MSc Research Skills
Lecture 15
Graphical presentation in a thesis

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What are graphics?

- Graphic presentation is anything that is not running (narrative) text.
- We identify the following types: tables, graphs, illustrations, maps, images.
- General issues for all types of graphics are:
  - positioning,
  - captioning,
  - referencing,
  - resolution,
  - typography, and
  - use of colour.
- But most important: why use a graphic? and which graphic is most appropriate in each situation.

Why use graphics?

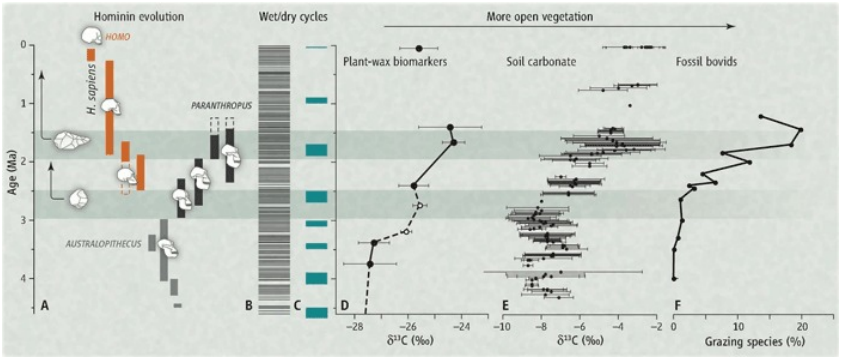
- Graphics are used when text is not effective in presenting the message.
- Well-designed graphics effectively communicate information.
  - *"One picture is worth a thousand words."*
- Conversely, confusing graphics at best irritate the reader and at worst hide or even distort the message.
- Almost always simpler is better: if all required information is present, legible and logical, the reader is informed rather than distracted.

What do you want to say?

Consider:

1. Why use a graphic rather than text?
2. What is the message you want the graph to convey?
   - Hint: write the caption and text referring to the proposed graphic
3. What kind of graph best conveys your idea?

An example of an effective graphic



A snapshot of African evolutionary and paleoclimate changes

Source: de Menocal, P.B., "Climate and human evolution", *Science* 331:540 (2011)

Why is this graph effective?

- Visually supports the article's main conclusion:
  - *"climate change and its effect on the African ecosystem may have played a key role in human evolution"*
- Presents a large amount of information visually
- Compares different kinds of evidence: climate (right), hominin fossils (left), vs. time
- Time axis (upwards to present) the same for all evidence
- The three "vegetation" evidence all oriented left to right for "more open"

Placing graphics in the document

- Graphics are floating blocks in a document.
- The typesetting engine decides where to place them.
  - For some engines such as LaTeX the author can give hints on preferred placement.
- So, figure or tables are not necessarily directly next to the text.
- Therefore, **the text must refer to the graphic**, in two ways:
  - Point it out: *Figure 4 shows the distribution of ...*
  - Explain it: *Observations were concentrated in the central part ...*

Captions

- Each graphic must have a caption, i.e. a brief description of its contents.
- Many readers skim the document looking only at the graphics, so ...
- ... the purpose of the graphic should be clear from the caption alone.

Example of a graphic with caption and text reference

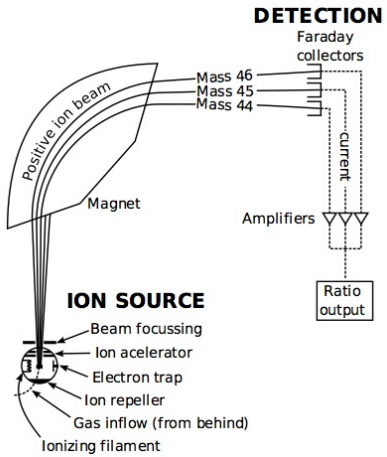


Figure: Mass spectrometer (schematic); Source: USGS Open-File Report 01-257

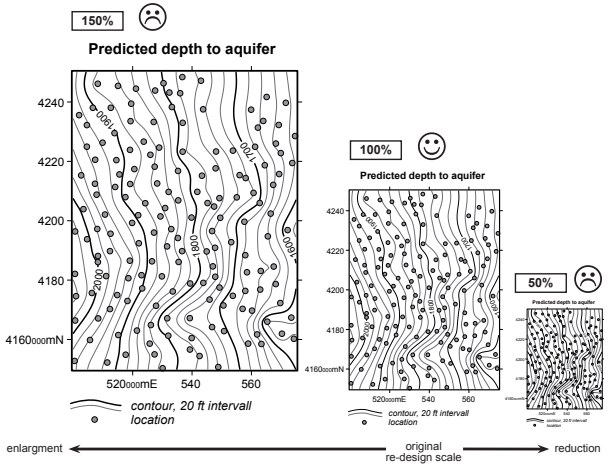
"A mass spectrometer is an instrument for determination of the elemental composition of a sample. Figure 1 shows schematically its three modules: an ion source, a mass analyzer to separate ions by their masses, and a detector, which measures the abundances of each ion in the sample."

Scalable vs. non-scalable graphics

There are two classes of graphics formats:

- Scalable formats store mathematical descriptions of their elements;
  - These are often called *vector* graphics.
- Non-scalable formats store a grid (matrix) of *pixels* ("picture elements").
  - Each pixel has a colour or greyscale value.
  - Pixels are also called *rasters*, another word for "grid".
- Scalable graphics can be displayed or printed at *any resolution*;
- Non-scalable graphics have a *fixed resolution*.

Example of scalable graphics



The middle figure was prepared at the actual size of the printed figure, therefore it's the "good" ☺ one. All have the exact same information and file size, because they have the same instructions to draw vectors.

Example of non-scalable graphics


original bitmap, 105x61 pixels

, scaled 2x, 310x122

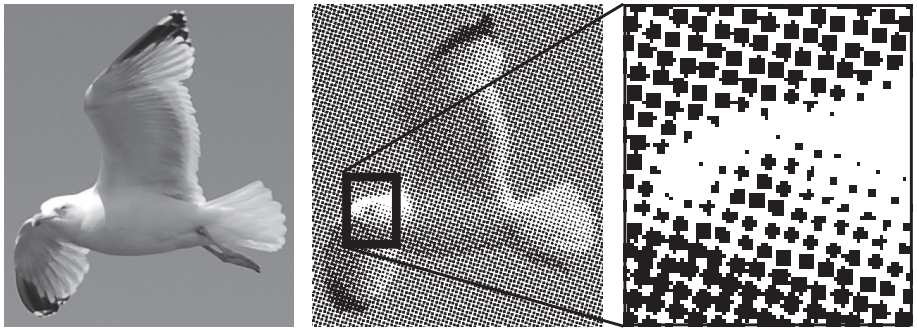
, scaled 4x, 620x244

scaled 12x, 1360x732

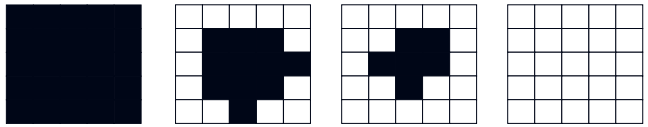
Monochrome printer resolution

Monochrome printers are incapable of showing grey-tones; they print either 100% or 0% ink.

Grey tones are produced by converting the continuous image into to dots placed as a fixed array in a standard cell called a halftone.



Example of halftone cells



Halftone screen frequency

The halftone grid size (e.g. 5x5) and printer resolution (e.g. 1200 dots per inch 'DPI') are properties of the printer.

- DPI/grid = (halftone) screen frequency
  - Typical: 1200 dpi printer; screen frequency 133 or 166 lpi, so halftone cell 9x9 or 8x8.
- Image resolution should be matched to the screen frequency of the specific printer.
  - Too low resolution gives a fuzzy image; too high resolution is a waste of size.
- As a rule of thumb, use image resolution 1.5 to 2 times the screen frequency.
  - For example, for a printer with a 133 line screen, the image should be somewhere between 200 and 266 ppi.

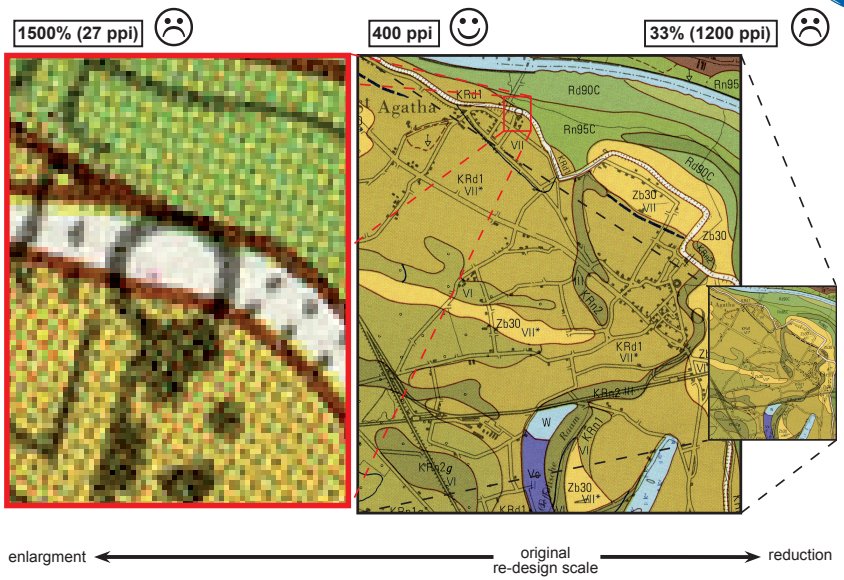
Computer display resolution

See lecture notes; this is not relevant for the printed thesis.

Scanning for publication

- A common task in thesis production is to scan a printed document, such as paper map, and reproduce all or part of it as an illustration in the thesis.
- This requires careful planning to get the correct output resolution.
  - If the resolution is too *high*, file space is wasted and the document is unwieldy.
  - If the resolution too *low*, the graphic is illegible and "jagged" (pixelated).

Example of a scan



Why use colour?

There are two reasons to use colour, rather than greyscale, in graphics:

1. Colour is a visual variable and thus can communicate information
   - It is thus an alternative or supplement to other visual variables such as size, shape, font, and pattern.
2. Colour is an aesthetic element which can make information more attractive.
   - Caution! "Beauty is in the eye of the beholder", what is really "attractive"?

Why not use colour?

- Colour can distract, irritate, or even deceive – so don't use it "just because it's there".
- Colour is expensive to print.
- Proper use of colour requires special skills, so ...
- **Colour is best avoided unless necessary.**

All about colour

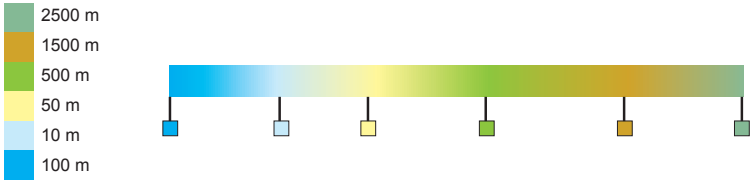
- Brown, A & Feringa, W (2003) *Colour basics for GIS users*. Harlow, Essex: Prentice-Hall
- Available in ITC bookshop.

Colour figures printed in greyscale

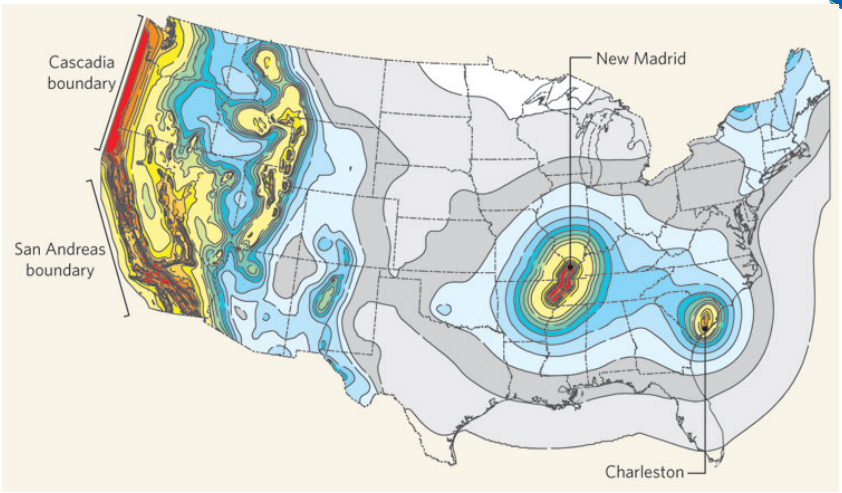
- If a colour figure will also be printed in greyscale, the colours must also be distinguishable when converted only to value and chroma (no hue).
- Here is a poor choice of colours, when printed in greyscale.

Colour ramps

- For continuous variables, use a continuous visual variable
- For colour, this is the *colour ramp*: a sequence of colours
- If possible these should be connotative, i.e. imply the meaning of the continuous variable.
  Example: A colour ramp created from an "altitude" range, creating gradual tints for the intermediate altitudes



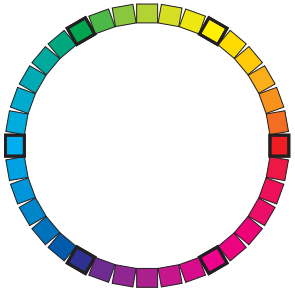
Example of a connotative colour ramp



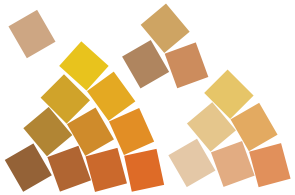
Probabilistic assessment of seismic hazard in the United States; Source: Open-File Report 02- 420, US Geological Survey (2002)

Contrasting and similar colours

- Contrasting colours are those that are clearly separated on the colour circle.



- Similar colours to show gradations or sub-classes of similar things



Use of similar colours

- For ordinal differences, tints (percentages) of a base colour have to be used, to show that one element is "more" or "less" than another element (darker is more, lighter is less).
  - Examples are population density, temperature, and altitude.
- For sub-classes, similar colours are required, but they should not show gradual differences; often patterns are used for a better distinction.
  - Examples are the subclasses in soil, geomorphological or geological maps.
- Example tint scale

  - In this scale, the darkest green should be used for the "densest", "largest", "heaviest" etc. end of the range, and progressively lighter tints for "more dilute", "smaller", "lighter" etc.

Typography

- The typeface (e.g. Arial) and style (e.g. normal, bold, italic, condensed, expanded, black) form a font family; adding the size defines a font.
- The font used has a large effect on its readability, and thus makes the content more or less accessible.
- Different fonts are optimal for screen vs. printed output.
- For the ITC thesis, a font designed for printed output must be used.
  - The ITC LaTeX thesis class uses New Century Schoolbook for running text and Computer Math for mathematical typesetting.
  - The MS-Word thesis template uses Helvetica (sans serif) for titles and Times (serif) for running text.
  - ITC also has a license to use the Lucida Bright typeface.
- Sans-serif typefaces are preferred for figures; tables should be the same font as running text.

Example typefaces and dimensions

Use of type in figures

- Use the same font family and the same base-sizes throughout the whole document.
- Create all illustrations on the correct scale (as used in the document). Re-scaling the illustrations means a change of font size in the final output.
- Use a sans serif font (e.g. Arial, Helvetica, Verdana).
- Use a maximum font size of 11 points and a minimum font size of 7 points, at the output scale.
- Avoid text overlapping/crossing other graphic elements (like lines or patterns) of the same colour.
- Maintain a good contrast between the text and the background.
- Place text in the illustration near the element it is referring to.
- Respect the correct reading direction for the application, e.g. contour values facing uphill.

Graphical elements

We discuss each of these in turn:

1. tables
2. graphs
3. illustrations
4. maps
5. images

Use of tables

Large amounts of numerical or descriptive data can generally be better understood as tables. E.g this text:

> *"Of the visitors to the web portal during the trial period, 76% were from Europe (32% Netherlands, 22% Germany, 9% Belgium, 5% France, 5% United Kingdom, 3% other European) and 24% from rest of the world (10% Americas, 12% Asia/Pacific, 2% Africa)."*

can better be presented as a table and commented on in the text:

> *"Visitors to the web portal were predominantly from Europe, especially The Netherlands and Germany (Table X)."*

Europe						**Other**		
total 76						*total 24*		
NL	D	B	F	UK	other	America	Asia/Pacific	Africa
32	22	9	5	5	3	10	12	2

Table X: Web site visitors, location (%)

When not to use a table

Conversely, a few numbers should be presented in the text, and do not require a table. For example, the following table:

Yes	**No**
20	10

Table Y: Wetness in soil profiles

can much better be presented as:

> *"Twenty of the thirty soil profiles showed signs of subsoil wetness."*

Table design guidelines (1)

- Tables should be understandable without reference to the text
  - The text should comment on and interpret a table, but should not be needed to understand its contents.
- Each table must have a caption, which is understandable without reference to the text. This is repeated in the List of Tables.
- Each column and row must have a heading which very briefly identifies it.
- A table should be as simple as possible, given the information it must present.
- The position of data items in the table should be as intuitive as possible.
- All rows, columns, sub-rows or columns etc. must be clearly labelled so the reader can tell to what a particular item (cell) refers.

Table design guidelines (2)

- The same data should generally not be presented in the text, table, and figures. Avoid phrases like:

  "According to Table X, 35.3% of the respondents preferred the first option ..."

  But, the table already gives the exact number, so the text does not need to repeat it; instead, the text comments on it:

  "A substantial minority of the respondents preferred the first option ... (Table X)."

  Here the author interprets ("substantial minority") the exact number (35.3%) shown in the table, and relates it to the overall argument.
- Use of symbols, units and terms in tables should agree with the text.
  - For example, a column heading "water bodies" in the table should not correspond to a category called "lakes" in the text.

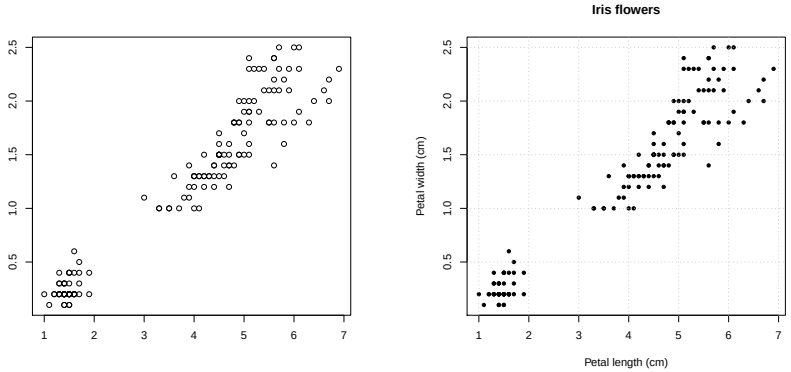
Table design guidelines (1)

- If categories given in rows and columns are naturally ordered, this should be respected in the table.
  - For example, educational levels "none", "primary", "secondary", "tertiary" should follow this order in rows or columns.
- Tables must be numbered sequentially, either by chapter or for the whole document. They must be referenced in the text, either in parentheses or as a noun (subject or object):
  - *Table 3 shows the model parameters.*
  - *The model parameters are shown in Table 3.*
  - *Initial model parameters were set according to literature (Table 3).*

Use of graphs

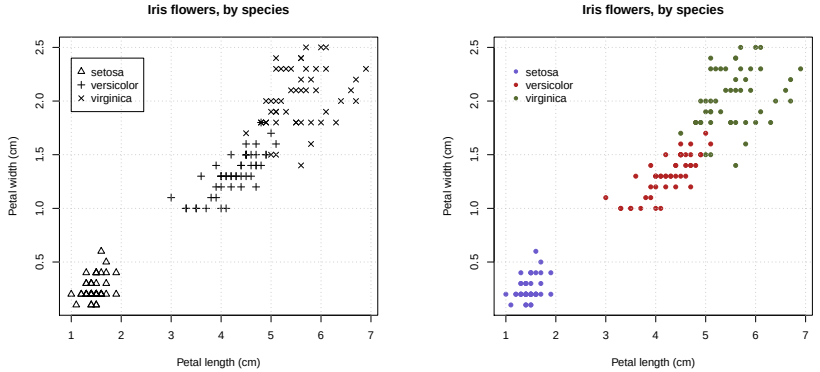
- Graphs are used to report the results of exploratory data analysis (looking for patterns) ...
- or statistical analysis (interpreted results).
- They must contribute to the argument.
- They must be labelled, captioned, and referred to in the text.
- The graph type must match the nature of the variables and their relation.

Scatterplots



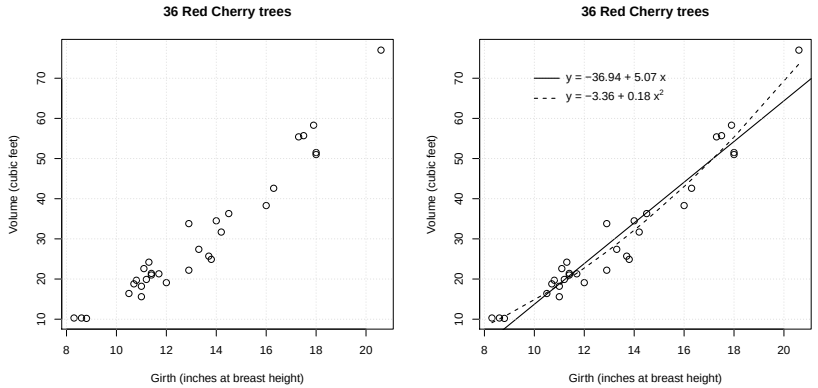
Missing information (left); complete (right)

Classified scatterplots



Showing three species; with legend, by symbol (left) and colour (right)

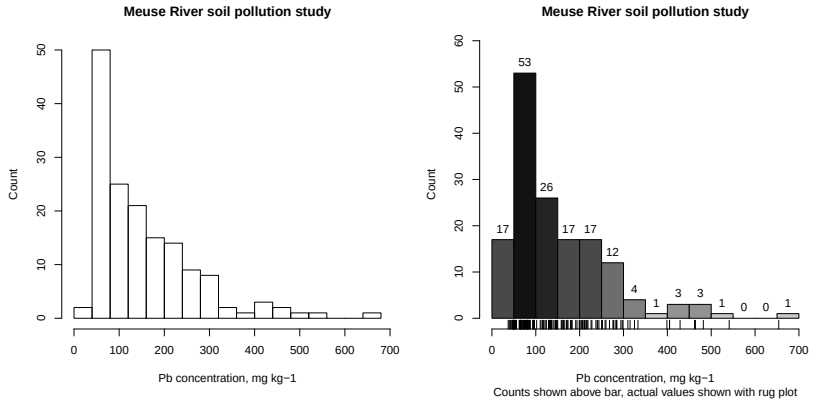
Use of lines to show interpretation



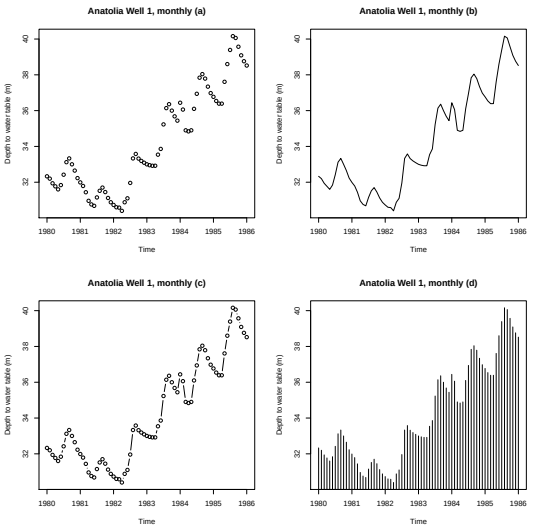
Note that the lines force an interpretation on the reader.

Histograms

These show univariate distribution; plain (left), enhanced (right)



Time series

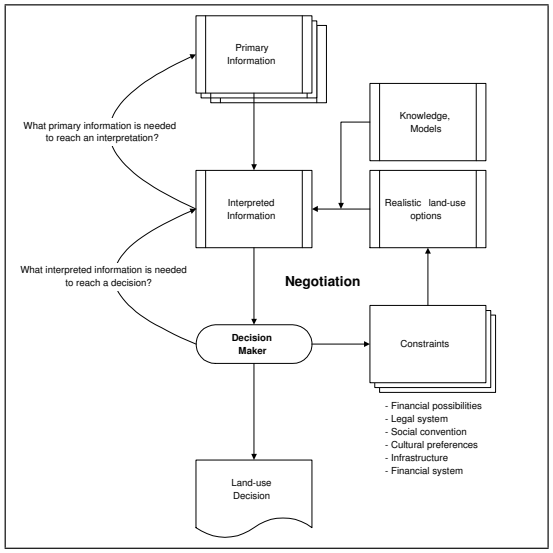


The Y-axis is some variable as a function of the X-axis, which is a time sequence

Use of Illustrations

- Line drawings are original artwork that illustrate some apparatus (e.g. schematic diagrams) or procedure (e.g. flow diagrams).
- They are usually monochrome (either black-white or with some grey-scale shading) but may have colour elements if these add to the reader's understanding.
- They should be legible and as simple as possible, while showing the required information.
- They must be labelled, captioned, and referred to in the text.

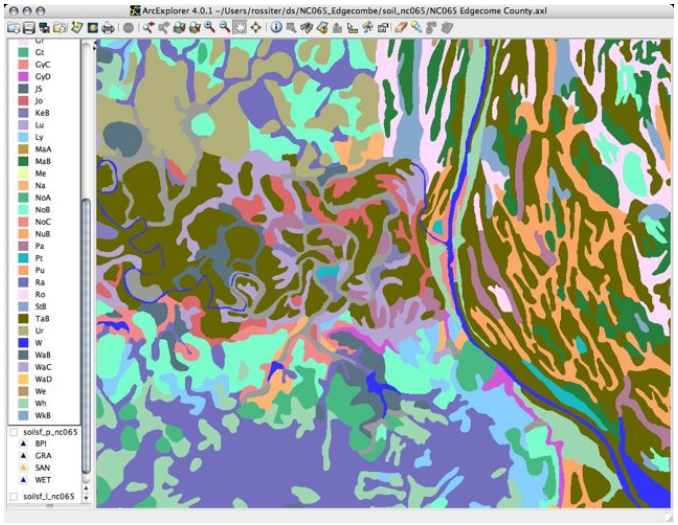
Example flow diagram



Use of maps

- Maps are a special class of figure that present geographical information.
- Geometrically-correct maps must include enough information to determine location, scale and orientation.
- Maps must be georeferenced, at least implicitly; an exception are topological maps.
- Colour in a map must not be confusing and, if possible, should be connotative.

Incorrect use of map colours



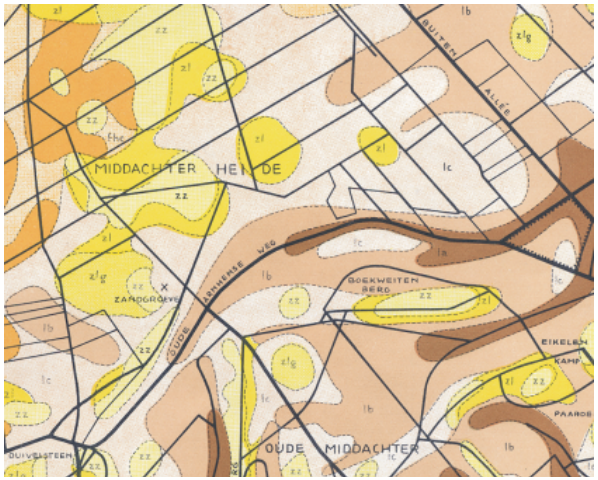
Soil types, Edgecombe County, NC (USA)

Error: Highly-contrasting colours are used for similar soils.

Connotative colours

- These suggest something about the class from the visual perception.
  - For example "blue = water"; "dark blue = deep water (ocean)", "light blue = shallow water (ponds, streams)"
- These can be established conventions in a given type of mapping.
  - An example from soil mapping is purple for organic soils, blue for clayey soils, browns for loamy soils, and yellows for sandy soils.

Example of connotative map colours



Soil map units, Middachten estate, Dieren (NL)

Good: Colour is used to show soil moisture, the controlling factor for land use in this area

Use of images

- Images are bitmapped graphics, they should only be used when an actual image is needed, not as a rasterized drawing.
- Images that can be presented are screen dumps, photographs, scans of paper maps, and remote sensing imagery.
- Screen dumps illustrate specific processing steps, they should not be used for program output.
- Photographs should help the reader visualize a complex object that can not be adequately described in words.
- Pay careful attention to resolution, which depends on the type and capabilities of the output device.

Photographs

- Photographs help the reader visualize a complex object that can not be adequately described in words.
  - For example a landscape or an apparatus
- They can also help the reader appreciate how a procedure was carried out (e.g. field sampling).
- They should be used when "a picture is worth a thousand words", i.e. when visualization can explain more than text description.

Effective use of photographs

- Show the object of interest as clearly as possible, without distractions.
- The subject mentioned in the text should be obvious.

Example photograph

"Dune stabilization begins with small patches of grass (Figure X), which stabilization in turns promote more grass in a positive feedback loop."

Figure X: First stage of dune stabilization; Kootwijkerzaand (NL)

Overview and detail photos

Sometimes both an **overview** and **detail** photo should be included side-by-side:

"Weathering can proceed rapidly even in cool climates. Figure X shows a memorial stone engraved in 1921. The detail (right) shows clearly the pitting of the granite, with the resistant quartz grains standing out prominently, and the accumulation of moss on the surface."

Figure X: Weathering of granite memorial stone, Judithoeve, Losser (NL)

What kind of graphic will best communicate?

The example here is from:
TikZ and PGF, Manual for Version 2.00 (2007)
Till Tantau; `http://sourceforge.net/projects/pgf`
Text:

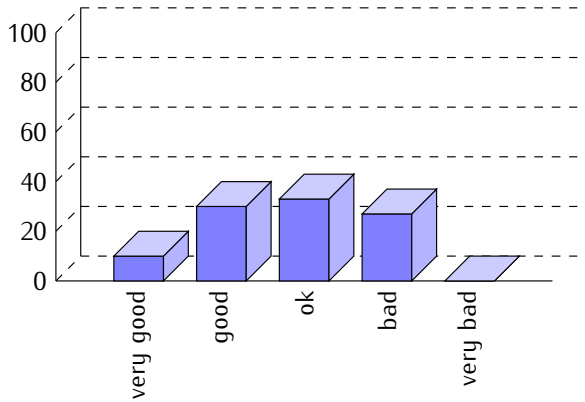
> *At the end of a seminar a lecturer asked the participants for feedback. Of the 50 participants, 30 returned the feedback form. According to the feedback, three participants considered the seminar "very good," nine considered it "good," ten "ok," eight "bad," and no one thought that the seminar was "very bad."*

As a table

Rating given	*Participants (out of 50) who gave this rating*	*Percentage*
"very good"	3	6%
"good"	9	18%
"ok"	10	20%
"bad"	8	16%
"very bad"	0	0%
none	20	40%

All the information is here and accessible. It is easier to find a specific number here than in the text.

As a bar chart



"Looks nice" (?), at least the classes are in correct order, but ...

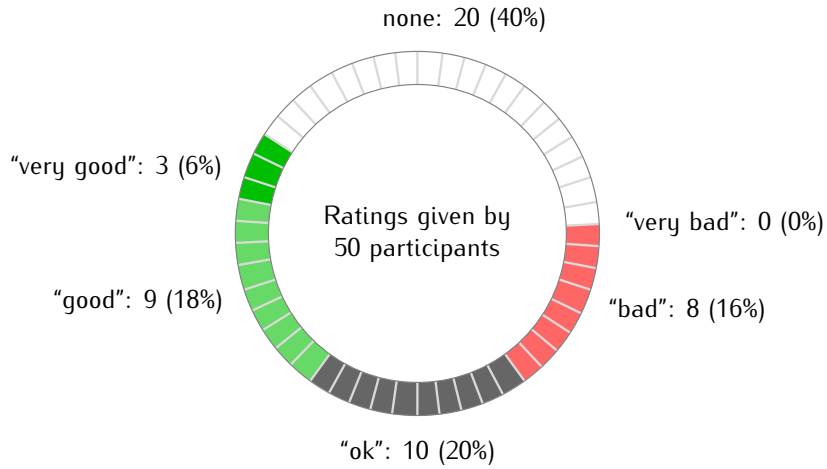
Can the bar chart answer these questions?

- How many participants were there?
- How many participants returned the feedback form?
- What percentage of the participants returned the feedback form?
- How many participants checked "very good"?
- What percentage out of all participants checked "very good"?
- Did more than a quarter of the participants check "bad" or "very bad"?
- What percentage of the participants that returned the form checked "very good"?

Graphic faults in this 3D bar chart

- The whole graphic is dominated by irritating background lines.
- It is not clear what the numbers at the left mean; presumably percentages, but it might also be the absolute number of participants.
- The labels at the bottom are rotated, making them hard to read.
- The third dimension adds complexity to the graphic without adding information.
- The three dimensional setup makes it much harder to gauge the height of the bars correctly. Consider the “bad” bar. It the number this bar stands for more than 20 or less? While the front of the bar is below the 20 line, the back of the bar (which counts) is above.
- It is impossible to tell which numbers are represented by the bars.
- What do the bar heights add up to? Is it 100% or 60%?
- Does the bar for “very bad” represent 0 or 1?
- Why are the bars blue?

This graphic communicates all the information



Note the connotative colours, the even treatment of each class, the natural order, the complete information.

The art of keeping it simple

- This refers to the illustration itself (“clean” design) ...
- but even more to the contents: the message must be clear to the reader.

Recommended steps to come to a good graphic

1. The idea: Identify the need for a figure.
   - What should it communicate?
   - Where should it be placed in the argument?
   - How does it complement the text?
2. The content: Specify the minimal required content of the illustration.
3. The sketch: See next slide; don’t use the computer yet!
4. The realisation: Now do the actual layout, design, and production in the chosen program.

How to sketch

1. Determine the simplest possible illustration for the point you want to make.
2. Make a sketch on paper to more or less the correct scale.
   - It's no problem if your drawing skills are poor, it even helps in forcing to keep things simple.
3. When drawing on paper do not focus on visualization aspects such as colour, fonts, shadows etc.; only consider the content.
4. Do not include elements that are redundant like cell-lines in a table. The human eye and brain is well-suited to discover patterns.

Layout & design (1)

Here are some tips for effective design.

- Design to scale, effectively using the available space
- Use a consistent design: specify type, colour, lines, symbols and graphic elements and use them consistently.
- Use a consistent and legible typeface for text; best for illustrations is a sans-serif face such as Arial.
- Decide if colour is really required to make your point – would it really enhance the information content? If required, than make a decision on the colour palette to use.
- Variation in line styles (full, dashed, thickness) can create a good visual hierarchy.

Layout & design (2)

- When using symbols in a diagram, graph or map make sure they are visually-distinct and if possible related somehow to what they represent.
- Do not use too many different symbols, they are difficult to distinguish.
- Graphic elements are non-functional, but visual elements to enhance the attractiveness of an illustration. Examples are drop-shadows and shaded backgrounds. If used, use consistently.
- Distinguish figure (the main information) from ground (background, orientating) – see next slide.

Example of figure and ground

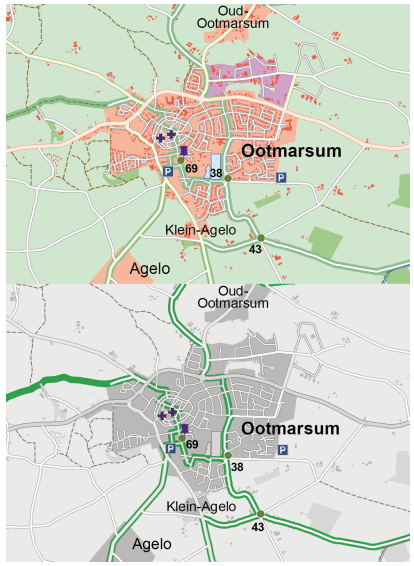
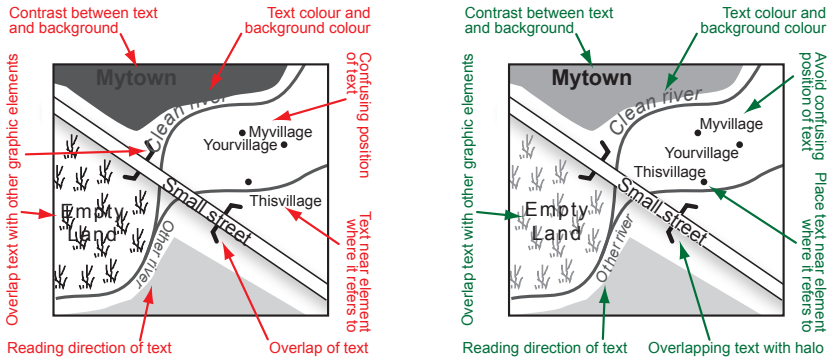


Figure & ground; poor (top) and good (bottom) for a tourist map

Layout & design (3): contrast

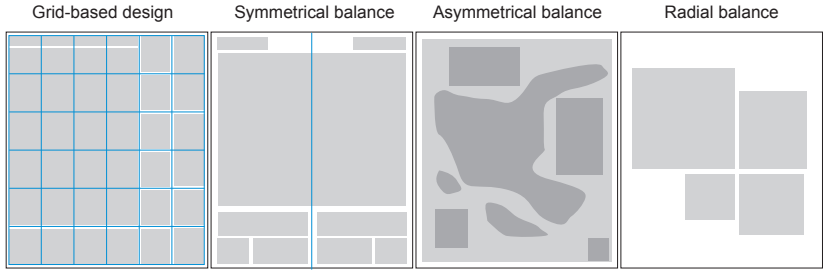
- Contrast is the difference in colour and light between parts of an image or illustration. It can be used to:
  - show the relation between figure and ground;
  - distinguish different elements in the figure.



Poor (left) and good (right) contrast

Layout & design (4): balance

- Choose an appropriate balance.



Tools for constructing graphics

Three routes to making graphics:

- Directly output from an analysis program;
  - Statistical analysis: R, SPSS, Systat ...
  - GIS: ArcGIS, ILWIS, GRASS ...
  - "Office" programs: Excel, Word, Open Office, iWork, ...
- Drawn in a dedicated graphics program;
  - Adobe Illustrator, Visio, Gimp ...
- Output from an analysis program and enhanced in a specialized graphics program.
- Enhancement must not distort or mis-represent!

ArcGIS map construction flow

1. Set the correct dimensions of the map in the "Page and Print Setup". Set it to the exact space reserved on the page, do not include surrounding white space.
2. > In the "Layout view" make the "Data frame" fit with the "paper size" and make sure that the content fits in the data frame.
3. When creating a map for use on screen enlarge ("zoom") to 100%; for paper output, which can show more detail, the zoom can be 250%.
4. Make sure that all details are readable. Set line weight, font size, colours etc. according to specifications. Pick text fonts based on printed samples.
5. Export the map in an appropriate format for the document e.g. emf, eps, ai, pdf, svg, bmp jpeg, png, gif and tiff.
   - For paper output: tiff (24 bit true colour) if the map contains images and many transparencies, but pdf when working with tints, lines and text.
   - For screen output: jpeg (if the map contains images) and gif (when making use of tints, lines and text), png combines the two.
6. Check the output files for correctness.

To summarize ...

- Think hard about why you want to use graphics; what type of graphic will best communicate your message.
- Then, design your graphic to be as simple as possible (but no simpler), while still communicating the message
- Think as hard about your graphics as your text ... or maybe harder!
  - More people will look at your graphics than read the text
  - Graphics make a very strong impression on the reader!
    - Sloppy, inconsistent, useless, unintelligible? Probably the author is similar confused and careless about their research.
    - Neat, consistent, informative? Probably the author is a careful scientist.

Summary

- It should be clear from this presentation that effective use of graphics is not simple.
- The advantage of good graphic presentation is effective communication of research.
- Poor graphics reflect poorly on the researcher and can be worse than nothing.
- Good graphics, intelligently placed, well-constructed, and contributing to the argument considerably enhance the presentation of research.
- In writing, omit needless words; in graphics, omit needless elements – both of these serve to emphasize the message.
- Do not be satisfied with the default output