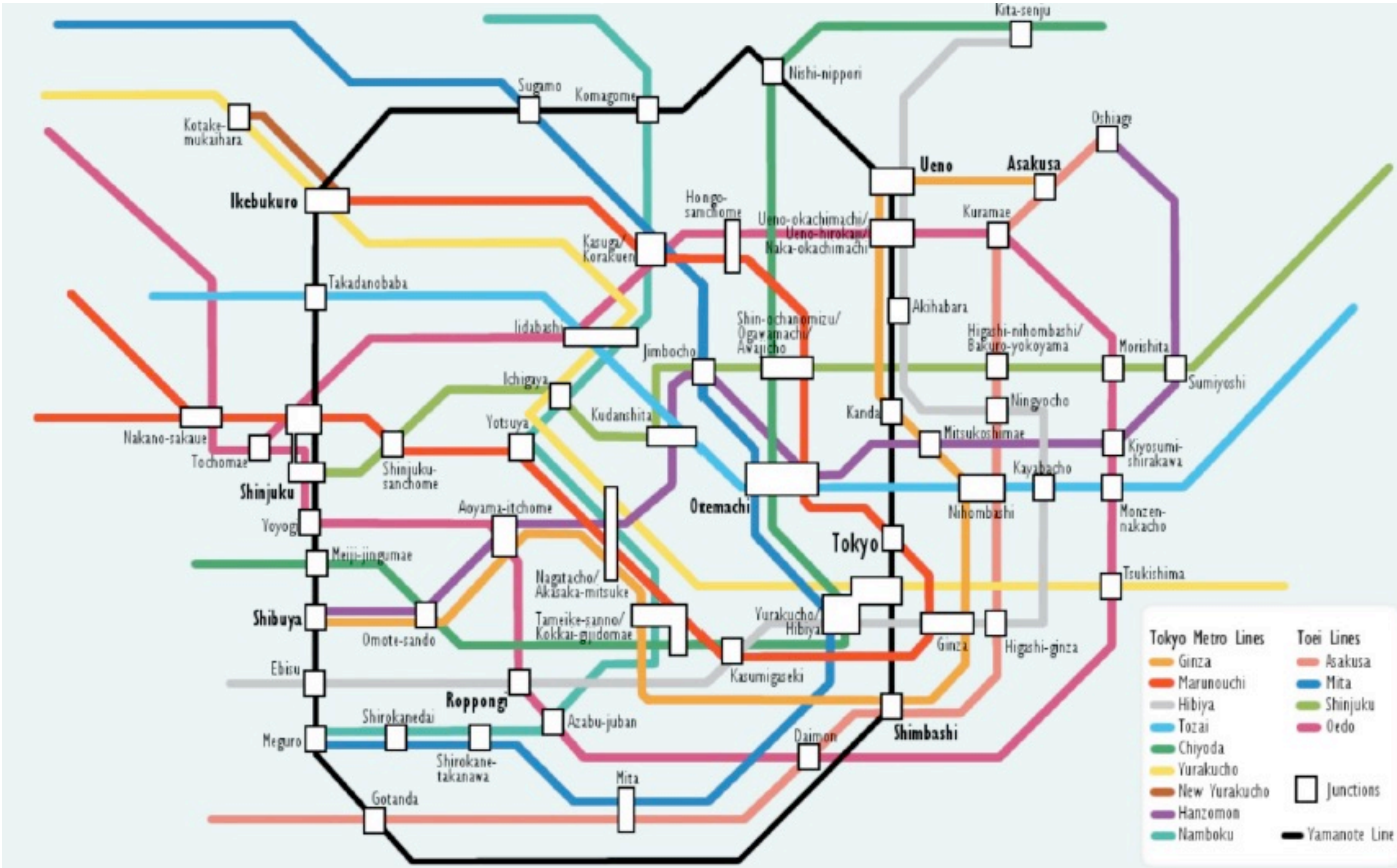


Image: Wikimedia Commons

MINARD'S MAP

- Early time-series example
- Linked geographic and time series data in a static representation.

Napoleon's march on Moscow Russia in 1812. The width of the line describes the size of the army at that location. Colour indicates the direct of movement. The temperature experienced during retreat is plotted beneath. Map served to communicate troop losses from ~500K to ~30K.

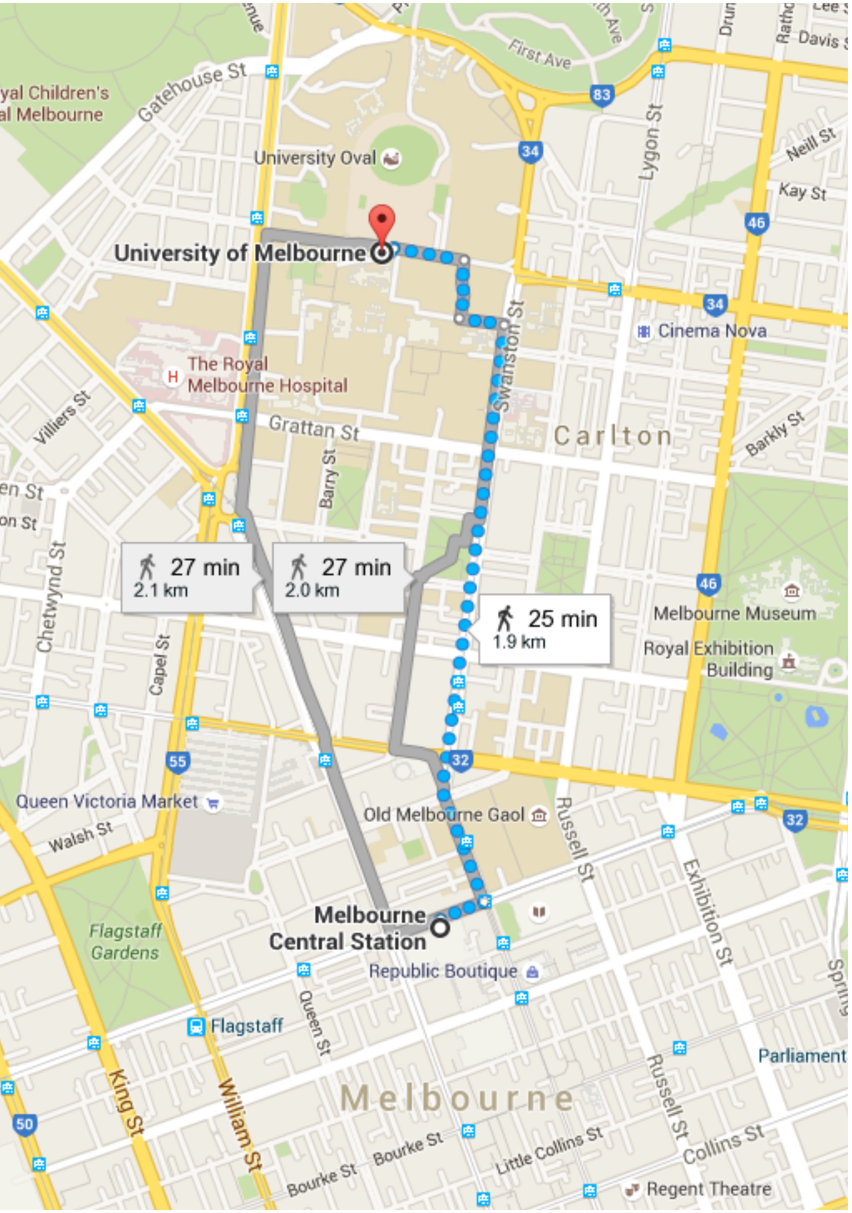


Wikimedia Commons

TRANSPORTATION MAPS

- Topological example

A logical (yet distorted) representation of the Tokyo Underground highlighting qualitative (topological) relationships. Easy to understand.



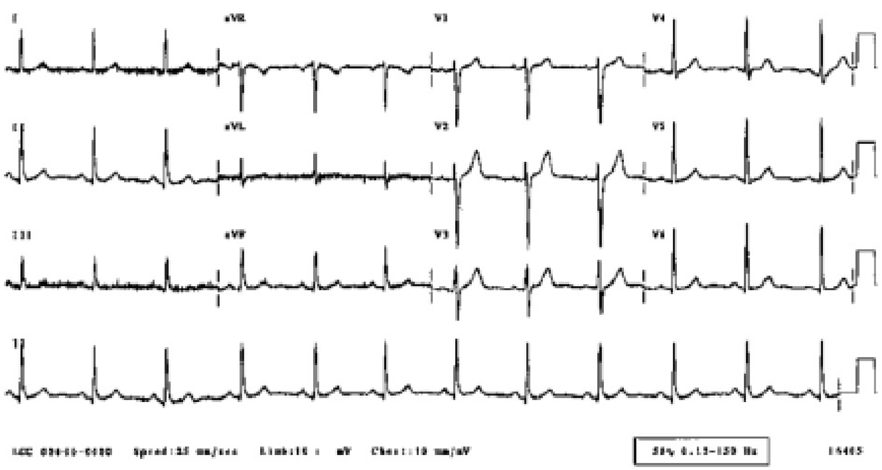
http://maps.google.com.au

ONLINE AND MOBILE MAPS

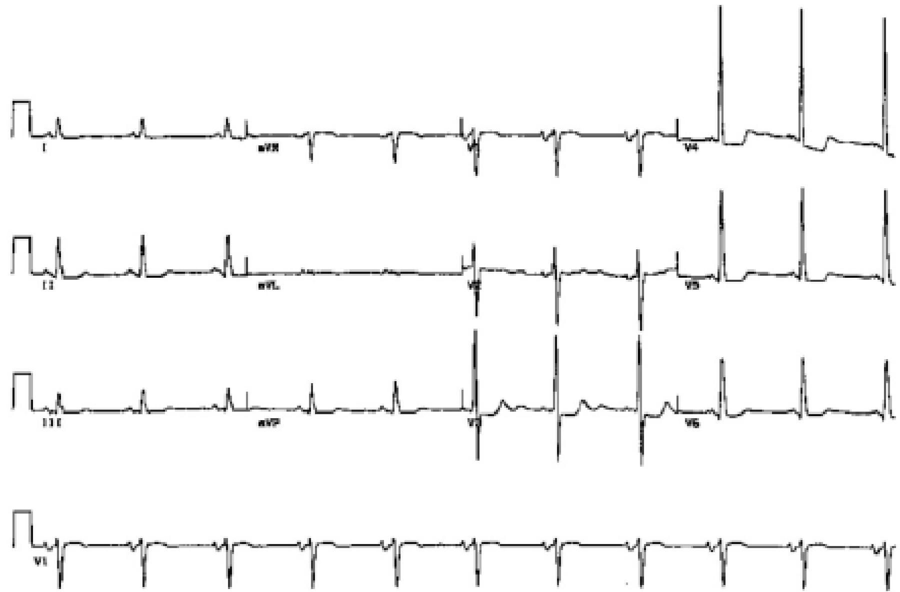
- Interactive applications e.g. Google Maps
- While **multimedia cartography** applications may satisfy the communication of known data, their classification as a visualisation **requires care**

  Refer to MacEachren's Map Use Cube

A normal adult:



An 83-year-old adult with heart problems:



ECG OUTPUT

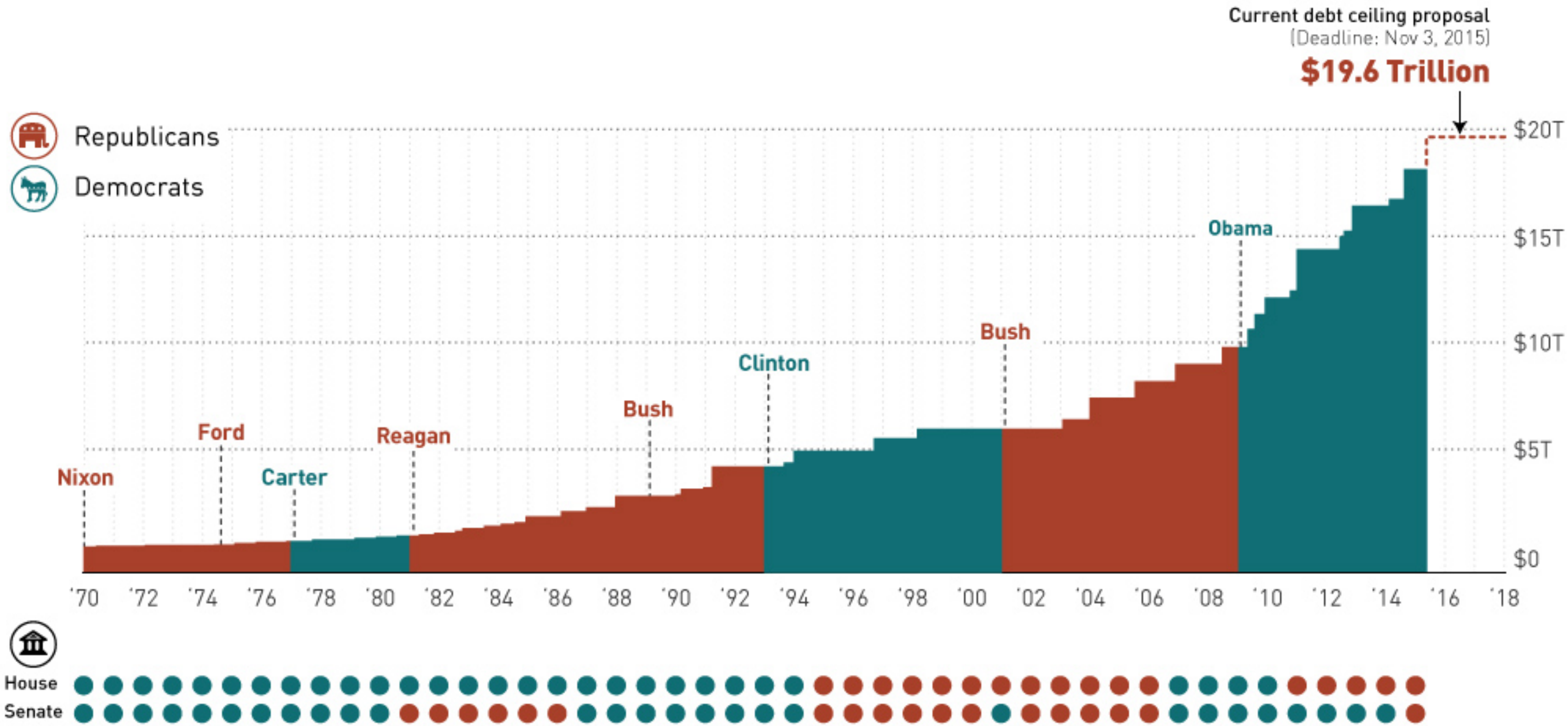
- Example data visualisation

Recording a heart's electrical potential captured from various leads connected to the body. Every line mark is recorded data.

Chart of the Week

THE U.S. DEBT CEILING HAS RISEN NO MATTER WHO IS IN OFFICE

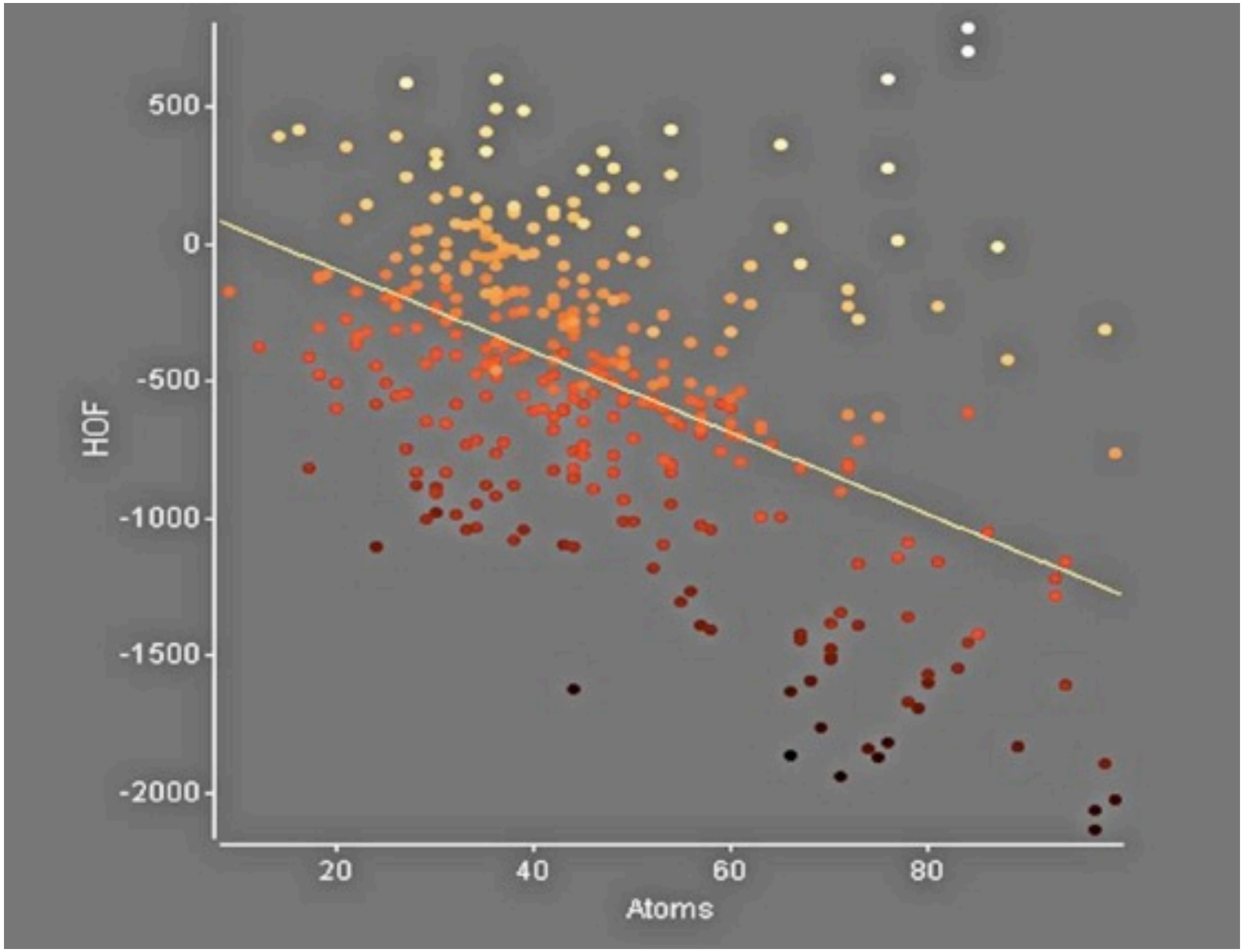
Lawmakers divided on current proposal for $19.6 trillion ceiling. Deadline to raise is Nov. 3, 2015



visualcapitalist.com

http://www.visualcapitalist.com/the-u-s-debt-ceiling-has-risen-no-matter-who-is-in-office-chart/

SCATTERPLOTS



UVP Software example, http://www.uvp.com/visionworks.html

- Yeast action data
- Regression line computed from data without the image
- Image allows the user to explore in more detail such as spread, potential outliers

- Colour represents the Gibbs energy at each point, revealing patterns which may not have been identified in statistical analysis

THE VISUALISATION PIPELINE

1. Data modelling:	User structures the data to be modelled from a file or database to facilitate visualisation
2. Data selection:	User or software identifies a subset of the data to be visualised using various methods
3. Visual mappings:	Critical stage. User investigates and defines mapping of data values to graphical entities
4. Scene parameters:	The user specifies attributes of the visualisation that are independent from the data

INTRODUCTION TO GRAPHICAL EXCELLENCE

"Graphical excellence is…

the well-designed presentation of interesting data – a matter of substance, of statistics, and of design…

that which gives to the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space…

nearly always multivariate. And graphical excellence requires telling the truth about the data"

(Tufte, 1983)

Principles of (Good) Data Graphics

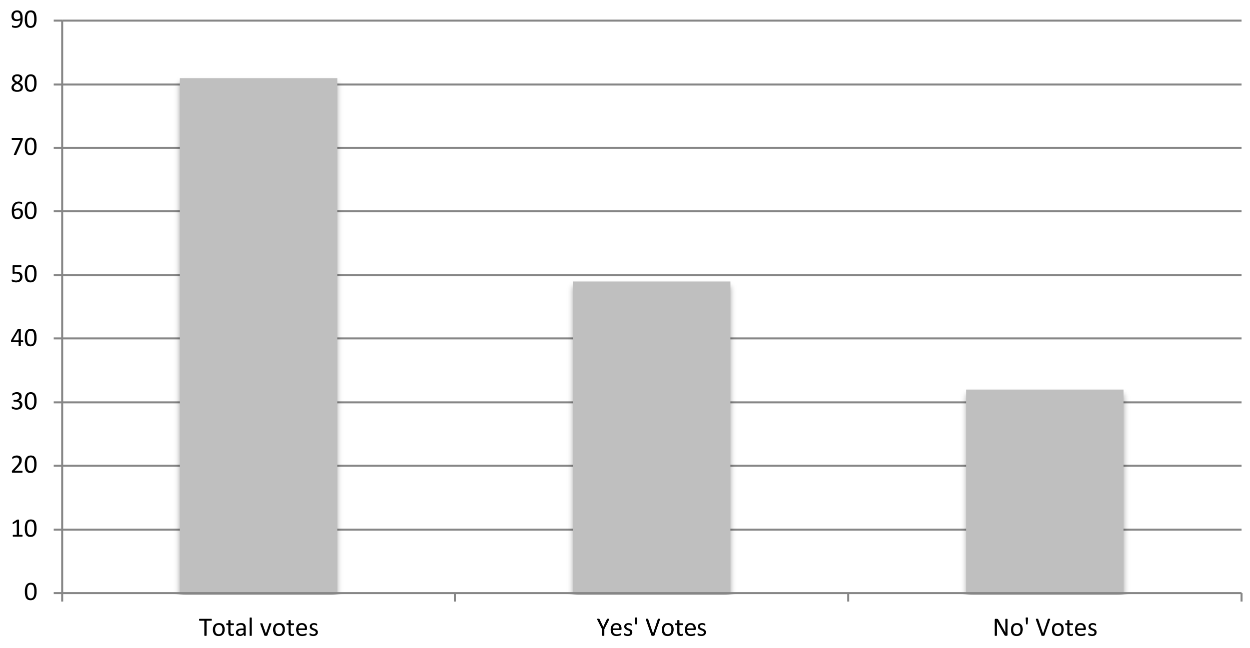
- Data Density
- Data Correspondence
- Data Integrity
- Data Aesthetics

Principles of (Good) Data Graphics

Data Density = useful data-ink / available display area

Only 2 numbers and two labels in this graph.

Not a dense or very useful graph.



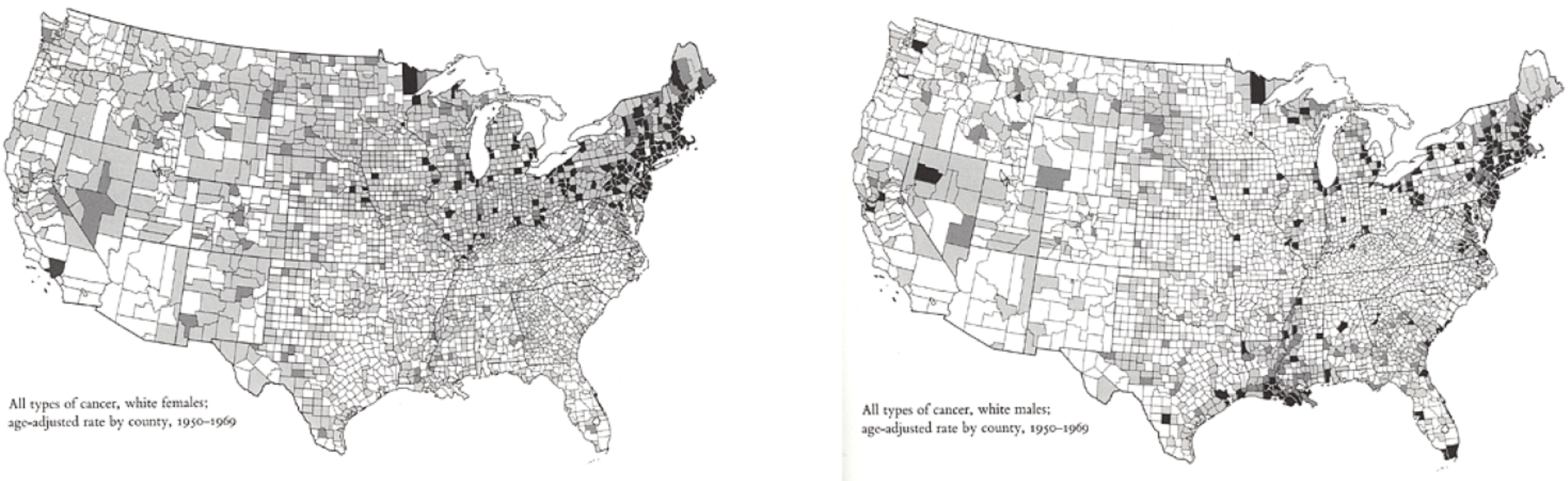
Principles of (Good) Data Graphics

Each of these data maps portrays ~21,000 numbers

Although very dense, the images draw attention to hot spots

DEATH RATE FROM VARIOUS CANCERS

FEMALES MALES

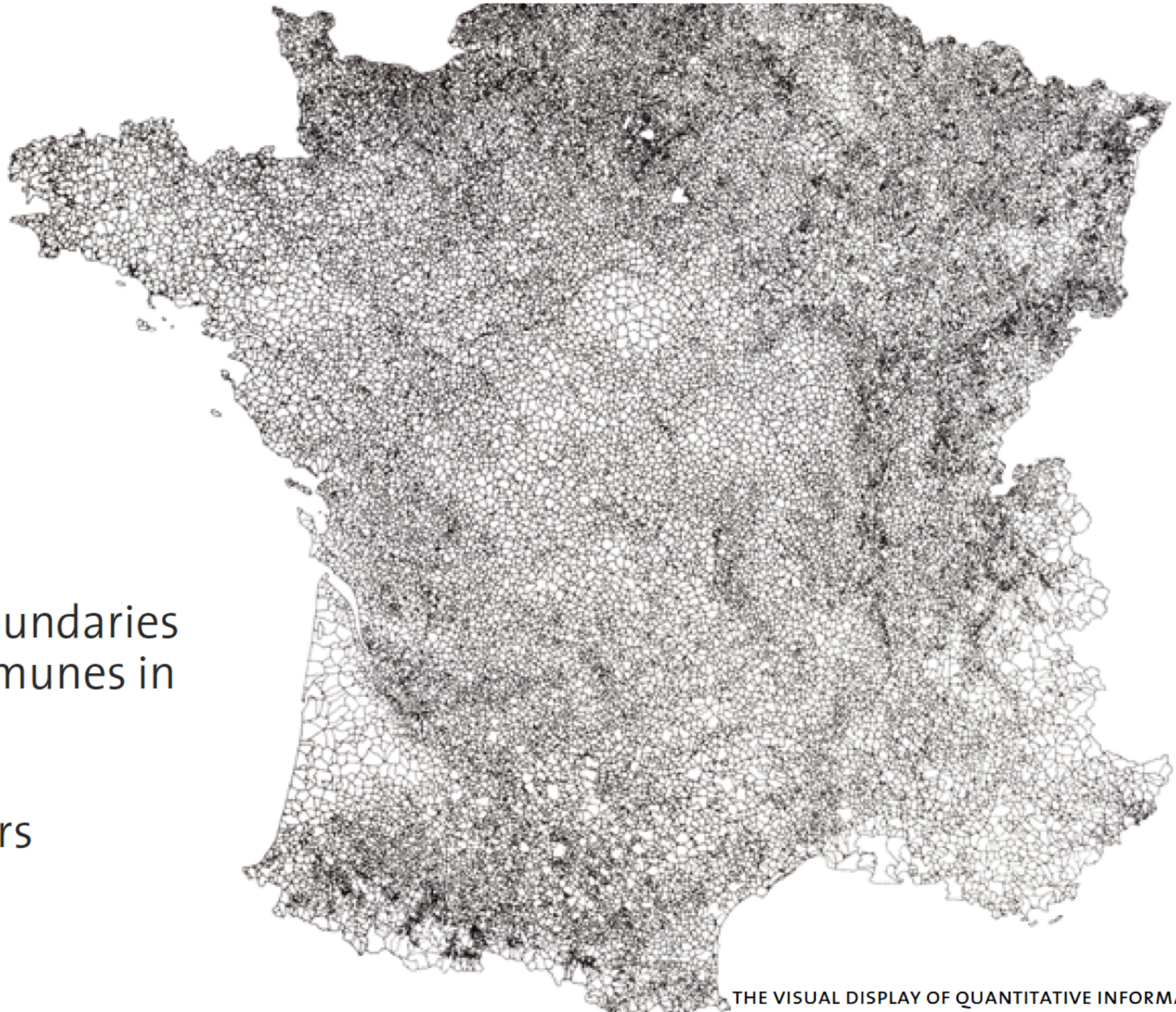


THE VISUAL DISPLAY OF QUANTITATIVE INFORMATION
EDWARD R TUFTE, 2001, 2ND ED

Principles of (Good) Data Graphics

locations and boundaries of 30,000 communes in France

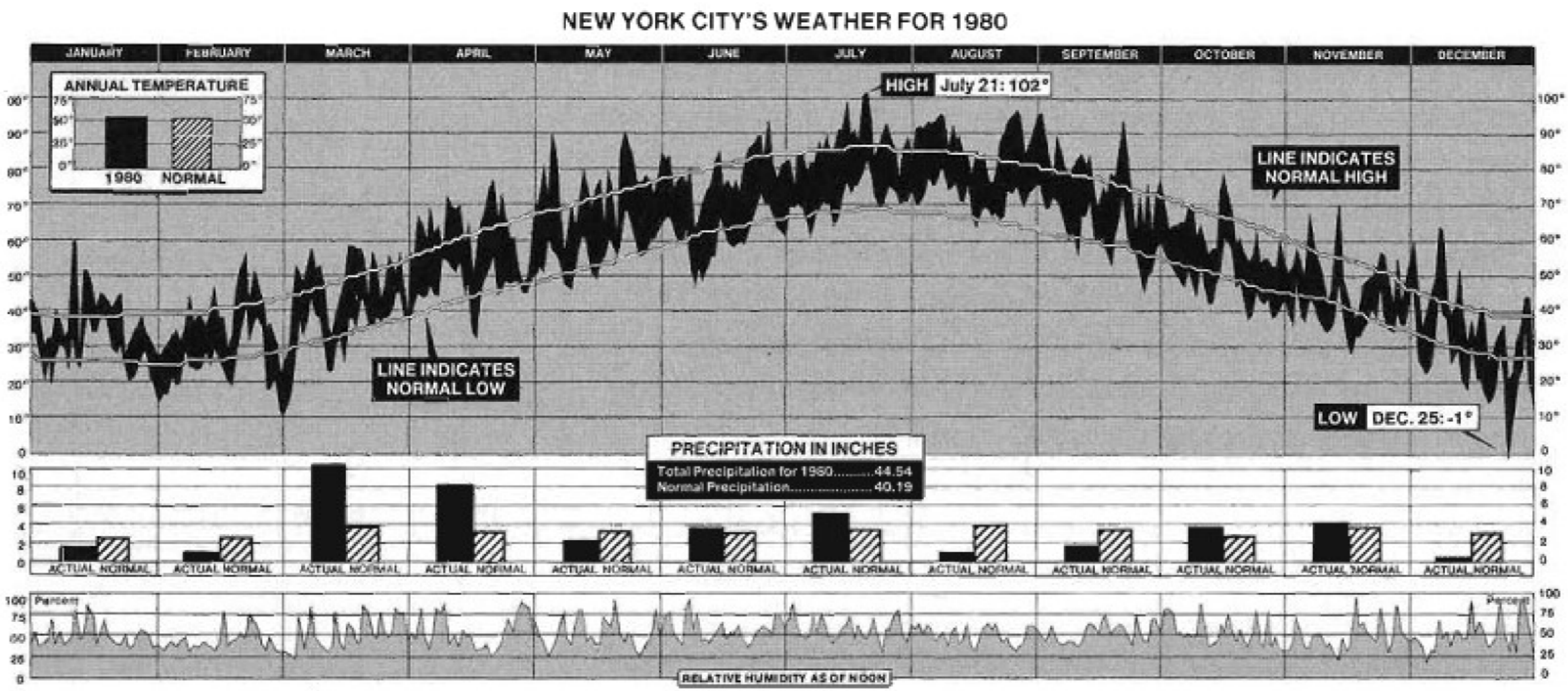
240,000 numbers



THE VISUAL DISPLAY OF QUANTITATIVE INFORMATION
EDWARD R TUFTE, 2001, 2ND ED

Principles of (Good) Data Graphics

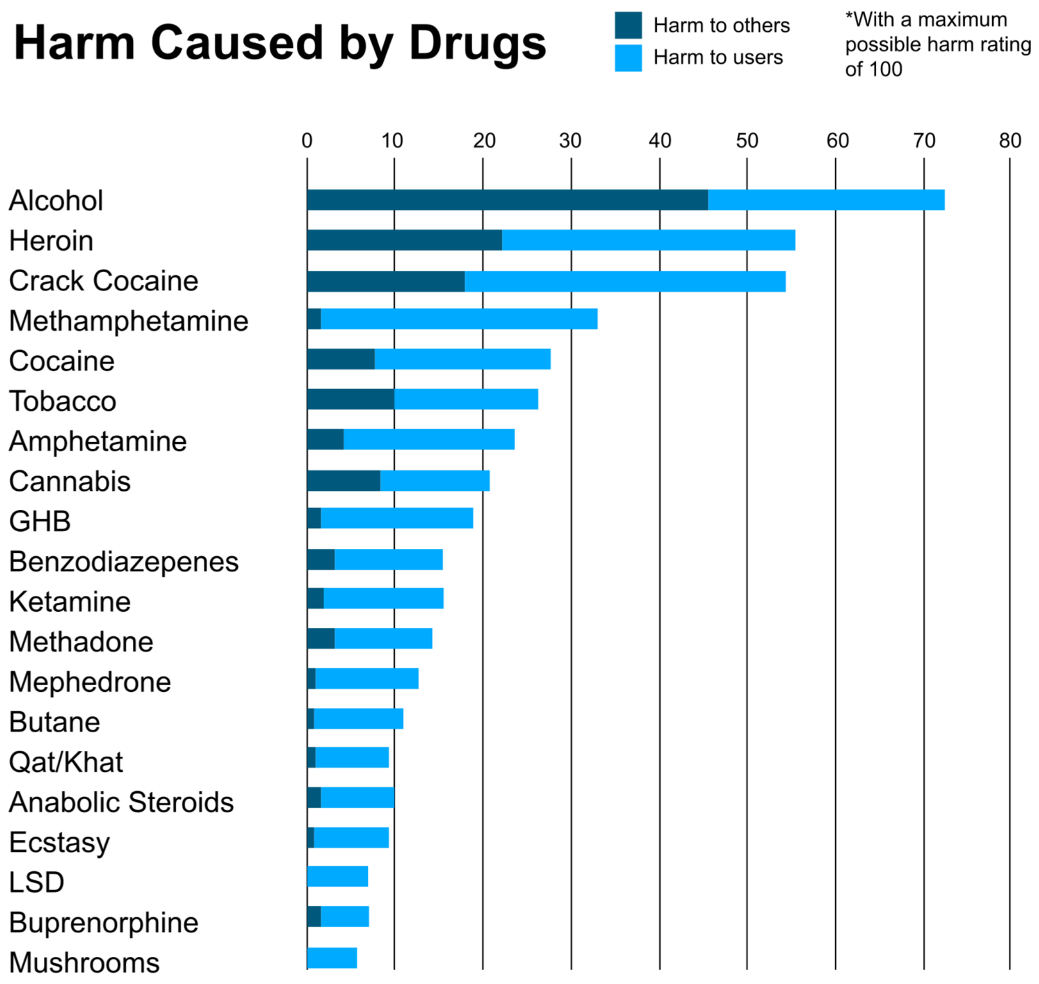
Another well designed dense graph



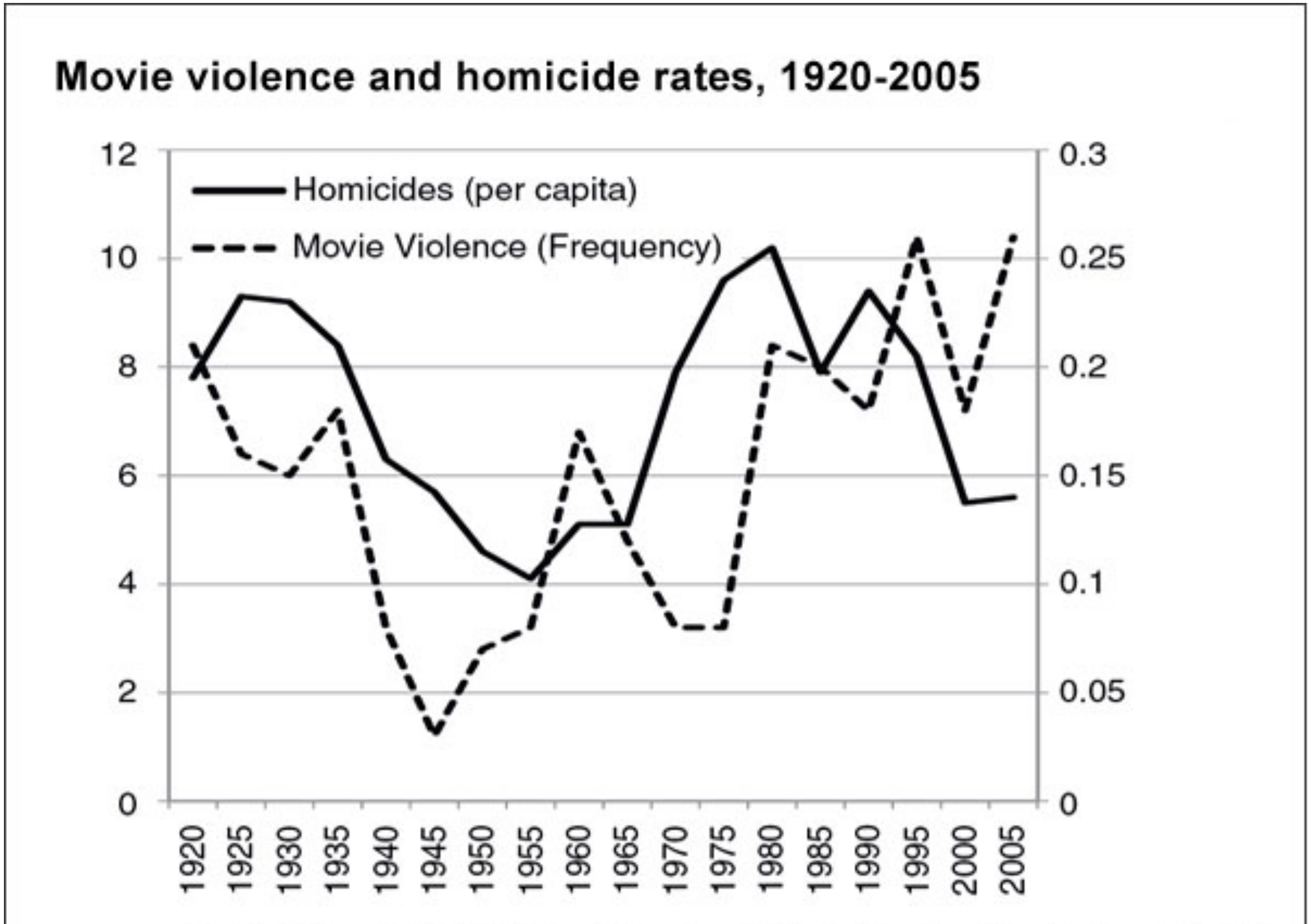
New York Times, January 11, 1981, p. 32.

Principles of (Good) Data Graphics

Data Correspondence



Principles of (Good) Data Graphics



"Does Media Violence Predict Societal Violence? It Depends on What You Look at and When," *Journal of Communication*, 2014

NEXT LECTURE

- Perception/Stats

READING

- A Brief History of Data Visualisation (Friendly, 2008)

GENERAL

Tufte, R. E. (2001) *The Visual Display of Quantitative Information*, 2nd edition, Cheshire Connecticut: Graphics Press.