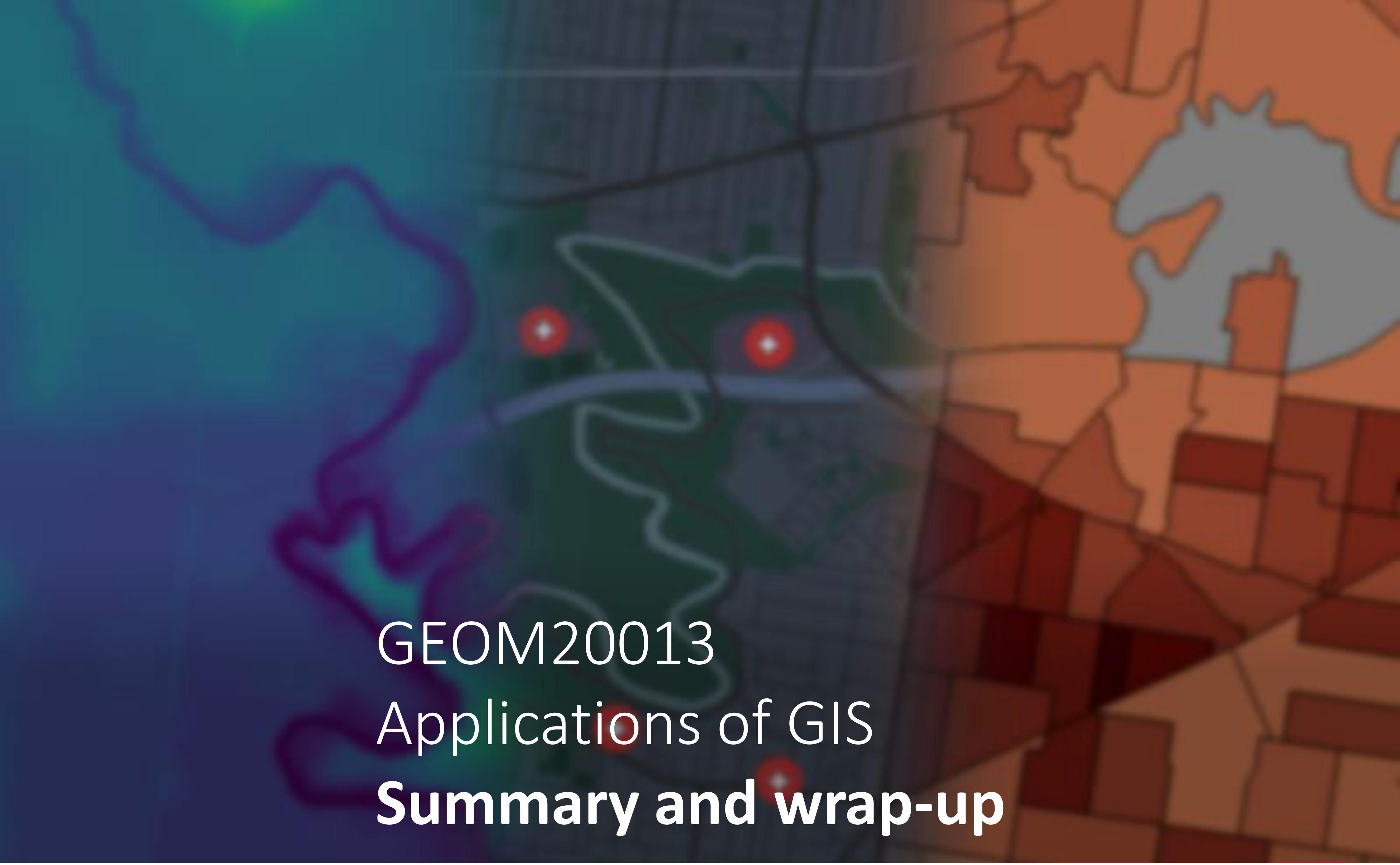


GEOM20013
Applications of GIS
Summary and wrap-up

Alan Thomas & Martin Tomko

Spatial subjects

Second Year

GEOM20013 Applications of GIS

GEOM20015 Surveying and Mapping — *capturing **vector data** and creating a survey plan*

Third Year

GEOM30009 Imaging the Environment — *interpreting and manipulating **raster data***

GEOM30013 Land Admin Systems — *the intersection of spatial systems, property and planning*

Available as **electives** in BSc/BDes + **breadth**

No prerequisites!

Spatial Systems major

Second Year

GEOM20013 Applications of GIS

\+

GEOM20015 Surveying and Mapping + **COMP20005** Eng Computation

\+

Third Year

GEOM30009 Imaging the Environment + **CVEN30008** Eng Risk Analysis

\+

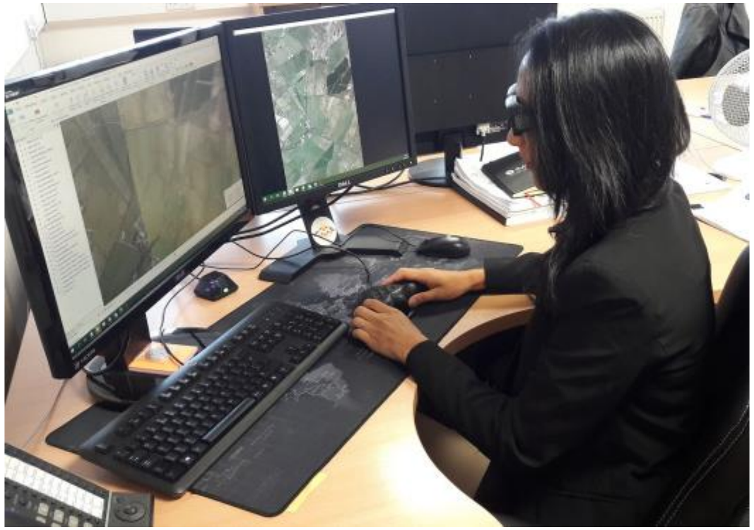
GEOM30013 Land Admin Systems + **GEOM30012** Integrated Spatial Sys

bringing it all together with a ***field camp***

\+ first-year maths

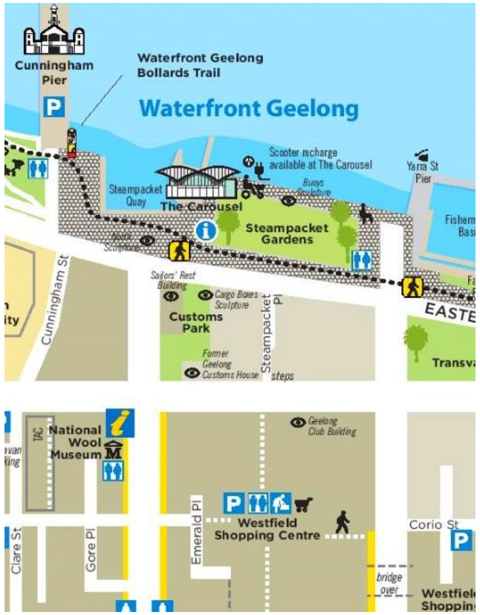
= Spatial Systems major (**BSc** and **BDes**)

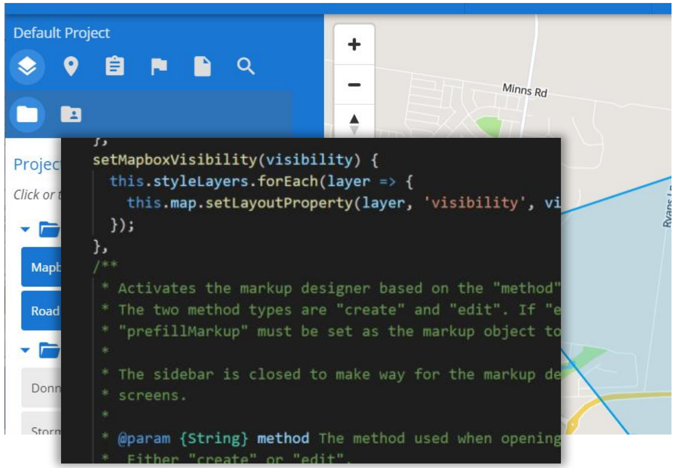
Spatial careers



GIS analyst
Local government,
state government,
planning consultancy,
…

Cartographer
Freelance or
consultancy



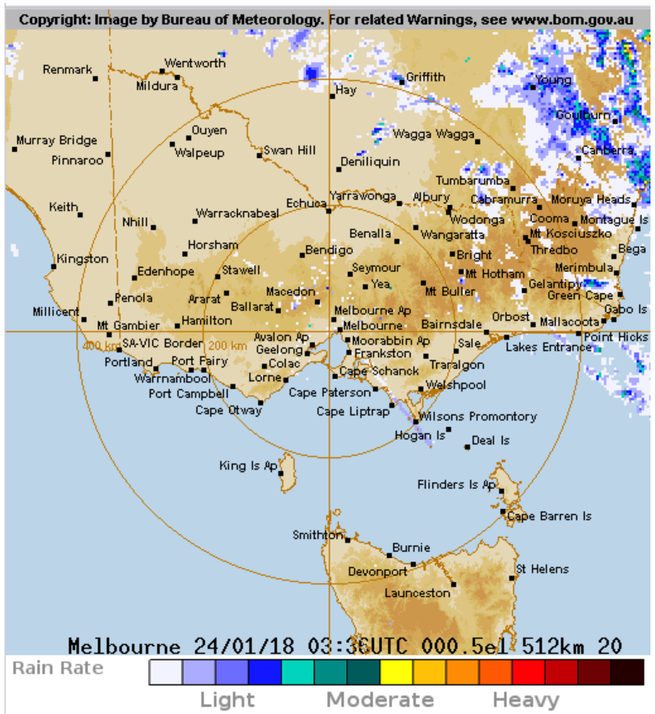


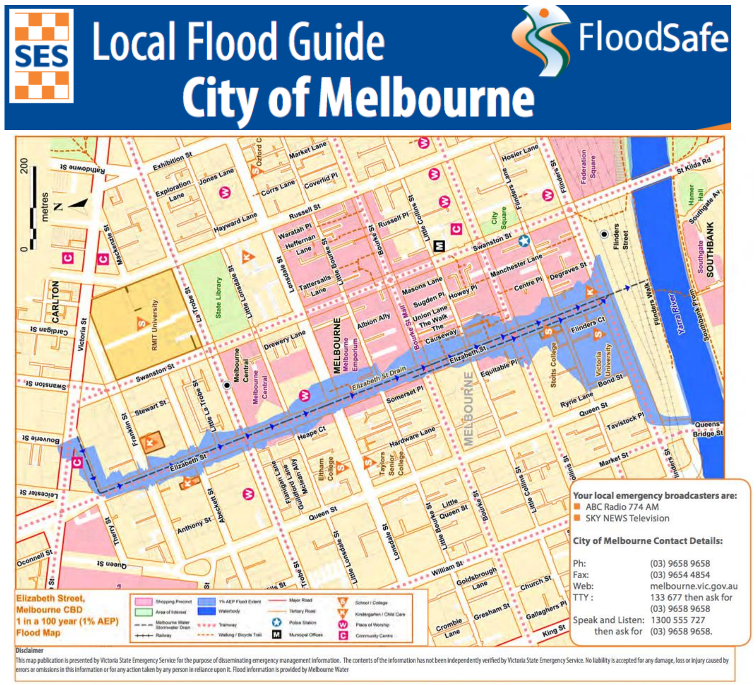
Geospatial software developer
Tech industry

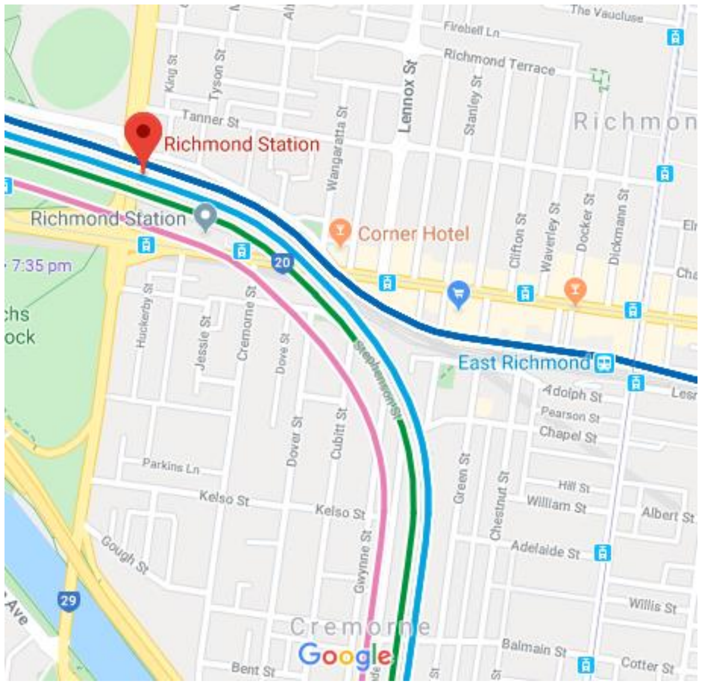
Most Spatial students continue to our professional Master degrees: **Master of Engineering (Spatial)** or **Master of IT (Spatial)**

Spatial is everywhere

- Everything happens <u>somewhere</u>
- Everyone uses spatial data to support their <u>decision making</u>







Learning objectives for the course

- Explain the basic **principles and procedures** associated with application of GIS to the solution of spatial problems;
- Demonstrate **practical skills** such as understanding of the collection, storage, manipulation and visualization of spatial data;
- Demonstrate a practical understanding of the principles of **spatial reference systems** and basic **spatial analysis** and **visualization** of spatial data using GIS;
- Describe **how GIS can be applied** in a range of situations, such as urban planning, site selection, environmental management, facilities and network management, and many more;
- Explain the particular role that GIS plays in **decision making** for problem solving purposes;
- Use GIS software to **demonstrate the application of a GIS** to support decision making in a selected problem area.

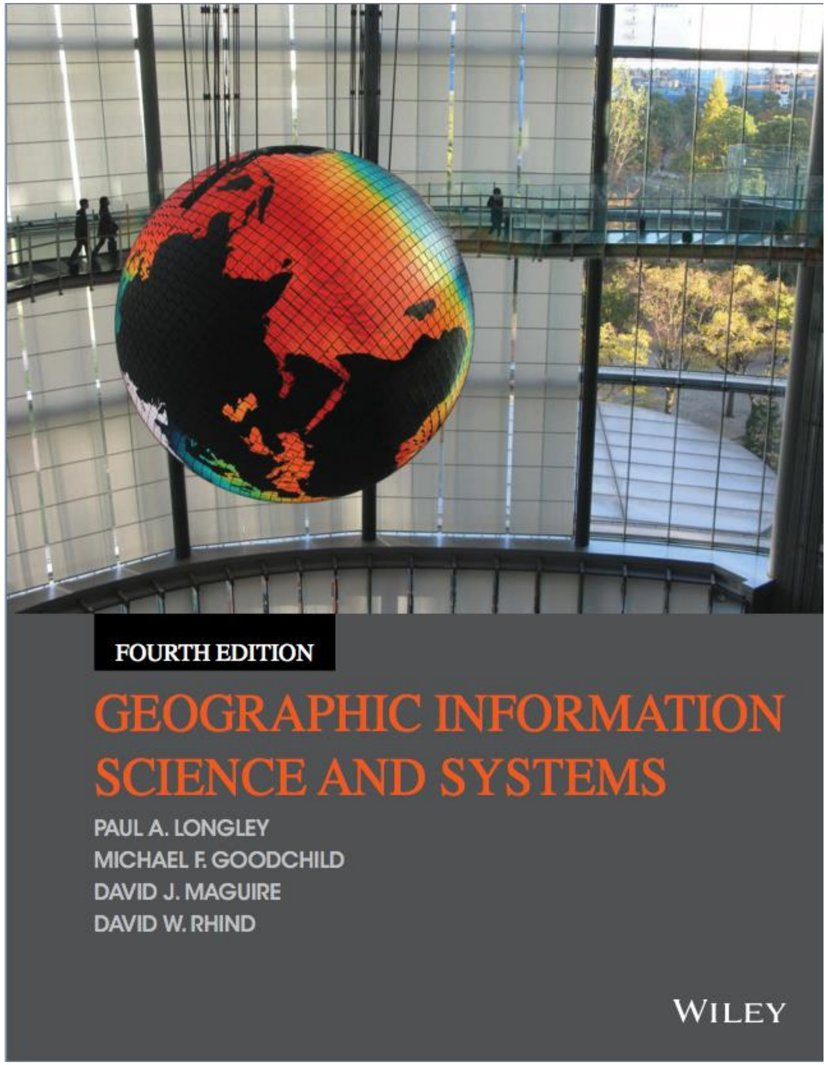
  - Note: tan-coloured slides will be used for learning objectives for each lecture, and the lecture summary

You will…

- **Understand fundamental concepts of GIS**
  - Be knowledgeable so that you know what is feasible
- **Gain basic skills as gateway to more advanced tools**
  - Learn technical skills suited to many different apps
- **Discover how to independently explore further**
  - Connect to relevant literature and GIS community
- **Appreciate and consider limitations and issues**
  - It's not magic!

Overview: Book

- *Geographic Information Science and Systems*, 4th Edition, Paul A. Longley, Michael F. Goodchild, David J. Maguire, David W. Rhind, ISBN: 978-1-118-67695-0, Mar 2015, 496 pages
- Available as e-book from library
  - Notify us if not enough copies available



Review of the semester

Lectures

1	Introduction to GIS
2	Representing spatial data
3	Representing places on Earth
4	Mapping and visualisation
5	Capturing spatial data
6	GIS in legal proceedings
7	GIS in infrastructure projects / multicriteria analysis
8	GIS in emergency management / ecology
9	GIS in place names / demography and communication
10	GIS in public health / ethics

Assignments

- A1
- A2
- A3
- A4

Lecture 1

Introduction to GIS

Lecture 1: Overview

- "Spatial" problems occur across a diversity of application areas
- What is GIS? What are its main functions?
- Where is GIS used?

Spatial questions

- **Where is X?**
- **What is at location Y?**
- **What is the *nature of* X at location Y?**
- **How far/large/… is X (from Y)? How fast does it move?**
- **How do X and Y interact?**
- **When will X be at location Y?**
- **Why does X behave as it does in its setting?**

Spatial is Special

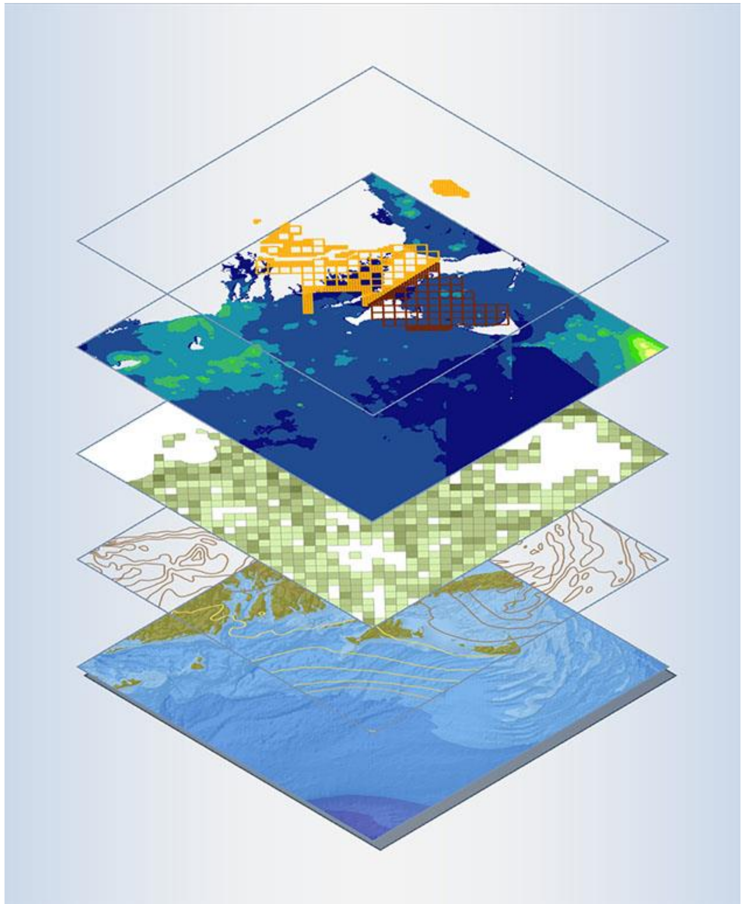
- **What sets spatial problems apart from other kinds of problems?**
  - Scale (spatial, temporal)
  - Modelled – selection and abstraction
  - Multi-dimensional data
  - Space, Time, Attributes
  - Multiple means of representing the data digitally
  - Representation in 2D through projection
  - Autocorrelation – all things are related, but close things are more related than distant

What is a GIS?

- **Geographic Information System**
  - An *information system* that stores, manipulates and displays *geographic information*
- **GIS is…**
  - A spatial data storage and transformation tool
  - A mapping and visualisation tool
  - A spatial analysis tool
  - A spatial decision-making tool

Characteristics of a GIS

- **Handles georeferenced data**
  - Has characteristics of a data management tool
- **Overlays data that belongs in the same location**
  - Allows analysis and visualisation of spatial relationships
- **Produces graphical output**
- **GIS is complex!**
  - Unlike any other software you have ever used
  - You don’t work on one file at a time



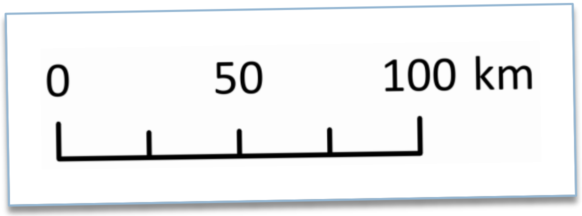
Applications of GIS

- Mapping
- Measurement
- Monitoring
- Modelling
- Management

Scale

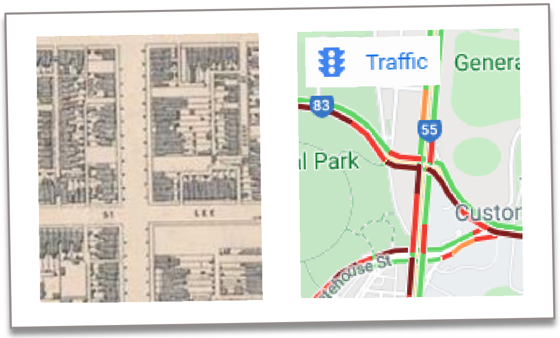
+ Scales of measurement

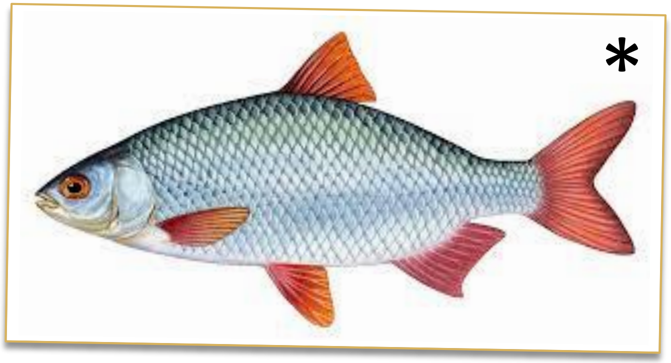
Map scale



Geographic scale

Temporal scale





* *not examinable*

Lecture 1: Summary

- Spatial is Special
- GIS can help us to answer spatial questions and solve spatial problems
- All about representing the real world in an abstract environment

Lecture 2

Representing spatial data

Lecture 2: Overview

- **Fields and objects**
- **Conceptualizing real world objects**
  - How we sense objects
  - The main data structures used in GIS
- **Tying the representation to the real world**
  - Referencing a location in different ways
  - Coordinate systems are the standard
- **In the book**
  - Chapter 2 (part 2), Chapter 3 and Chapter 7

Geographic facts

place + time + attribute

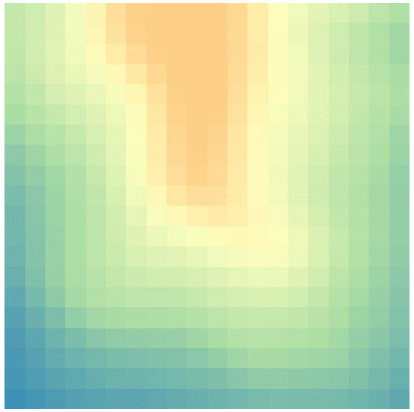
Laby Theatre	Right now	100 people are present
Cabo Delgado province, Mozambique	2014	44.8% of people live below the poverty line
Mount Everest	????	Looks like this: 
…	…	…

Mozambique Ministry of Economics and Finance (2016). *Poverty and well-being in Mozambique: fourth national poverty assessment*.

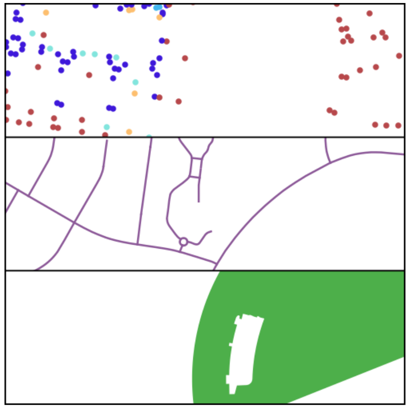
Fields and objects

New slide in this lecture

- **Fields**
  - Thinking of the world as a dense field of varying values: $f(x, y)$
  - Typically modelled in GIS as **raster data**: a uniform grid of values

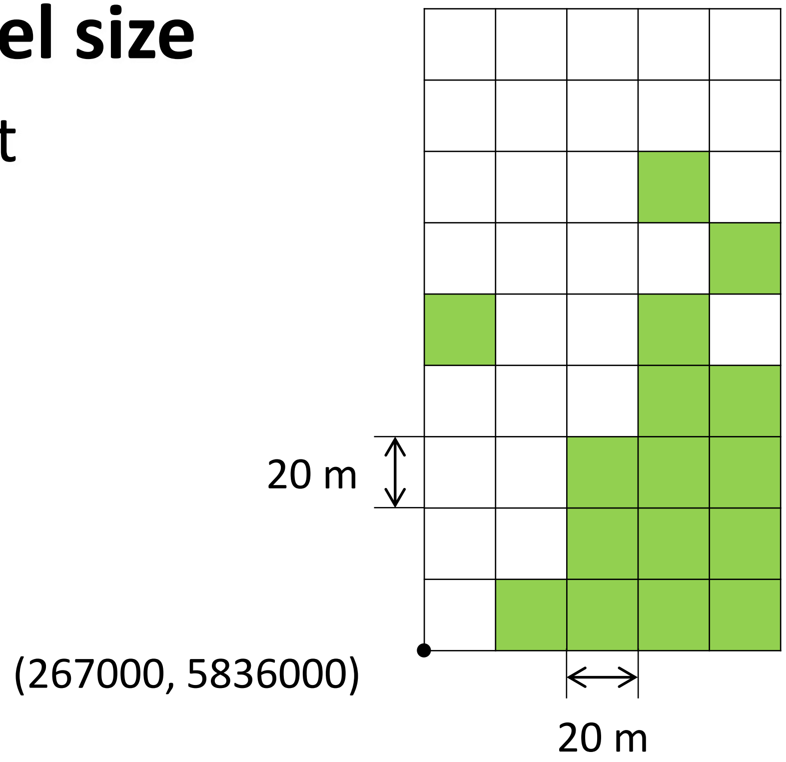


- **Objects**
  - Thinking of the world as a blank space, populated with objects we can count
  - Typically modelled as **vector data**: points, lines or polygons



Characteristics of a raster

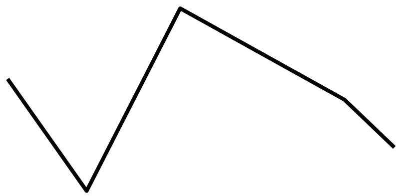
- **Spatial resolution/cell size/pixel size**
  - Size of the cell or picture element
  - Defines level of spatial detail
  - All variation within pixels is lost
- **Assignment scheme**
  - How is a value assigned to cell?
- **Bit-depth**
  - Types of numbers it can store



Vector representation

point

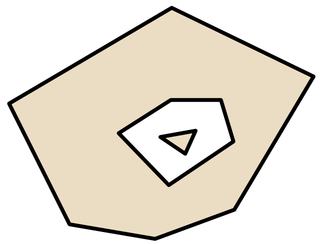
One coordinate pair



line

(also called "polyline")

A set of ordered coordinate pairs



polygon

A line that forms a closed loop

- May contain holes or island polygons

Lecture 2: Summary

- Fields and objects – different approaches
- In digital form they become rasters and vectors
  - Rasters are a uniform grid of values
  - Vectors are collections of point, line or polygon objects
- Vectors are enriched by attribute tables
- There are many standard file formats for GIS data
- Other representations of spatial data exist

Lecture 3

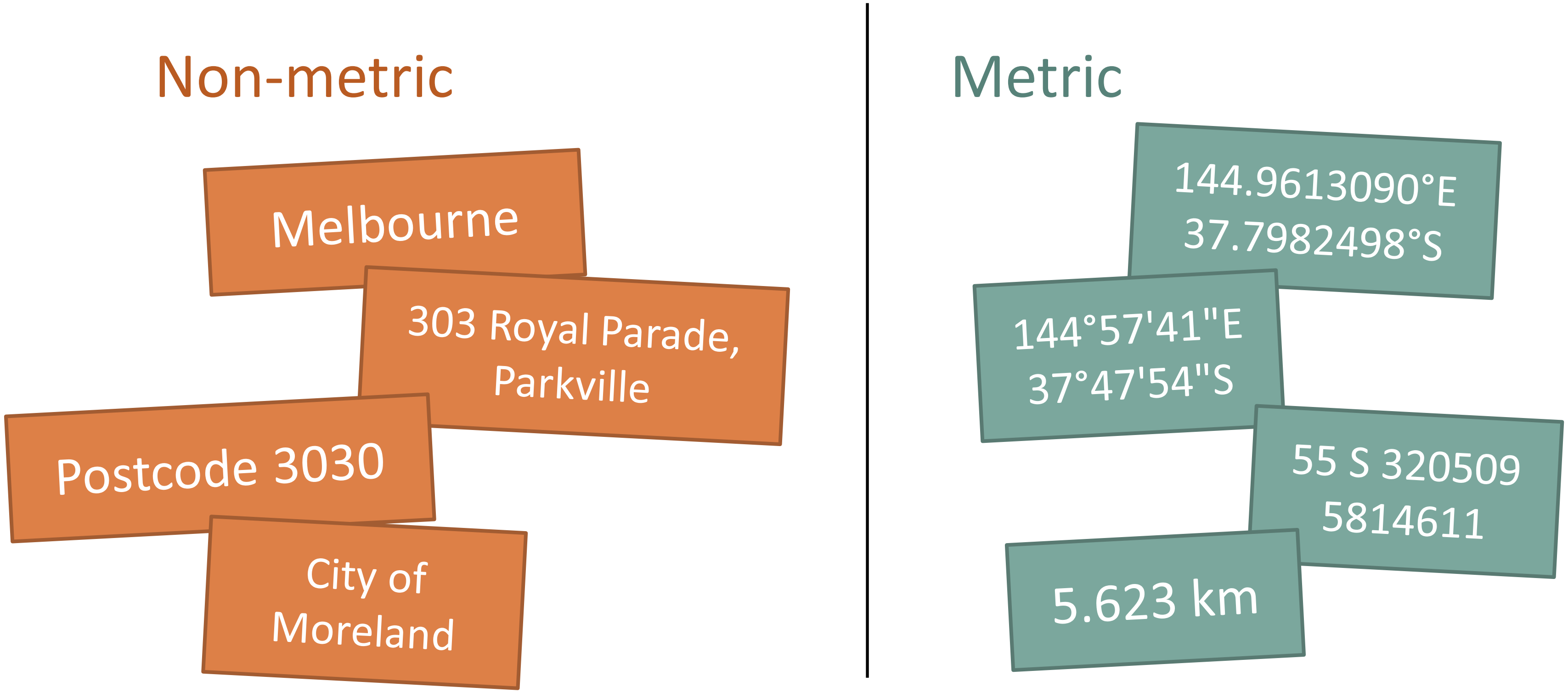
Representing places on Earth

Lecture 3: Overview

- **Location systems help us identify places on Earth**
  - Referencing a location in different ways
  - Some use measurement, some do not
- **Coordinate systems are the standard**
  - Geographic and projected coordinate systems
  - Map projections
- **In the book**
  - Chapter 4

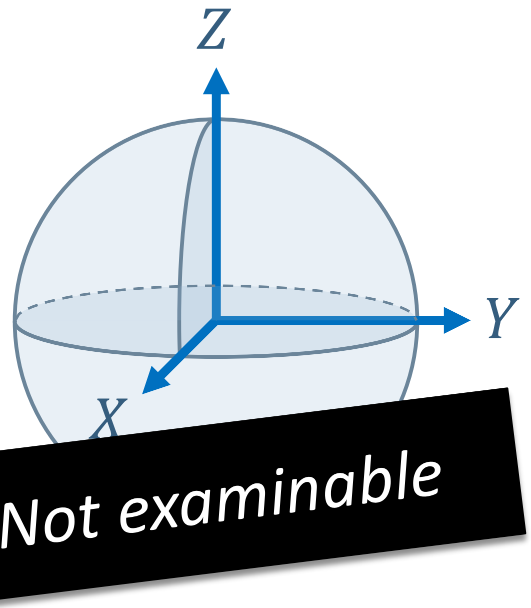
Location systems

- **Places can be identified using non-metric or metric location systems**
  - Here, “metric” means measurement-based

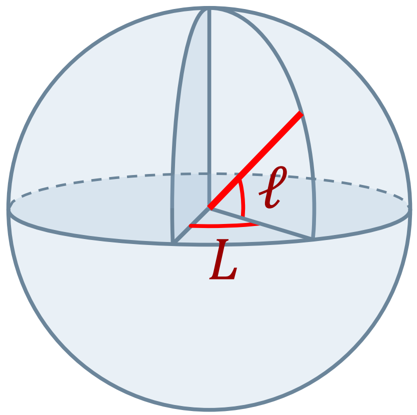


Coordinate systems

- Three types



Geocentric CS
(ECEF)

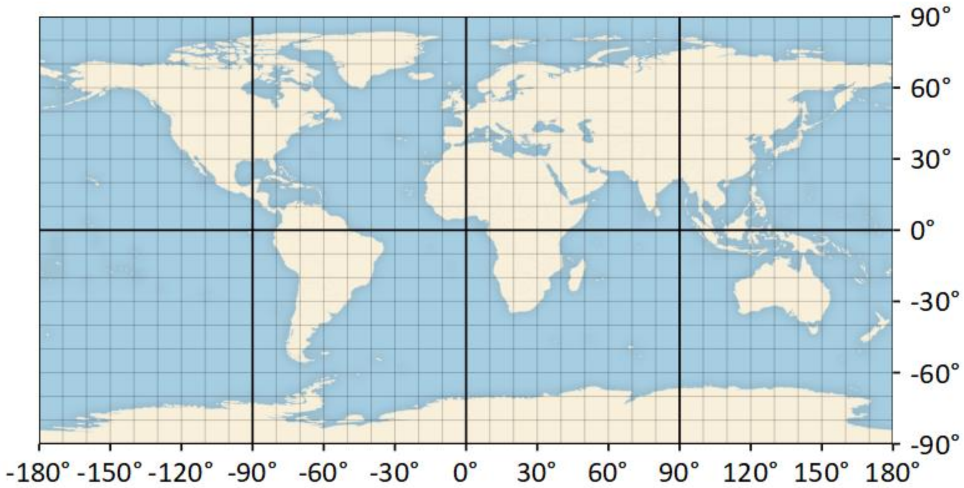


Geographic CS
(latitudes and longitudes)

Projected CS
(grid coordinates)

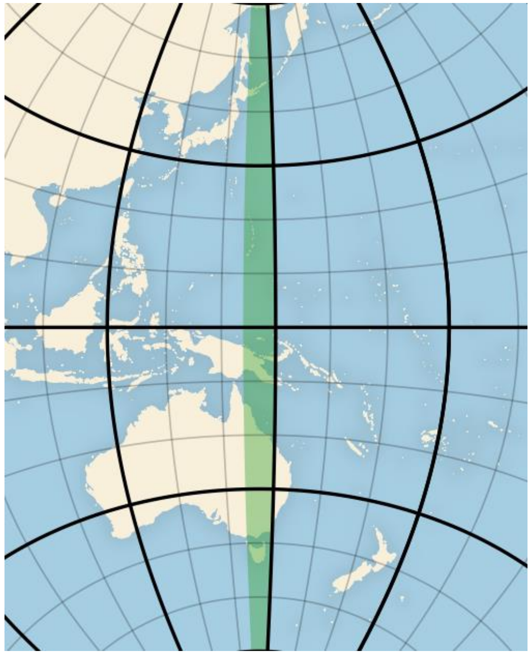
Map projections

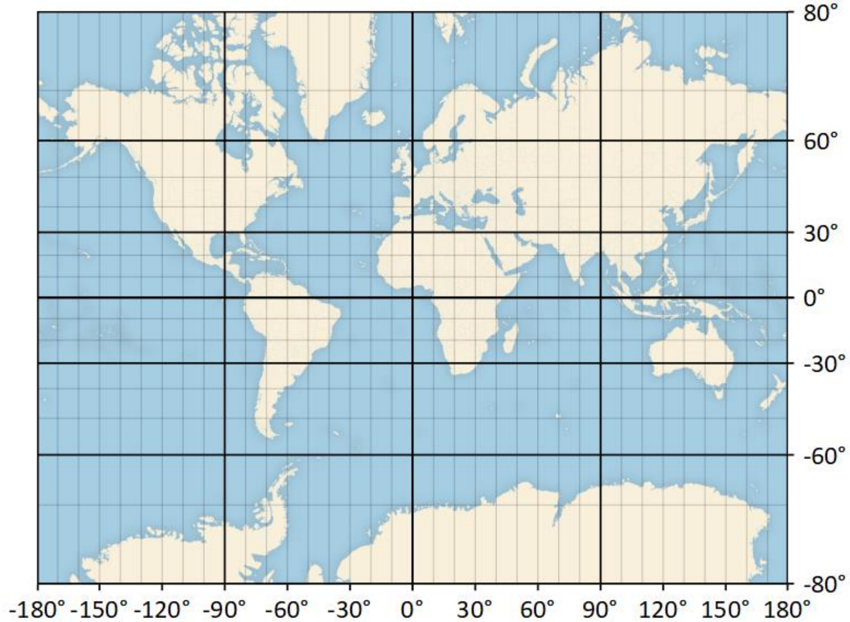
New slide in this lecture



Equirectangular/*plate carrée*
Treats latitudes and longitudes as Cartesian coordinates

UTM (Zone 55 pictured)
Great for small areas, comes with coordinates





Mercator
A cylindrical projection built for shipping

Properties of map projections

- ***Conformal*** **projections preserve angles**
  - The shapes of “small” areas are preserved
- ***Equal-area*** **projections preserve size**
  - If Country 1 is 150% larger than Country 2 in real life, it will also be 150% larger on an equal-area map
- **Impossible to have both!**

City of Moonee Valley

On a globe

Mercator projection

Mollweide projection centred at 0°E

Lecture 3: Summary

- **We locate places on Earth using location systems**
- **Non-metric location systems are widespread**
  - Human-friendly, but can be difficult to use in a GIS
- **Metric location systems are more precise**
  - Geographic coordinate systems use latitude and longitude
  - Map projections transform the curved Earth to a flat surface
  - Projected coordinate systems

Lecture 4

Mapping and visualisation

Lecture 4: Overview

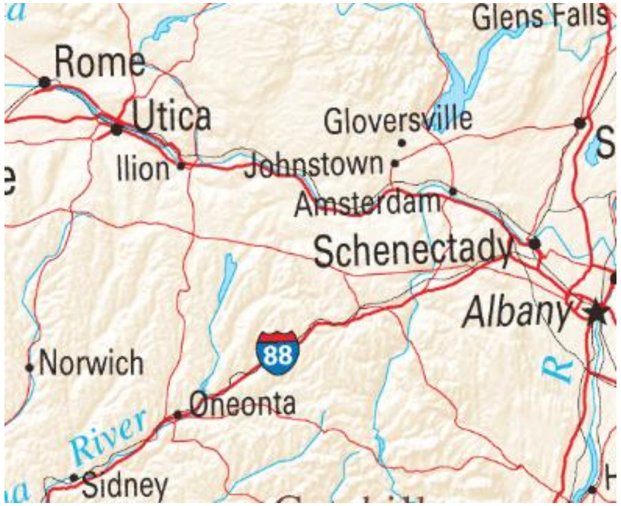
- **Getting information out of a GIS is crucial**
  - This process normally involves visualisation
- **Mapping is the primary way of displaying GIS outputs**
- **In the book**
  - Chapter 3 (section 3.8), Chapter 11 and Chapter 12

What is a map?

- **What is a map?**
  - A static or interactive representation of geography
  - A way to visualise spatial information
  - A projected representation of the Earth drawn to scale
- ***Cartography* – the study of mapmaking**

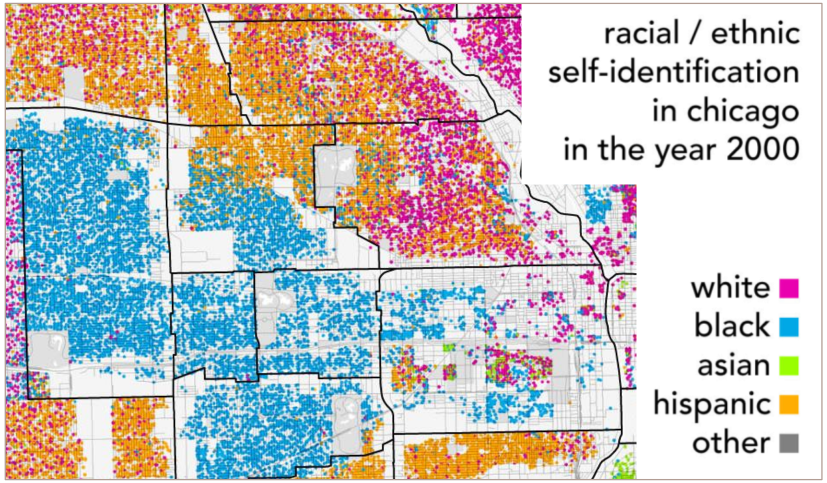
Types of maps

New slide in this lecture

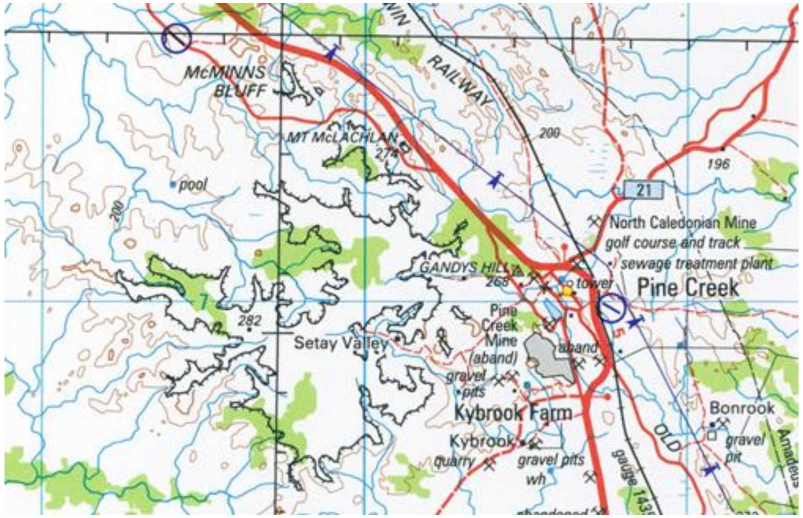


Reference maps
All-purpose maps
for everyone

Thematic maps
Tailored to a purpose
and audience



Bill Rankin: http://radicalcartography.net/index.html?chicagodots

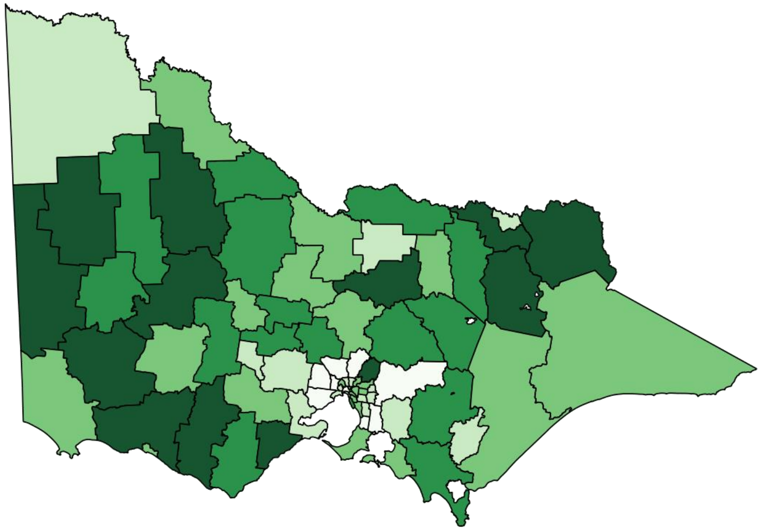


Topographic maps
Specialised maps
of a landscape

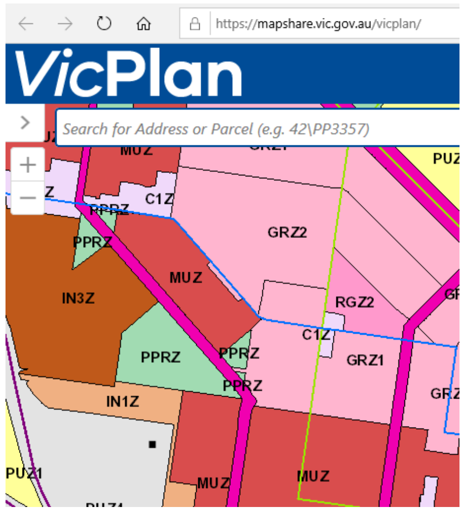
Types of thematic maps

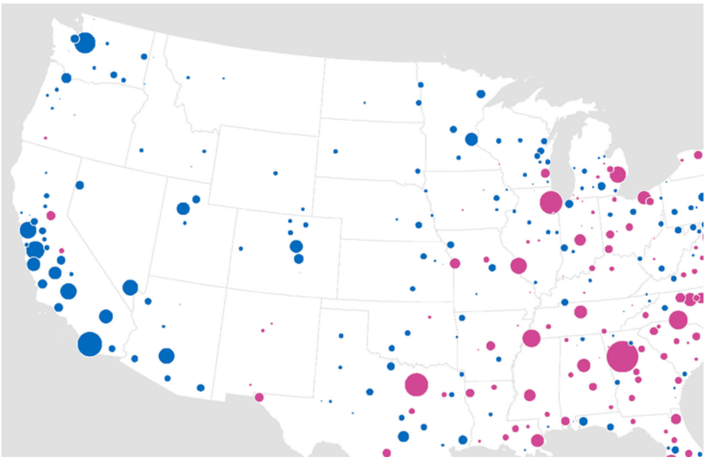
New slide in this lecture

Choropleth map
Assigns a colour to each administrative region



Chorochromatic map
Coloured according to the variable being mapped



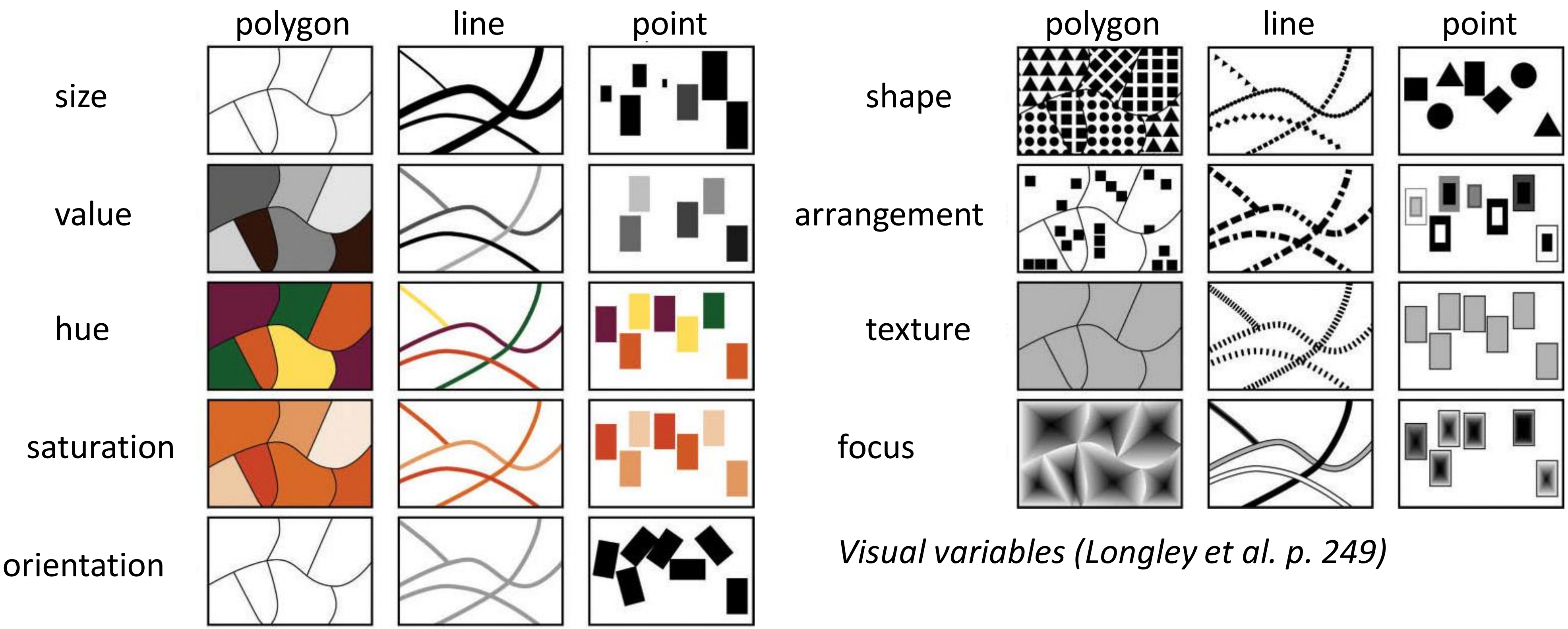


Proportional symbol map

...and many more!

Visual variables

- **Attributes are mapped using symbols**
  - You can modify the symbols in different ways to communicate the varying value of an attribute



Visual variables (Longley et al. p. 249)

Issues in cartography

New slide in this lecture

- **Simplifying and removing unnecessary detail**
  - Classed colour scales
  - Cartographic generalisation
- **Data-ink ratio**
- **Mapping time**
- **Spataillly intensive vs extensive variables**

Lecture 4: Summary

- **Maps are a key tool in the GIS process**
- **Many different types of maps**
  - Many types of thematic maps
- **Map furniture provides context to the map**
- **There are a number of issues to be mindful of**
- **Maps are not the only way to visualise spatial data**

Lecture 5

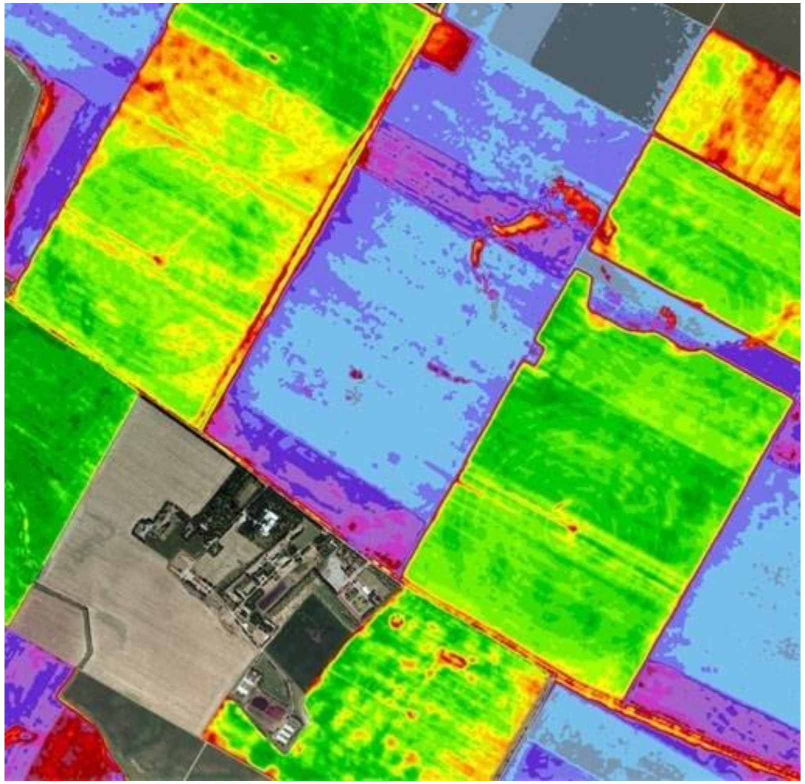
Capturing spatial data

Lecture 5: Overview

- **Where does our spatial data come from?**
- **We'll cover some of the key sources**
  - Remote sensing
  - Surveying
  - Finding existing data
- **In the book**
  - Chapter 8 and section 10.2

Remote sensing

- **Deriving properties of an object without direct contact**
  - Usually using electromagnetic radiation
  - Usually from a significant distance
- **Methods of remote sensing**
  - Satellites
  - Aerial imagery
  - LiDAR, radar, sonar



Remote sensing of rasters

- **Advantages of satellites**
  - Most data is free
  - Captured on a regular, predictable basis for years on end
  - Covers the whole Earth
  - Multiple bands allow for deep analysis
- **Advantages of aerial data capture**
  - Drone flights are not very expensive (aircraft-based remote sensing is costly)
  - Custom flights can be organised
  - Not impacted by cloud cover
  - Very high (5 cm) spatial resolution is possible

Surveying

- **Advantages of surveying**
  - Extremely precise
  - Can obtain vector data with many attributes
  - Often legally required (land development, speed camera calibration, crime scenes, …)
- **Disadvantages of surveying**
  - Very costly
  - Requires specialised equipment and trained personnel
  - Labour-intensive

Take **GEOM20015 Surveying and Mapping** (second-year undergrad) if you're keen to learn more!

Metadata

- **Metadata is data about data**
  - Like the information in a library catalogue
  - Like the label on a product from the supermarket
- **Metadata helps answer the question “Is the data suitable for my project?”**
  - For example: Does it cover the right area? Is it recent enough?

Lecture 5: Summary

- **Remote sensing is a key technique for data capture**
  - Uses the electromagnetic spectrum to create imagery or point clouds
- **Vector data can be captured using surveying**
  - Or other related techniques
- **There is plenty of data out there already**
  - We look at the metadata to see if it is useful for our project
- **Be mindful of uncertainty**

Lecture 7

Multicriteria Decision Making with GIS

Lecture 7: Learning objectives

- Understand the main concepts that underpin spatial data analysis and decision making with GIS
- Understand and be able to explain the concept of modelling and the inherent simplification and abstraction it involves;
- Be able to explain and critically investigate how a model operationalizes often vague assumptions and statements about a phenomenon;
- Reason about the different influences on the accuracy of the outcomes of the models, in particular with respect to the combined influence of multiple factors.

Thematic variables levels of measurement

- **Nominal**
  - Meadow, Forest, Built up area
  - Lygon St, Grattan St, Queensberry St
  - Bus, car, motorbike, other
  - Carlton, Parkville, 24600 (City of Melbourne)
- **Ordinal**
  - Very good, good, ok, bad, very bad
  - Very high, high, low, very low
- **Interval**
  - 10ºC, 20ºC, 35ºC,-3ºC, 0ºC
- **Ratio**
  - 15km/h, 30km/h
  - 10ºK, 0ºK, 273,15ºK
  - 20%, 60%

- **The level of measurement (or measurement scale) determines what operations we can do with the data!**

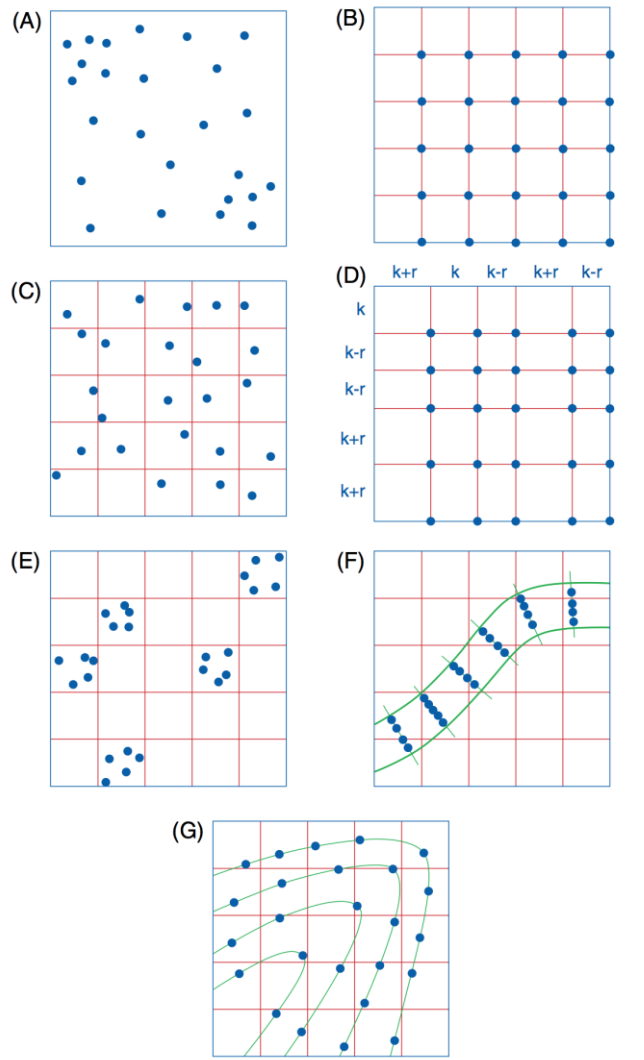
More statistical operations possible

Stevens, S. S. (1946). On the Theory and Scales of Measurement. *Science*, *103*(2684), 677-680.

Sampling

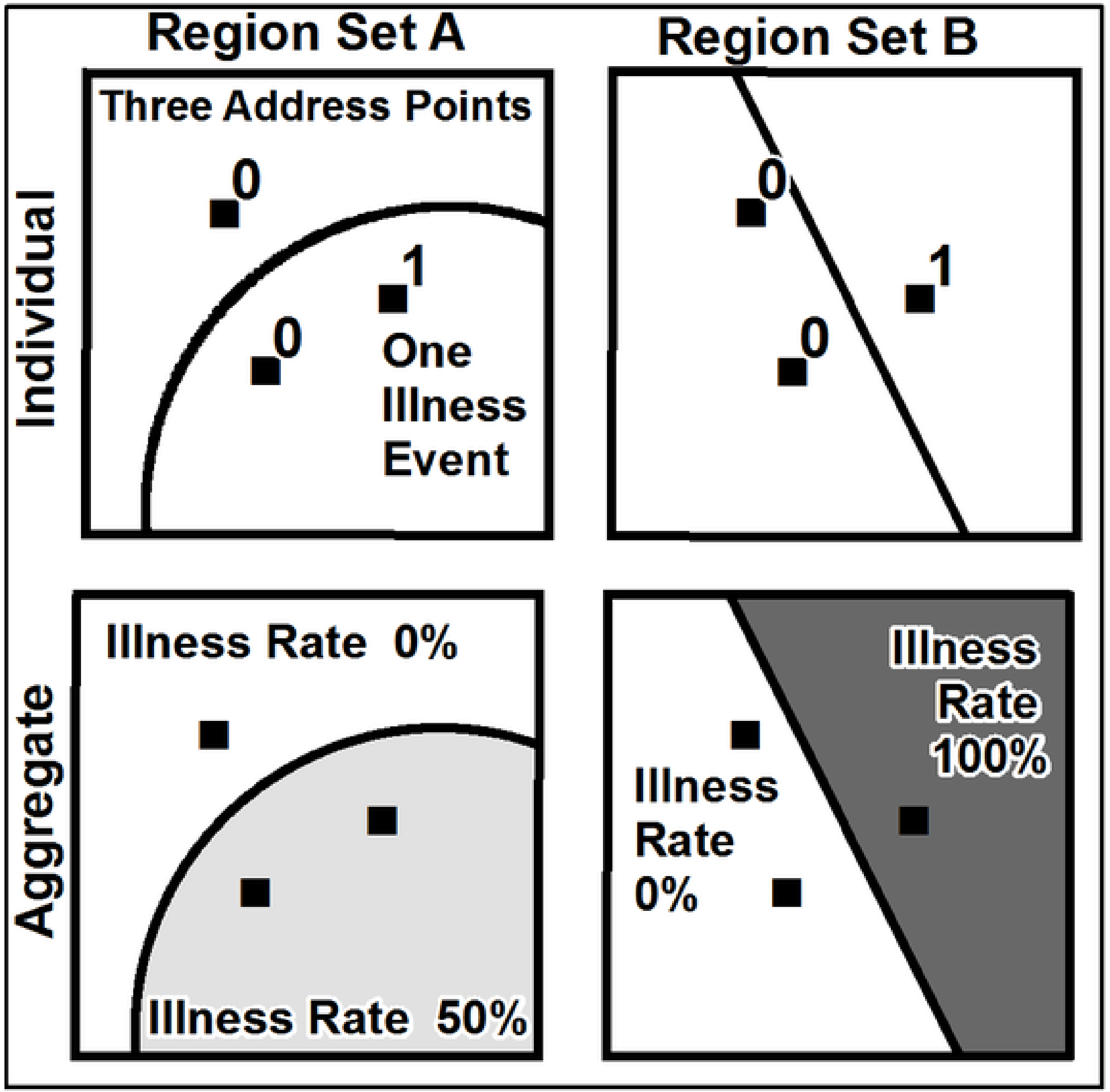
- **We cannot measure everything everywhere**
- **Selection** is important
- **We approximate** regions of interest and then **fill in data:**
  - Interpolation
  - Smoothing

Figure 2.4 Spatial sample designs: (A) simple random sampling, (B) stratified sampling, (C) stratified random sampling, (D) stratified sampling with random variation in grid spacing, (E) clustered sampling, (F) transect sampling, and (G) contour sampling.



Longley, P.A., Goodchild, M., Maguire, D., Rhind, D. *Geographic Information Science and Systems, 4th Edition*. Wiley, 2015-02-26.

Aggregation

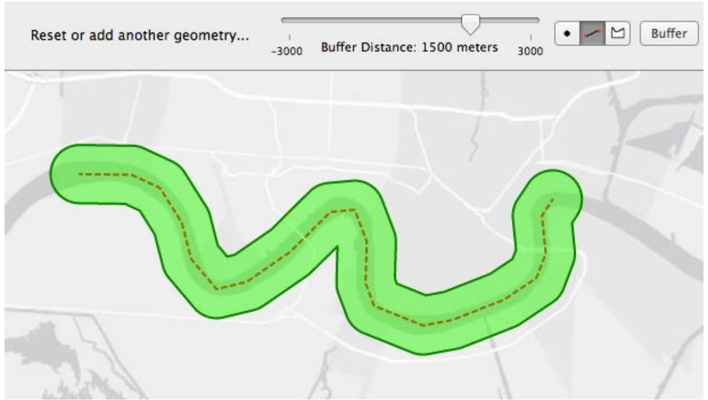


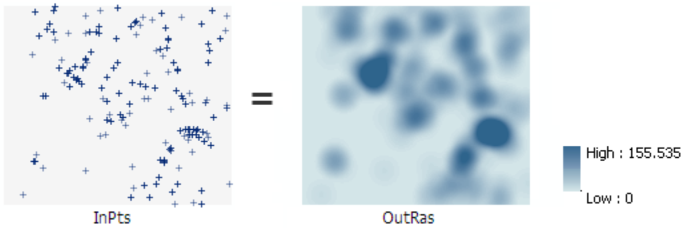
The effects of scale and aggregation are generally known as the Modifiable Areal Unit Problem (MAUP).
(Longley 123)

Figure: https://en.wikipedia.org/wiki/Modifiable_areal_unit_problem

Parametrisation of a model

- Parameters (or arguments) modify the behavior of an operation;
- The choice of parameters defines the output of the operation – responsibility of the analyst;
- Some operations often offer default parameters – the analyst MUST evaluate their suitability;
- Sometime the default parameters are not disclosed – impacts on the ability to replicate results in other systems





The default search radius (bandwidth) is calculated based on the spatial configuration and number of input points. This approach corrects for spatial outliers—input points that are very far away from the rest—so they will not make the search radius unreasonably large

http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/kernel-density.htm

Multicriteria decision making

Many decisions depend on identifying relevant factors and adding their appropriately weighted values. (Longley 353)

Longley, P.A., Goodchild, M., Maguire, D., Rhind, D. *Geographic Information Science and Systems, 4th Edition*. Wiley, 2015-02-26.

Operationalisation of a model

- **Operators and parameters (descriptive and generative)**
  - **Operations on Geometry**: distance, length, buffer, boundary,
  - **Operations on Topology**: intersects, inside, meets, intersection,
  - **Operations on Theme**: <val, == val, *,/,+,-,mean, mode, median
  - **Operations on Sets**: union, difference, and/or/not,…

Not all criteria are made equal

- **Soft vs Hard**
  - Must be satisfied vs good to have
- **Priorities and weights**
  - How <u>preferred</u> is one criterion relative to another
  - What <u>weight</u> does one criterion have compared to another

Lecture 10

Ethical considerations and GIS

Lecture 10: Learning objectives

- Understand how Ethics and GIS relate;
- Understand that map inherently have an agenda;
- Be able to reason about ethical and unethical use of GIS;
- Understand technical means to protect individual data (privacy);
- Critically evaluate what is ethical and what is unethical data analysis.

But hold on, GIS is …

- **Just a tool**
  - Yes, but it is who handles it, and for what
- **Data are always objective**
  - Now, data always reflect bias of their collectors
- **Methods are always impartial**
  - Yes, but methods are always parametrized by people and reflect their needs/attitudes
- **Maps just display data**
  - Visual variables (symbols, colours, styles) are chosen by people to communicate their agenda

Lecture 10: Summary

- You are now able to critically evaluate how your actions as GIS analysts impact on the perception of the whole spatial profession;
- You should have an awareness of how to behave as ethical spatial professionals;
- You know what guidelines can provide guidance if unsure;
- You are able to evaluate spatial data products critically.

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Guest lectures

Lecture 5a: Searching for resources

Guido Tresoldi

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GIS in Forensic/Legal procedings

Gary Hunter

GIS in infrastructure projects

Connor Wilson

GIS in Emergency response support

Payam Ghadirian

GIS in Ecology

Roozbeh Valavi

GIS and Georeferencing

Rafe Benli

GIS and Information Visualization

Simon Kuestenmacher

GIS and Public Health

Suzanne Mavoa

Conclusion

- **Spatial is special**
  - Spatial data is special
  - Spatial analysis is special
  - Spatial visualisation is special
  - But critical in so many everyday applications
- **GIS software is powerful and complex**
  - You now have **experience** and **transferable skills** you can apply to any GIS package or context
- **If you need ArcGIS Pro licenses for future subjects, contact Alan or Kenny**